March 14, 1871.

CHARLES B. VIGNOLES, F.R.S., President,
in the Chair.

No. 1,296.—“ On Phonic Coast Fog-Signals.” By ALEXANDER
BEAZELEY, M. Inst. C.E.

FEW, if any, portions of the coasts of these islands are exempt from occasional fogs and mists,¹ which render a landfall precarious by day, and which are not unfrequently so dense that by night even the powerful beams of the electric light fail to penetrate them to any but the most moderate distance. It is, therefore, not a little surprising that, except of late years, the subject of fog-signals for the guidance and warning of the mariner under such circumstances should have received so little attention; and that, with the exception of a few inventions of recent date, the knowledge of the present day respecting the means of producing and projecting to a long range the sounds to be employed, is but little in advance of what it was a century ago. The literature of the subject is extremely meagre: here and there, scattered among the scientific records of this and other countries, an occasional notice or a brief suggestion may be met with; but of systematic research and experiment, and their proper offspring, practical result, there are few traces. The purpose of the Paper is to endeavour to show what has hitherto been done, and to place before the Institution a brief account of the present state of information upon the subject.

Before entering upon details, it may be well to notice a misconception which is generally prevalent, and which seems to have received some degree of sanction from no less an authority than M. Reynaud, Director-General of the French Lighthouse Department,² viz., that great power and long range of sound are by

¹ Meteorologists discriminate between fog and mist as distinctly different atmospheric phenomena. In the present Paper the general term ‘fog’ is applied to all obscuring media suspended in the atmosphere at or near the surface of the sea.—A. B.

² “On n’a pas jugé que, dans l’état actuel des choses, la navigation de notre littoral eût assez d’intérêt à percevoir les sons à grande distance pour motiver les dépenses que nécessiteraient l’établissement et l’entretien de ces machines” [pour comprimer de l’air à plusieurs atmosphères].

“Il n’a pas été fait d’expériences par des vents violents; mais on sait que, quand ils sont debout, ils arrêtent les sons les plus forts. On sait aussi d’ailleurs

no means essential to fog-signals, inasmuch as fogs are usually found to occur in comparatively calm weather. This may be true of some coasts, but it certainly is not the case with those of England, as the following facts show :—

On the Yorkshire coast, in the years 1868-69, fog occurred fifty-one times, with a total duration of $254\frac{3}{4}$ hours. During the period of these fogs, the average direction of the wind was S. by E., and its force 4.28. The average force of the winds¹ blowing from the eastward of the meridian was 4.55, against an average of only 2.59 for those blowing from the westward. The strongest wind, with a force of 8, was from E.N.E.; the next strongest, with a force of 7, from S.S.E. and S.; and, of those of the highest strength, average 5.52, the average direction was S.E. None of the fogs occurred during calm.

In the same years, at the entrance of the Bristol Channel, fog occurred one hundred and twenty-five times, with a total duration of $713\frac{3}{4}$ hours. During fogs the average direction of the wind was S.W. by W., and its force 3.94 (including calms, of which there were only five instances). The average force of the winds blowing from the westward of the meridian was 4.15, against an average of 1.82 for those blowing from the eastward, of which there were only eleven instances. The strongest winds, which on ten occasions blew with a force of 8, had an average direction from W.S.W.; the next strongest winds, which on seven occasions blew with a force of 7, had an average direction from S.W. by W. Those of the maximum strength, average 6, the average direction of which was W.S.W., blew on fifty-three occasions.

In the same years, near Holyhead, fog occurred one hundred and seventeen times, with a total duration of $698\frac{1}{2}$ hours. During fogs the average direction of the wind was S.W. by S., and its force (including calms, of which there were only five instances) 4.79. The average force of the winds blowing from the westward of the meridian was 5.24, against an average of 3.65 for those blowing from the

que les brumes ne se produisent pas, en général, dans ces circonstances atmosphériques; elles arrivent presque toujours du large, il est vrai, mais conduites par une brise légère.”—Reynaud, “Mémoire sur l’éclairage et le balisage des côtes de France,” pp. 273, 274.

¹ The force of the wind is stated in this Paper according to what is known as the ‘Beaufort scale,’ adopted by the Meteorological Department and the Admiralty, ranging from 0 = calm to 12 = hurricane. Colonel Sir H. James, R.E., at page 31 of “Instructions for taking Meteorological Observations,” gives a table of pressures per square inch which he considers equivalent to the numbers on the Beaufort scale; but the subject is one upon which authorities differ.

eastward, of which there were but seventeen instances. The strongest winds, which on three occasions blew with a force of 9, had an average direction from S.W.; the next strongest winds on five occasions blew with a force of 8 from W.S.W., and once from N.E. Those of the maximum strength, average 6.22, the average direction of which was S.W., blew on sixty-seven occasions.

These figures indicate a prevalence and duration of foggy weather which must cover the date of arrival of a large amount of shipping on our coasts—a lee shore; the strongest winds blowing from seaward, and varying in force from a mean of 4.55 and a maximum of 8 on the eastern coast, to a mean of 4.47 and a maximum of 9 on the western coast.

Even in situations where fogs may not usually be accompanied by high winds, the necessity of power and range in fog-signals is in no way diminished; for the experienced seaman is aware that the heavy snow-storm, or the thick driving sleet and rain, which often accompany a gale of wind, are not less blinding and bewildering to him, when endeavouring to make a landfall or to discern a light, than the densest fog. The wreck of the 'Dunbar' at Port Jackson Heads on the night of the 20th of August, 1857, took place during a heavy gale, when the atmosphere was so thick that the ship ran on shore at the foot of the cliffs from which a revolving light of the second order is exhibited; and the sole survivor of the catastrophe emphatically stated that the light was never once seen. A more recent instance occurred in the case of the steamship 'Cambria,' which was lost on the night of the 19th of October, 1870, at Inistrahull, on the north coast of Ireland, in a heavy gale. There is, at the scene of this wreck, a revolving catoptric light of the first order, and it is affirmed that this light was never sighted. To which it may be further added, that, in heavy weather, a point of danger is most to be dreaded when it lies to leeward, and that, in such a case, the sound of the fog-signal is borne away from those for whose ears it is intended.

In 1854 some experiments, on different means of producing sounds for the purposes of fog-signals, were made by the engineers of the French Lighthouse Department.

In 1861-62 MM. Le Gros and Saint Ange Allard, of the Corps des Ponts et Chaussées, conducted a series of experiments upon the sound of bells, and upon various methods of striking them.

In November 1863, and January 1864, a committee of the Elder Brethren of the Trinity House of London made some experiments at Dungeness upon various fog-signals.

[1870-71. II. N.S.]

II

The above are the only published records of experiments, specially upon fog-signals for coast purposes, which the Author has been able to find. The results obtained, and the conclusions arrived at, together with some special trials of particular instruments, will be referred to subsequently.

It is stated¹ that, in 1864, a commission appointed by the Lighthouse Board of the United States instituted a series of experiments to determine the relative power of various fog-signals which were brought to the notice of the Board. The experiments were conducted by Professor Henry of the Smithsonian Institution, Washington; but the Author has not succeeded in finding any recorded account of them.

In June, 1863, a committee of the British Association for the Advancement of Science, consisting of the Rev. Dr. Robinson, Hon. M. Inst. C.E., Dr. Gladstone, and Professors Wheatstone and Hennessy, memorialized the President of the Board of Trade, with the view of inducing him to institute a series of experiments upon fog-signals. The memorial, after briefly setting forth a statement of the nature and importance of the subject, described what was then known respecting it, and several suggestions were made as to the nature of the experiments proposed. It was pointed out that, in the first place, it is necessary to obtain some definite standard of measure of the power of fogs to arrest sound; and it was contended that this should be the first point for investigation, since otherwise any results obtained from phonic signals would be full of anomalies. It was observed that the minimum of efficiency of a fog-signal "is when a ship, putting down her helm on hearing the signal, can just come round clear of the danger. For very large steamers this cannot be done in less than 2 miles; and, allowing for sea and currents, that limit should at least be doubled; so that it may be assumed as a law, that (except in harbour) all fog-signals should be distinctly audible for at least 4 miles under every circumstance."² The memorial then alluded to the great difference which is known to exist, as respects power of penetration and range, between the volume and the intensity of sound, and to the necessity of instituting a careful examination of that branch of the subject. Reference was made to the experiments of M. Colladon and others upon the transmission of sound through water; and, lastly, a detailed list was given of the instruments upon which it appeared

¹ Mr. F. S. Daboll to the Author, January, 1871.

² *Vide* "Report of the British Association," vol. xxxii., p. 105 *et seq.*

most desirable to experiment, and a general programme of the experiments was set forth.

The proposal does not appear to have been favourably entertained by the authorities to whom it was referred, and the experiments were not undertaken.

The general tendency of fog to intercept or modify sound in its passage through the air, and the absence of reliable data as to the precise conditions which affect or vary the intensity of its action in this respect, have led to the consideration whether water may not be employed as a medium for the transmission of fog-signals. In 1851 Mr. Charles Babbage communicated to the United States Lighthouse Board a memorandum of various suggestions for the improvement of lights and beacons; and, in the course of his remarks,¹ he recommended that experiments should be made upon the transmission of sound through water. Professor Hennessy also has strongly advocated the investigation of the subject. He states,² that almost all the knowledge possessed respecting it is due to M. Colladon, whose experiments were made on the Lake of Geneva in 1826. M. Colladon found that subaqueous sounds were totally reflected at the surface, at such angles as rendered it impossible to hear them above water for distances exceeding about 220 yards. By the use of an instrument contrived for listening below water, M. Colladon was able to hear the sound of a bell under the surface at about $8\frac{1}{4}$ miles; and he subsequently succeeded in transmitting distinctly audible sounds under water to a distance of about $21\frac{3}{4}$ miles. He also found that the noise of the winds and waves produced little or no effect in diminishing the subaqueous sound.

It would be foreign to the scope of the present Paper to enter more into detail upon this branch of the subject; but it appears to open a promising field of inquiry, and it is in the highest degree probable, that research and experiment in this direction will ultimately lead to important modifications in the principle of fog-signals.³

In the details of experiments hereinafter mentioned, the condi-

¹ *Vide* "Report of United States Lighthouse Board," 1852, p. 163.

² *Vide* "Report of the British Association," 1861, vol. xxx., p. 173.

³ Those who desire to refer to the original experiments will find them recorded in "*Mémoires présentés par divers savants à l'Académie Royale des Sciences de l'Institut de France*," tom. v., p. 320; and in "*Annales de Chimie et de Physique*," 3^{me} série, tom. ii., p. 525. An account of some later experiments on the same subject, by the Rev. Dr. Robinson, Dr. Gladstone, and Professors Hennessy and Wheatstone, will be found in the "Report of the British Association," vol. xxxv., p. 212.

tions of wind and weather are carefully noted, so far as they can be ascertained. It need scarcely be added that these conditions materially affect the value of deductions drawn from the experiments themselves. Fogs have a remarkable power of deadening sound, and act in this respect so irregularly, that experiments made during clear weather have little or no practical value, except as mere competitive trials of different instruments; and, until the knowledge respecting the laws which govern the transmission of various sounds through fog is considerably extended, it cannot even be safely assumed that the instrument which has the greatest range and distinctness in clear weather will invariably maintain its superiority under altered atmospheric conditions. It is only by a series of experiments, systematically conducted, and carried out with persevering and rigorous accuracy under a great variety of circumstances as to wind and weather, and especially during fogs and equivalent atmospheric obstructions, that any really valuable addition can be made to the stock of knowledge upon the subject: without this, all investigation of isolated cases can be little better than a vague groping in the dark; and it is to be hoped that a thorough and scientific inquiry may yet be undertaken by competent authority.

The instruments in use for fog-signals are gongs, bells, guns, whistles, and trumpets; the two latter sounded either by steam or by condensed air.

GONGS.

The gongs employed are mostly of Chinese manufacture. They vary in size from about 1 foot 7 inches to 2 feet in diameter, and 4 inches to $4\frac{3}{4}$ inches in depth, and weigh from about 14 lbs. to 35 lbs. or 40 lbs. Their pitch and tone vary, but the most usual note is C, D, or F, all more or less imperfect. They are suspended by a loop of stout line, and are struck by hand with an elastic-headed gong-stick. The Author is not aware that any of those in use are sounded by machinery. There appears to be no particular duration or interval prescribed for their sounding during fog. They emit a peculiar and characteristic sound, which is well adapted to catch the ear, but their power is small. Great diversity of opinion exists respecting the range of their sound. Reynaud states that it scarcely exceeds 500 mètres (550 yards), but omits to mention whether this is a maximum or an average. As a maximum, it is much understated. The gong of the 'Warner' light-vessel has been heard at the Nab, a distance of 3 miles, under presumably

favourable circumstances. There are, however, numerous instances in which gongs could not be heard at a distance of $\frac{1}{4}$ mile; and it is almost certain that their effect against a strong wind can be but slight. In the absence of accurate experiments, it is impossible to determine whether an increase in size would be accompanied with an increase of sonorous power sufficiently great in proportion to render such an increased size advisable. These instruments have the great recommendation of diffusing their sound equally all round, with but slight reference to the direction in which they are turned or struck, and they are therefore more suitable for use on board light-vessels (the situation in which they are chiefly employed) than for stations on shore.

BELLS.

The bells used for fog-signals are of various weights, ranging from 3 cwt. to 2 tons and upwards. Those at rock lighthouses on the English coast weigh usually from 5 cwt. to 7 cwt.

The result of the experiments already mentioned, made by French engineers, may be summarized as follows:—

It was found that a better sound was produced by striking with a hammer than by the action of a tongue set in motion by swinging the bell. The range of the sound increases with the rapidity of the strokes, the range of sound produced by twenty-five strokes per minute being to that of fifteen strokes per minute as 1·14 to 1, and the range of sixty strokes per minute being to that of fifteen strokes per minute as 1·29 to 1. A bell weighing 220 lbs., struck by a hammer weighing 11 lbs. falling $7\frac{1}{2}$ inches and immediately set off by a spring, was heard at about 1,320 yards against a fresh breeze (*bonne brise*); at $1\frac{1}{4}$ mile with the wind across; and at $2\frac{1}{2}$ miles down the wind. In a calm, or with a light breeze across the line of observation, the sound was heard at $1\frac{1}{2}$ mile. A hemispherical iron reflector, 4 feet 11 inches in diameter, encased in Portland cement, increased the mean range in the ratio of 147 : 100, over an arc of 60° , but from thence the increase due to the reflector diminished over an arc of 100° , beyond which an isolated bell had the advantage. In calm, or down the wind, the ratio of range over the same arc was as 170 : 100. Against a fresh breeze the ratio was as 130 : 100. It was found that a breeze across the axis of the reflector deflected the line of maximum range to nearly the same extent as that of the isolated bell; but it does not appear to have been ascertained whether, under these circumstances, the angular measurement of the arc of maximum range underwent any alteration. The same bell with reflector,

struck by a hammer having the same weight and fall as before, was then tested against an isolated bell weighing 495 lbs., struck by a hammer having the same fall, but weighing 19 lbs., and each bell was struck sixty times per minute. With a fresh breeze down the line of observation, the range of the isolated bell was 6,754 yards or 3·80 miles, and that of the bell with reflector 8,387 yards or 4·75 miles; and, over an arc of 60°, the average range of the heavy isolated bell was to that of the lighter bell with reflector as 100 : 128.

These trials were not extended to foggy weather.

The experiments made in 1863 and 1864 by a committee of the Elder Brethren of the Trinity House, of which a Report was published by order of Parliament,¹ gave, with reference to bells, results differing considerably from those above described. The bell was an experimental one of steel, weighing 10 cwt., and was struck thirty times per minute, but no details are given in the Report respecting the weight and fall of the hammer. In the experiments of November, 1863, it was found that, at 1 mile distance, with a moderately fresh breeze across, the sound of the bell could not be heard so as to be identified as a signal. In those of January, 1864, in a calm with light variable flaws, the bell was heard well at 1 mile, faintly at 2 miles, very faintly at 2½ miles, and not at all at 3 miles and upwards. At 1 mile, with the paddles of the committee's steamer going, the bell was not distinctly heard. The maximum range of a 10-cwt. bell, therefore, with a fresh breeze across, was found to be less than 1 mile; whereas the French experiments gave 1¼ mile as the range of a 220-lb. bell under the same circumstances. It is, however, to be borne in mind that steel has considerably less sonorous power than bell-metal, and the discrepancy is no doubt partly owing to the difference in the material of the bells employed.

These trials were not made during foggy weather.

The bell at Howth, on the Irish coast, weighing 2¼ tons, and struck four times per minute by a hammer weighing 60 lbs. falling 10 inches, has been heard only 1 mile to windward in fog against a light breeze. A similar bell at Kingstown, struck eight times per minute, has "been found useful" by the Holyhead packets in fog at 3 miles,² wind not stated. In connection with this bell, it

¹ Ordered by the House of Commons to be printed, March 14th, 1864. Parliamentary Paper No. 125.

² Secretary of the Irish Ballast Board to the Secretary of the Northern Lights Commissioners, December, 1862.

should be noted that the Holyhead packets are powerful steamers, with very large paddle-wheels, so that it may be reasonably inferred that the sound of the bell is good, if found useful to a vessel of that description under way at the distance stated.

Capt. Walden, of the United States Revenue service, states that a bell at the Outer Light at Boston, Mass., weighing 1,375 lbs., and struck by machinery every 47 seconds, was distinctly heard by him on board a small steamer under full way, at a distance of 5 miles at sea, with the wind across and ahead;¹ whether during fog or otherwise is not mentioned.

It is asserted² that a bell at Cape Elizabeth, near Portland, Maine, weighing 1,560 lbs., and struck by machinery every ten seconds, was heard only 2 miles or 3 miles in calm weather, and was not audible for more than 100 yards against a light breeze.

Bells used for fog-signals at rock lighthouses are suspended by brackets or cantilevers from the pedestal of the lantern or from the gallery, and are struck by a hammer set in motion by clockwork driven by a weight. Owing to the exposed situation of these lighthouses, the bells are not always safe from injury, notwithstanding the height above the sea-level—from 60 feet to 100 feet—at which they are suspended. During a heavy storm on the night of the 30th of January, 1860, the bell at the Bishop Rock lighthouse, weighing 3 cwt., and suspended at a height of 100 feet above high-water mark, was torn from its fastenings and broken by the violence of the sea.

As a precaution against accident, therefore, the bell is always sought to be placed at that side of the tower which is least exposed; a position in which, though its safety may be secured as far as possible, its usefulness as a signal is reduced to a minimum, since the tower intercepts and tends to deaden its sound over an arc of not less than 90°, in the direction in which it is required to have the longest range for the benefit of vessels arriving from seaward during thick weather, and to those on board of which the sound of the bell may be the only indication of their whereabouts. It is, unfortunately, more easy to criticize the defects of present arrangements than to devise schemes of improvement. To place the bell on the most exposed side, would be to incur the risk of accident, and the consequent destruction of what small service it may render. To suspend it by a framework above and attached to the roof, would add to the weight, already sufficiently great, which

¹ *Vide* "Report of United States Lighthouse Board," 1852, p. 473.

² *Ibid*, p. 190.

the lantern framing has to support; and if the standards of the superimposed framework were brought down and secured to the stonework of the tower itself, their great length would render them liable to too much vibration in storms. It is conceivable that a bell of hemispherical shape, similar to that of a clock or to that used as a guard's signal on locomotive engines, might be attached to the cone supporting the ventilating ball, and might even be made to form a protection to the cone, and thus allow the latter to be so reduced in weight as in a measure to compensate for the addition.

The patents connected with fog-bells are numerous. Most of them relate to mere details of the mechanism for striking. The earliest which the Author has met with, is that of Mr. D. Johns, who, in 1849, patented in the United States a method of ringing, and an adjustable clapper, to produce varied signals to indicate the locality. That of Mr. C. F. Stansbury, 1855, was for a mode of ringing by a lever carrying at one end the armature of an electro-magnet. In this scheme, the electric circuit was alternately completed and broken by wires attached to the verge of the escapement of a clock, which were dipped into cups of mercury as the pendulum oscillated; the apparatus being therefore adapted for the isochronous sounding of a bell at a distance from shore. Mr. C. Oliver's patent, 1861, referred chiefly to modifications of the clock-work for ringing; but it included a novel and ingenious device for ringing bell-buoys, by means of heavy spheres placed in troughs set end-on to the bell, which spheres rolled to and from the bell as the buoy moved with the sea. All such matters, however ingenious some of them may be, do not affect the question of sound and power of the bell as a fog-signal, and must be passed over with the above brief notice.

GUNS.

Cannon, and explosive signals generally, were excluded from the experiments made by the French engineers in 1854, the reason assigned being, that their use is attended with inconvenience and even danger.¹ At an isolated rock light, such a signal could not be used; and it is not unreasonable to suppose that, in the close vicinity of any lighthouse, the discharge of a heavy gun would be injurious. The experiment, however, is about to be tried on a large scale at Flatholm, by the establishment of a battery of heavy guns for defensive purposes within 80 feet of the lighthouse

¹ *Vide Reynaud, ubi sup.*, p. 272.

tower, and the result will probably settle the question in a practical manner.

Apart from considerations of safety and convenience, guns must be admitted to be, in many cases, efficient as fog-signals, and they are in use at several points on the English coasts. Those at Flamboro' Head, Lundy Island, and North Stack, are 18-pounders, and, during fog or other atmospheric obstruction, are fired every quarter of an hour, with a charge of 3 lbs. of powder. The light-vessels on the English coast are provided each with two 12-pounder carronades, firing a charge of 1 lb. or $1\frac{1}{4}$ lb. of powder; but these are not, strictly speaking, used as fog-signals, but rather as warning signals to a vessel seen standing into danger, and as alarms in case of wreck.

The Lundy Island gun has frequently been heard by the Author at Hartland Point, a distance of 10 miles, during dense fog, with a light breeze across the sound. It gave a dull faint report; and a moderate noise in his immediate neighbourhood would probably have been sufficient to drown it, unless the signal had been attentively listened for.

The gun of the Kish light-vessel is stated by the secretary of the Irish Ballast Board to be favourably reported on by the masters of the Holyhead steamers, and has been heard at a distance of upwards of $2\frac{1}{2}$ miles.¹ But details as to direction and force of wind are wanting, to serve for a judgment of the absolute efficiency of the signal in these cases. During a dense fog at Kingstown, in October, 1859, guns were fired from the guard-ship, for the guidance of one of the Holyhead packets, and the report of some of them was not heard at 1 mile distance.²

In the Trinity House experiments of January, 1864, made in calms and light airs, but not during fog or thick weather, an 18-pounder gun with a charge of 3 lbs. of powder was tried, with the following results. At distances of 2 miles and 3 miles, with the paddles going, the flash and smoke were seen, but no report was heard. When the paddles were kept just moving, the report was pretty good at 2 miles. With the paddles stopped, the report at 2 miles and 3 miles was very good, and at 4 miles it was faint.

It is a noteworthy circumstance, that the height at which a gun is situated above the water appears to be no detriment to its value as a signal. Such at least is the inference from the following case,

¹ Letter to the Secretary of the Northern Lights Commissioners, December, 1862.

² *Vide* Fitzroy, "Weather Book," p. 315.

mentioned by Dr. Gladstone: "Captains Close and Nisbet, of the Trinity Board, have made some experiments . . . at Holyhead mountain, where a gun was fired from near the surface of the sea, and another at a considerable height, and the respective reports were listened to from various distances at sea. They found the upper gun was heard best for six miles, after which it lost its superiority. But the most remarkable result was the irregularity of the noise from the lower gun, which at certain points, in fact, was not heard at all, though the flash was distinctly seen."¹

The cost of a fog-gun establishment may be taken at about £105 for two 18-pounder guns, &c., complete, and £850 for buildings, exclusive of purchase of land; together £955. The annual expenditure, reckoned upon the average at three stations during the year 1869, is as follows:—

	£	s.	d.
Wages of two gunners	81	0	0
Clothes and allowances	25	4	0
Stores, ammunition, &c. . . .	118	16	8
Total	£228	0	8

or at the rate of £18 1s. 10d. per twenty-four hours of fog as averaged at the same stations during the same period. Exclusive of wages and allowances, it is at the rate of £9 8s. 1d., per twenty-four hours of fog.

WHISTLES.

The sharp and piercing scream of the hemispherical or locomotive whistle possesses, in a very high degree, the quality of intensity as compared with volume, which is considered essential to a thoroughly efficient fog-signal. It is difficult to trace the first application of this instrument to the purposes of coast signals; the earlier attempts having been made rather with the view of adapting it as a warning signal on board vessels at sea. The late Mr. Alexander Gordon, M. Inst. C.E., appears to have been the first to suggest its use in combination with a reflector, for the purpose of collecting and condensing its sound into a phonic beam.² He proposed to sound the whistle by either air or steam; and to place it either in the double reflector of Bordier Marcet, for sounding equally all round the horizon, or in a focus common to three parabolic reflectors grouped together,

¹ Vide "Proceedings of the Royal Institution," vol. iv., p. 54.

² Vide "Evidence before Select Committee on Lighthouses," 1845, Nos. 4,453-4,457.

revolving on a vertical axis. In the course of his evidence he pointed out that a shrill sound, high in the scale, is carried much further than a lower note, although the sound of the latter may be more powerful when near at hand. "Shrill sounds," he says, "penetrate further, and are better heard." But he stated that he did not know of any instance of the locomotive whistle having been applied to the purpose of a fog-signal.

In 1850 the late Mr. C. L. Daboll brought out a whistle, sounded by compressed air. One of these machines was erected by order of the United States Government, at Beaver-tail Point, near Newport, R.I., in 1851. It had a condenser of 225 gallons capacity, filled by two air-pumps 3 inches in diameter, and 8 inches stroke, worked from a cranked axle driven by simple gearing, and moved by one horse. The condenser could be filled to a pressure of from 40 lbs. to 50 lbs., in $7\frac{1}{2}$ minutes by slow gearing, and in 4 minutes by fast gearing; and the whistle sounded once every 3 minutes. It was estimated by Captain Walden, who made an official examination of the apparatus, that, in order to maintain a regular series of signals, it would require the work of one horse during one-third of the time over which the signals extended [or at the rate of one-third of a horse-power per hour].

The testimony as to the efficiency of this whistle is abundant and favourable. During dense fogs (wind not stated), it was distinctly heard at from 6 miles to 8 miles, in the town of Newport even when there was considerable noise of drays and carriages in the streets. It was distinctly heard in the same town at 6 miles in dense fog, against a light breeze, early in the morning, when there presumably was but little noise in the streets; and at Jamestown, distant 5 miles, in foggy weather, with the wind (strength not stated) blowing across the sound. Captain Walden heard it distinctly at a distance of $2\frac{1}{2}$ miles, in a rough sea, and with a strong wind blowing across the sound.¹ The President of the United States Lighthouse Board bears testimony to its efficiency as a signal, from personal observation. He says: "The early part of the night was clear, but as the steamer approached the east end of Long Island and the passage between Beaver-tail and Brenton's reef, the fog became so dense that navigation would have been extremely hazardous without some better guide than the compass and lead; and this was found in the whistle, which sent its clear and shrill notes far over the water, indicating the bearing of the point on which it is placed, much more accurately than a bell or a

¹ Vide "Report of the United States Lighthouse Board," 1852, pp. 466-473.

gun would have done, and enabling the steamer to arrive, with little loss of time, at her port.”¹

The estimated cost of four of these machines, three of them worked by horse, and one by hand-power, including buildings for two of them, was at that time $\text{£}3,500$,² or $\text{£}729$.

In 1854 Professor J. C. Cresson, an American authority, proposing the employment of a steam-whistle, made a calculation of the quantity of steam required to sound it; which, for a whistle intended to be heard 5 miles or 6 miles (under what conditions of wind is not stated), blowing blasts of 2 seconds duration, with intervals of from 2 minutes to 3 minutes, he estimated at less than one-tenth of a horse-power³ [per hour?]. But he gives no data for this calculation.

In 1856 Mr. William Smith patented in England a compound whistle, consisting of four whistles combined, with their sounding edges straight on plan instead of circular, of which a detailed description and drawing is to be found in his specification, No. 56/2105. It does not appear that any experiments with this instrument have been made public, and therefore its value as a fog-signal cannot be determined.

In January, 1860, Mr. E. A. Cowper, M. Inst. C.E., communicated to the Trinity House of London a design for a fog-signal, in which it was proposed to employ a whistle 15 inches in diameter, placed in the focus of a parabolic sound-trumpet, 25 feet long, and blown by steam from a 12 H.P. boiler. This apparatus does not appear to have been tested in practice, but its large size leads to the expectation that it would be an instrument of great power. Mr. Cowper also, at that time, perceived and pointed out the propriety of making the intervals and character of the sounds of a fog-signal to correspond with the character of the light to which it is auxiliary.

In 1861 Mr. Delabere Barker patented in England (No. 61/1031) a fog-whistle to be sounded by superheated steam, being a communication from Mr. T. T. Vernon Smith, of St. John's, New Brunswick. The claim of the invention is: “1st. The employment of high-pressure or superheated steam for sounding a whistle as a telegraphic signal at sea, operated upon by machinery at certain intervals of time, so as to signal not only by the note, but by the

¹ *Vide* “Report of the United States Lighthouse Board,” 1852, p. 466.

² *Ibid.*, p. 467.

³ *Vide* “On the Use of Phonic Signals in Navigation,” *Journal Franklin Inst.*, 3rd Series, vol. xxviii., p. 397.

interval between the notes. 2nd. The employment of two or more whistles, thus operated upon, to give an identity to the locality in which they are used, and to prevent the confusion with other signals. 3rd. The use of reflectors to concentrate and intensify the sound of steam-whistles, and tubes to conduct the same in different directions." The apparatus of this machine is extremely simple. The boiler is vertical and tubular, surmounted by a steam-chest or dome for superheating the steam. Connected with this is a whistle or whistles, from 5 inches to 6 inches in diameter, sounded by clockwork, or other suitable automatic movement, for opening the valve of the steam-pipe at regulated intervals.

An apparatus of this description, the boiler of which is capable of working about 2 H.P., has been for many years in operation at Partridge Island, St. John's harbour, New Brunswick. It appears to have been established at some time between 1850-60. Through the courtesy of the authorities at the Colonial Office and the Board of Trade, his obligations to whom it affords him much pleasure here to acknowledge, the Author is enabled to lay before the Institution some particulars relating to this apparatus.

An official communication from the Commissioner of Public Institutions,¹ after describing the general character of the machinery employed, states that the whistle is sounded once a minute, the blast lasting ten seconds. "The pressure of steam under which it is intended to be worked is about 100 lbs. on the inch, the safety valve blowing off at 105 lbs. With a pressure of from 90 lbs. to 95 lbs. the whistle can easily be heard in calm weather a distance of 6 or 7 miles, and has been heard by a steamer in a heavy gale, and sea running high, at a distance of $5\frac{1}{2}$ miles to windward, but it was then not audible till the paddles were stopped.

"In August, 1863, Commander Malcolm, H.M.S. 'Barracouta,' made some experiments with regard to the steam-whistle, and reported to the Admiral on the station, of which the following is an extract.

"On the 8th instant, in Her Majesty's ship under my command, when sailing from St. John in a dense fog, the horn bearing about N. by W. half a mile, wind S.W., force 4, I steered S.W. by S., put the patent log overboard, and when we lost the sound the patent log showed $2\frac{1}{2}$ miles. So, on this occasion, we may infer, being to windward of horn about 3 miles, fog being very dense, and breeze moderate (about 4), that the sound of the horn, in such

¹ Letter to the Hon. S. L. Tilley, March 23, 1864.

weather, may fairly be supposed to have a radius of from 3 to 6 miles.'

"Shipmasters and pilots frequenting this port have uniformly expressed their sense of its value.

"The Chamber of Commerce passed a resolution acknowledging the advantages derived from its use, and it is a well-established fact that many vessels have been enabled to make this port guided by this alarm, when without it they must have remained in the bay in the worst weather. . . . The result of the last two years' operations gives an average expense of 21s. 8½d. [19s. 10d. sterling] for twenty-four hours' working, this covering everything but wages, which . . . are probably here at a minimum."

The above report enclosed also a letter from the parties who erected the apparatus, making some suggestions for improvement in the details of its machinery, which would allow the engine to be reduced in size. They state: "As the power required to work the horn is very small, the boiler would be about 3 feet diameter, with 61 tubes 2 inches diameter and 6 feet long, capable of working 6 H.P., and calculated to sustain a working pressure of 200 lbs. to the square inch. The horn would be larger than that on Partridge Island, which . . . would enable it to be heard at a much greater distance. The cost of one similar to the one now in use would be about £200 sterling. The cost of one of the improved . . . would be about £240 sterling."¹

A later Report² states that the whistle on Partridge Island "was found to be most useful both to steamers and sailing vessels, at times when the light on the island was found to be perfectly useless, and vessels have frequently been enabled to make their way up the harbour to their wharf or anchorage-ground without even seeing either land or light, solely by the aid of the fog whistle. As the usefulness of this description of navigation security became better known, the American Government sent their officers to examine it, and now there are several in operation on the American coast.

"The British Admirals have also visited the one at St. John Harbour, and have highly approved of it.

"The Trinity House of London has also obtained plans of it from this department, and one has recently been erected at Aberdeen Harbour.

¹ Messrs. Fleming and Humbert to Commander Malcolm, R.N., 8th August, 1863.

² *Vide* "Report by the Minister of Marine and Fisheries," Ottawa, 2nd No., 1870.

“The Government of Canada has also extended their use, and there are now four in operation, viz., one at Partridge Island, one at Lepreau, one at Yarmouth, and one at Seal Islands. There are also two more constructing; one for Cranberry Island, Cape Canso, and one for Anticosti; and arrangements are now being made for placing one in a new iron light-ship, which this department is building for Red Island reef, River St. Lawrence.”

The cost of an engine, boiler, and whistle complete, is estimated in the above Report at \$2500 (about £521 sterling), or more than double the cost estimated in 1863. It is not easy to reconcile this discrepancy, unless it be supposed that wages and prices have greatly risen, and that experience has suggested additional alterations and improvements, leading to increased cost.

With a view of further developing the capabilities of the whistle as a fog-signal, it is much to be desired that periodical reports upon the performances of these instruments, and upon alterations and improvements made from time to time in their construction, should be obtained from the authorities in the localities where they are in use. The bay of Fundy, and many other parts of the North American coast, are so frequently beset with dense fogs as to afford ample opportunity for examination of their effect upon phonic signals.

The whistle at Aberdeen to which reference has been made, was established by the Aberdeen Harbour Commissioners in December, 1869, from the designs of their engineer, Mr. W. D. Cay, Assoc. Inst. C.E., to whom the Author is indebted for the information respecting it. It is on the Vernon Smith principle; the whistle is 6 inches in diameter, and is sounded at intervals of one minute, the blasts lasting ten seconds. It is sounded by steam at a pressure of 60 lbs., supplied from a tubular boiler. Mr. Cay states¹ that he has no reports from the captains of vessels as to the efficiency of the signal, but has been given to understand that it is very useful to captains of steam vessels seeking the harbour in foggy weather. He has also experimented on it at sea in clear weather in a tug, and heard it quite distinctly 5 miles with the wind and 2 miles against the wind. In foggy weather it can be distinctly heard at about $2\frac{1}{2}$ miles, with a hill and houses intervening; and it is said to be a great annoyance to the inhabitants of Aberdeen living 2 miles to 3 miles from it.

The cost of the building and apparatus for this signal was £405 16s. 1d.; and its working expenses in 1870 were as follows:—

¹ Letter to the Author, January 27th, 1871.

	£	s.	d.
Wages of keepers	49	8	5
Coke	13	5	6
Sundries	4	8	0
Total	<u>£67</u>	<u>1</u>	<u>11</u>

or at the rate of £4 5s. 1d. per twenty-four hours of working. Exclusive of wages, the working expense per twenty-four hours was 22s. 5d. The amount expended for wages is moderate, the keepers being employed on the other harbour works when the signal is not in action.¹

In 1865 Mr. H. T. Humphreys, M. Inst. C.E., devised an apparatus for automatically sounding a whistle, in which the motive power is afforded by the rise and fall of the tide. The tide, while flowing, acts upon a turbine, and, while ebbing, upon a second turbine, of a power calculated for the rise and fall of the tide at the particular station where the signal is to be placed. These turbines, one of which is constantly at work except during the period of slack water, are contrived to drive a pump, which delivers the sea-water into an elevated tank. The water thus raised is employed to drive a smaller turbine, which, by means of a cam, raises and lets fall a heavy ram or hammer. This falls upon a piston working air-tight in a cylinder, the valves of which are so arranged as to admit air into the cylinder when the piston is raised, and to pass out the contained air, when compressed by the blow of the hammer, into a whistle or whistles. The cam revolving, lets the hammer fall upon the piston, suddenly compressing the air in the cylinder and driving it with violence through the whistle, producing a note of great shrillness and intensity—hence the name “Clamor Æstus,” or “Tide-shriek,” applied to the apparatus. As soon as the cam lifts the hammer, a spiral spring returns the piston to its place in the upper end of the cylinder, ready for another blow. The amount of water pumped into the tank is so regulated as to provide a supply for efficiently working the turbine which lifts the hammer, during the periodical inaction of the tidal turbines at slack water. It was intended to use phonic reflectors, or a trumpet-shaped blast-director, in combination with the whistle, if required for the purpose of condensing the sound in particular cases. The inventor’s calculation of the relative proportions of his apparatus, requisite to produce a 2-feet blow

¹ Mr. W. D. Cay to the Author, January 27th, 1871.

from a 1-ton hammer twice a minute, gives $\frac{1}{3}$ H.P. for each of the tidal turbines where the maximum range of tide is 6 feet.

The expense of the construction of a complete apparatus on the "Clamor Æstus" principle prevented the trial of its powers in actual practice. The experiments made by Mr. Humphreys had for their object the establishment of his idea of the advantages of a percussive blast of air through a whistle. He considers that those advantages were fully proved to exist; and that the peculiar and entirely characteristic sound produced by the fall of a heavy weight on an air-vessel would be superior to that produced by a fog-horn or steam-whistle, and could be at once distinguished from all other sounds, and its source recognized most readily.¹ Mr. Humphreys's invention deserves notice, not only on account of the novel and ingenious idea of a percussive blast, but also as a workmanlike attempt at solving the problem of applying tidal action to the purpose of a fog-signal.

Before quitting the subject of the whistle as a fog-signal, it should be added that there undoubtedly is room for improvement in the construction of the instrument itself. It appears, from an experiment made by Professor Holmes, that even in the best specimens of the hemispherical whistle the steam or air does not act upon the whole circumference of the sounding edge. To prove this, he interposed a metal plate between the lip and the slot at those parts where no sound was produced, and found that, in a 10-inch whistle of the best make by Flaud, of Paris, the blank portions amounted to fourteen-fifteenths of the whole; the sound of the whistle in this condition being in no degree diminished, but, if anything, improved, thus showing that the portions blanked had no effect in augmenting the sound, but that the non-effective steam rather interfered with the proper vibration of the metal. If, therefore, it be possible to construct a whistle, every portion of which shall be properly acted upon, it may be expected that an efficient instrument will be produced, probably twelve or fourteen times as powerful as the best specimen of similar size now obtainable. This, if ever it be accomplished—and it appears to be a mere problem in mechanical accuracy of manufacture—will be of the utmost importance with reference to the use of the whistle as a fog-signal, increasing in an extraordinary degree its intensity and range, without at all increasing its working expenses.

¹ Mr. H. T. Humphreys to the Author. January 24th, 1871.

TRUMPETS.

The use of horns¹ as fog-signals is of old date; but, so long as the means of sounding them was limited to the human lungs, their power must have been too small to be effective at long distances. Apparently the earliest attempt to apply machinery to the purpose was to the 'Telephone,' which was laid before the Admiralty in 1844 by the late Admiral J. N. Tayler. The apparatus consisted of a condenser, filled by air-pumps worked from a cranked axle driven by a winch. A set of piston-keys allowed the air to pass into the sounding-pipes, which were four in number, having metallic springs or reeds to produce the sound. By combining and varying the notes, it was proposed to convey signals during fogs. It was stated that this instrument would convey a signal 6 miles or 8 miles in foggy weather; and, when a greater range was required, the inventor proposed to add to it a parabolic phonic reflector. It is believed that some experiments were tried with this apparatus, but the Author has not been able to discover any report upon them. The metallic reed of the pipe or trumpet may have furnished an idea to subsequent inventors.

In 1851 the late Mr. C. L. Daboll designed a trumpet, having a metallic reed, and sounded by compressed air, one of which was then in actual operation at Beaver-tail Point. It was attached to the condenser employed for the whistle, and appears to have been occasionally sounded in alternation with the latter, since both instruments are mentioned by some of the persons who testify to the range of the sound.² It is said to have been distinctly heard at 6 miles distance, against a light breeze and during dense fog; and Captain Walden states that he distinctly heard it at $2\frac{1}{2}$ miles distance, in a rough sea, and with a strong wind across. Evidently the value of this instrument was fully recognized by the authorities, since Captain Walden proposed that similar ones should be established at certain places instead of whistles, as originally intended, in order to give the navigator a better opportunity of determining his position than if all the signals were of one character;³ and it is in the highest degree

¹ The term 'horn' has been occasionally applied in the preceding section to the apparatus connected with the whistle. In the present section the term is restricted to those instruments which are of the nature of a bugle, and to those which are sounded with a reed.

² *Vide* "Report of the United States Lighthouse Board," 1852, pp. 471-472.

³ *Ibid.*, p. 468.

improbable that this recommendation would have been made unless he had been perfectly satisfied of the efficiency of the trumpet as a fog-signal.

In June, 1860, Mr. Daboll patented in the United States, and in November, 1863, in Great Britain (No. 63/2962), the application of air condensed by machinery to the sounding of whistles or horns, and the revolution of the horn whilst sounding. In this apparatus air is forced by suitable engine power into a condenser, and this by a pipe communicates with the trumpet or other wind instrument, a valve being interposed which is made to act by the engine employed to condense the air; and the length of the blasts and intervals of silence regulated by suitable gearing. The condensing engine and apparatus may be at a considerable distance from the trumpet, the compressed air being communicated by a pipe which becomes a continuation of the condenser, and the valve being worked from the distance by wires or rods. Where a method of sounding at a distance from the engine can be successfully adopted, it may prove of great importance, allowing the employment of the trumpet as a fog-signal in situations where, owing to the small space available, the exposed position of the site, or other local circumstances, the requisite buildings and machinery for the motive power could not be erected at the same spot. It will be seen below that the same end is attained by Professor Holmes in a different manner. The engine preferably used is Ericsson's caloric engine; which, owing to the short time required to set it to work, the low cost at which it can be worked, its simplicity and non-liability to get out of order, and its freedom from danger of explosion, appears to be very suitable for the purpose. It can be started to work in from twenty minutes to thirty minutes, a matter of no slight importance where it is requisite to commence sounding the signal promptly on the appearance of a fog; and, should the fog clear off, the fire can be immediately drawn, after which the engine will continue to work for twenty minutes or thirty minutes by its own heat, so that if the fog reappears there need be no delay in continuing the signal. And, as has been suggested by Mr. J. N. Douglass, M. Inst. C.E., if the fire-box of the engine be kept warm by a lamp burning inside, the time required to start the machine in the first instance may be reduced to less than ten minutes.

The rotation of the horn is a feature of great importance where only one is employed, as it permits the axis of the mouth to be directed to every point of the horizontal arc over which it is required to act, and thus to distribute the sound as it moves: the

apparatus acts, in fact, as a revolving light; and, if the trumpet were continually sounding and revolving, the analogy would be perfect. But the analogy fails when the rotation is reciprocating, since the recurrence of the sound on the line of axis does not take place at an equal interval of time, but occurs sooner at the ends of the arc. The trumpet must either revolve entirely, or else be made to return in silence to the opposite end of the arc in time to commence sounding there again at the proper interval.

When the reciprocating rotation of the horn is to be uniform, it is accomplished by an eccentric-rod rocking a bevelled toothed quadrant, which drives a pinion keyed on the vertical shaft of the horn. When it is to be intermittent, it is effected in the following manner:—A mitred wheel, kept constantly revolving in one direction on a horizontal shaft, is geared into two mitred wheels, one above and one below, running loose on the shaft of the horn, and keeps these wheels in constant motion in opposite directions. Between the horizontal mitred wheels, and sliding on a feather on the shaft of the horn, is a clutch, which engages a corresponding clutch on either the upper or lower mitred wheel, according as it is lifted or depressed. A weighted arm on the axle of the clutch-lifter tends to keep the clutch constantly engaged with the upper wheel, and therefore to keep the horn always revolving in the same direction. Another arm from the axle of the clutch-lifter, bent downwards, and having a small friction-roller at its lower end, is moved by wipers on a horizontal wheel revolving with the horn. According to the shape of the wipers, the clutch is either retained in the middle between the horizontal mitred wheels, the horn being then stationary; or it is pressed down to engage the lower one, when the horn revolves in a direction the reverse of that produced by the upper one: where there are no wipers, the bent arm is not acted upon, and the weighted arm lifts the clutch, and engages it with the upper wheel. By making the wipers of suitable shape and number, the rotary motions of the horn, and its intervals of rest, can be regulated with the greatest nicety.

In the Trinity House experiments of November, 1863, before mentioned, the Daboll fog-trumpet employed was one of what is termed in America the third class, 4 feet 6 inches long, $2\frac{1}{2}$ inches in diameter at the smaller end, and 21 inches at the mouth, and was worked by an 18-inch caloric engine.¹ It was a straight stationary trumpet, placed horizontally, 8 feet above the shingle of

¹ The denomination of the caloric engine is determined by the diameter of the outer piston.

the beach, its mouth projecting about 2 feet 6 inches from the building containing the engine. The blasts continued four seconds, with intervals of twelve seconds. The weather was not foggy, and a moderately fresh wind was blowing across the line of axis of the horn. In a line with the axis, the horn was distinctly heard at $2\frac{1}{2}$ miles, and the sound was observed to diminish as this line was departed from. When the line of observation was at right angles to the axis, the horn being then to leeward, it was not audible beyond $\frac{1}{2}$ mile. In a similar position, but with the horn to windward, it was heard at a distance of 4 miles or $4\frac{1}{2}$ miles.

In the experiments of January, 1864 the same apparatus was used, the pressure of air in the condenser being 10 lbs. The weather was calm, with variable flaws, and no fog. In the line of its axis, with the paddles going, the horn was not distinctly heard at 1 mile. With the paddles stopped, it was heard well at 2 miles, very fairly at $2\frac{1}{2}$ miles, faintly but good for the distance (and, immediately afterwards, distinct and marked) at 3 miles, and not at all at 4 miles. At an angle of 45° from the axis of the horn, with the paddles stopped, it was distinctly heard at 1 mile, and faintly at 2 miles. At an angle of about 60° from the axis of the horn, with a light air across the line of observation, its sound was not good at 1 mile, and was faint at 2 miles.¹

This apparatus was subsequently removed from Dungeness, and placed on board the Newarp light-vessel, where it is now used during fogs. At this station, it can be distinctly heard at $5\frac{1}{2}$ miles distance, during foggy weather, against a light air, but not against a moderate breeze or during very dense fog. In clear weather it has been heard at about 4 miles, with a very light air across; and at about 7 miles down the same wind.

The Daboll apparatus which replaced it at Dungeness in 1865, and a similar one erected in 1868 at St. Catherine's in the Isle of Wight, are of the American second class. The trumpet is curved at the upper end, its main length being placed in a vertical position. Its axial length is 9 feet, with a diameter of 2 feet across the mouth and of $2\frac{3}{4}$ inches at the small end. The condensers are two in number; each 3 feet 3 inches in internal diameter, and 4 feet 4 inches in internal length. The apparatus is worked by a 24-inch caloric-engine, estimated to be of about $2\frac{1}{2}$ H.P., and consuming 12 lbs. of coke per hour. The blasts are of five seconds duration, with intervals of twenty seconds at Dungeness and of fifteen seconds at St. Catherine's. At the commencement of

¹ Vide "Report of the Trinity Board Corporation," *ubi sup.*

the blast the pressure in the condenser is 20 lbs., diminishing at its termination to 5 lbs., per square inch. The cost of the present engine and apparatus at Dungeness was about £1,238, and of that at St. Catherine's £1,338, both inclusive of expense of erection. The estimate for the requisite buildings will be given hereafter.

In 1863 Professor Holmes devised a trumpet, to be sounded by compressed air, having a reed of german silver, which, for high-pressure trumpets, is $5\frac{1}{2}$ inches long, 1 inch wide, and $\frac{5}{16}$ inch thick; and for low-pressure, $6\frac{1}{2}$ inches long, $2\frac{3}{4}$ inches wide, and $\frac{5}{16}$ inch thick. The leading feature of this trumpet, so far as its power is concerned, is, that it is constructed to vibrate in unison with its reed, and thus to form a truly homogeneous instrument; herein differing essentially from Daboll's, which acts merely as a condenser and conductor of the sound produced by the reed. The result is a considerable increase in the effective power of the signal. A report made in 1865 by a Commission appointed by the French Minister of Public Works, and presided over by M. Reynaud, states that, in clear weather, against a wind estimated at force 3, a steel bell weighing 8 cwt. was heard at 984 yards, a 10-inch whistle blown by steam at 75 lbs. per square inch was heard at 3,281 yards (1·88 mile), and Holmes' horn blown by air at 30 lbs. per square inch was heard at 7,655 yards (4·35 miles). To show the small power required to work the trumpet, the apparatus was subsequently disconnected from the engine, and was driven for two hours by a small horse of the same kind as the usual Parisian cab-horse.

Some experiments were subsequently made by the French Lighthouse Commissioners; in which it was found that Holmes' trumpet was heard at a distance of 7,108 yards (4 miles), against a slight breeze; whilst a steel bell weighing $2\frac{1}{2}$ cwt. was not distinctly audible beyond about 2,187 yards ($1\frac{1}{4}$ mile). And it is added, that the fishermen of the island of Molène declare that a trumpet of the same description was heard there, in calm weather, when being experimented upon at Ushant, a distance of nearly $9\frac{1}{2}$ miles.¹

Another important improvement of Professor Holmes' is in the construction of the horn itself, which he makes of such a form, both in the conical body and in the bell part, that the issuing sound, instead of passing out only in the line of axis and immediately dying off on all sides, is perfectly uniform in intensity

¹ Vide "Exposition Universelle, 1867. Notices . . . réunis par les soins du Ministre . . . des Travaux publics," p. 333.

throughout an angle of 90° ; a problem requiring for its solution a thorough knowledge of the laws of sound, and an extreme nicety of calculation. Two light-vessels, recently constructed, from the designs of Mr. J. N. Douglass for the China Lights service, are each fitted with four of these trumpets, placed with the axes of their mouths at right angles to each other, forming a holophone round the whole horizon.

An apparatus embodying all Professor Holmes' latest improvements has recently been erected at the new lighthouse station at Souter Point. The condenser and trumpets are situated at a distance of about 350 feet from the air-pump, which is driven by the steam-engine employed for the generation of the magneto-electric current for the light, the air being conveyed to the condenser by a 2-inch cast-iron pipe. The trumpets, two in number, will be placed with the axes of their mouths at right angles to each other, so as to emit their sound over an arc of 180° , corresponding with the illuminated arc of the light. They will be sounded simultaneously at intervals of thirty seconds, by the following contrivance, which is another of Holmes' improvements. The only communication between the condenser on which the trumpets are fixed, and the engine-room, is the pipe which conducts the air; and, as soon as the pressure in the condenser rises to 30 lbs. per square inch, a tumbler is automatically thrown over, and the valve admitting the air to the trumpets is suddenly opened. When the pressure is reduced by the blast to 28 lbs., the valve is as suddenly closed by the tumbler falling over in the opposite direction, and the valve remains closed until the pressure again rises to 30 lbs. The intervals between the blasts are regulated by simply changing the capacity of the condenser, by pouring in more or less water, so that the air-pump shall require less or more time to recover the 2 lbs. of pressure expended. This ingenious contrivance obviates the necessity of using rods or wires for working the trumpet at a distance as proposed by Daboll; but it is a question of some interest, whether the air in the condenser may not become so charged with moisture from the water employed, as to be prejudicially affected by severe frost.

In order to utilize the whole of the sound, a considerable portion of which would be sent upwards at too great an angle, owing to the large phonic arc of the improved trumpet, Professor Holmes proposes to employ a kind of sounding-board, to be placed above the mouth, to send out the rising sounds in a horizontal line.

The patent of the Ericsson caloric engine having expired, it can now be manufactured free of royalty; and the cost of a 24-inch

one, with one of the improved Holmes trumpets, is estimated at £450, and £20 for each additional trumpet.

The cost of an engine-house, keeper's dwelling, &c., for a fog-horn establishment, may be estimated at £1,500; this estimate being based upon the data afforded by experience in the work at St. Catherine's, which is selected on account of the permanent and substantial character of the buildings there erected. The cost of the engine and apparatus has to be added, according to the particular kind employed.

The working expenses of the establishment at St. Catherine's during the year 1869 were as follows:—

	£	s.	d.	£	s.	d.
Wages of one attendant . . .	49	10	0			
Clothing and allowances . . .	12	10	0			
				62	0	0
Stores	6	3	1			
Fuel, viz.:—Coke (two tons) . . .	3	0	0			
Coal (one ton)	1	8	0			
				10	11	1
Total				£72	11	1

In the same year the fog-signal was worked during 279 hours 50 minutes, at a cost of £6 4s. 5d. per twenty-four hours. Exclusive of wages and allowances, the working cost per twenty-four hours was 18s. 1d.

Upon a review of the various fog-signals which have been mentioned, it will be at once perceived that the whistle and the trumpet stand out prominently as regards power and manageableness. Guns, besides their heavy working expenses, have the disadvantage of requiring a longer interval between the signals, and of entailing continuous work upon the attendant. It appears, therefore, that it is to the improvement and augmentation of power of the two former that a more efficient instrument must at present be chiefly looked for. Whatever may be the fog-signal adopted in practice, power of sound and certainty of action are indispensable conditions. Better, it has been said, no signal at all, than one that cannot be relied upon; and, undoubtedly, if the mariner is led to expect a signal at a certain place, and at a sufficient range to ensure him time to act upon its warning, it ought to be so heard with un-failing certainty. Among existing signals there are some which in ordinary fog and moderate weather will fulfil these requirements. But it is doubtful if they will act with certainty to windward against a heavy gale. The howling of the wind; the groaning

and creaking of hull and spars; the shock and roar and thunder of the sea; the drenching, blinding spray, driven like a concentrated battery of hail; the fierce blast, cutting like a knife, and striving as it were to stifle and beat back even the attempt to breathe; the thick mist, closing everywhere around, and shutting in the ship as if to be the solitary mark for all the wrath and savagery of the elements;—these are the antagonists against which the fog-signal has to try its powers; and powerful indeed must be its voice if it afford in time a friendly warning.

There is another point with respect to fog-signals where in connection with a lighthouse, which ought not to be overlooked; namely, the importance of making the character of the sounds, and their duration and intervals, correspond with the character of the light. The fixed light may be denoted by continuous sound, or better by a quick succession of sounds; the revolving and the flashing light by corresponding blasts; and coloured beams alternately with white light, by a lower and higher note alternating in a similar manner.

One difficulty in the way of employing, at rock lighthouses, any fog-signal but a bell, or such other instrument as can be sounded by the application of simple clockwork, is the unsuitableness of such buildings for the reception and working of a steam or caloric engine, and the severe labour which would be entailed upon the keepers by the use of powerful machinery worked by hand. But the Author still entertains the opinion which he formed sixteen years ago, that the vast dynamical power afforded by the rise and fall of the tide will yet be utilized and applied to the compression of air for the purposes of fog-signals at such stations.

In conclusion, the Author ventures to lay this Paper before the Institution; encouraged by the hope that it may be the means of directing more general attention to a subject, of which—intimately connected as it is with the peaceful interests of navigation and commerce, and with the safety of valuable property and priceless human life—it would be difficult to exaggerate the importance.

[Mr. A. BEAZELEY