Mr. Douglass. were calculated from Mr. Allard's formula; they were not the photometric results obtained by Trinity House, which were considerably less. Instead of using a panel of 60°, practically the whole circle of 360° was available, and therefore six times the power was obtainable. So far as he was aware the mariner had on all occasions been very grateful for the short flash. In the case of Cape Leeuwin, one of the commanders of the Peninsular and Oriental steamers, on sighting the light for the first time, wrote to the Premier of Western Australia expressing his gratification for this installation; he had seen the light at a distance of 38 miles. That was the opinion of a man who traversed the sea between England and Australia and practically saw the whole of the lights. So far as the Trinity House was concerned, the old lights were arranged for flashes of 10, 8, 6, 4, and 3 seconds' duration. Evidently the point in connection with quick-flashing lights had been appreciated, for in the light recently installed on Lundy Island the flash was reduced to $\frac{2}{3}$ second, and this practice was repeated at St. Mary's Isle. He was therefore in hopes that in the course of a few years the authorities would decide to further reduce the flash to the minimum perceptible, which was $\frac{1}{10}$ second.

Correspondence.

Mr. Bourdelles. Mr. O. BOURDELLES, of Paris, desired to acknowledge the courtesy with which the Authors had referred to the feux-éclairs and to their inventor, and to congratulate them upon the ingenuity of the arrangement which they proposed. He regretted, however, he was obliged to advance criticisms to which he considered the latter open. The first and most important had reference to the excessive speed which the action of the arrangement entailed, and the consequent serious loss of luminous power. In the feux-éclairs adopted in France, the optical apparatus consisted of contiguous lenticular panels, equal in number to that of the flashes which constituted the group. The portion of the horizon not occupied by the panels was furnished with a reflector, and the corresponding free space was used for conveniently carrying out the attendance to the burner and the repair of the apparatus. With such conditions one complete revolution of the system sufficed to emit the group composed of flashes, with short and long eclipses; the light was never eclipsed over the whole horizon, and it gave its full effect without interruption. The arrangement proposed, on the contrary, made one half revolution for each short eclipse

(neglecting the short duration of the flash); and to give the long eclipse, which separated the consecutive groups, it was necessary to occult and extinguish the lights over the whole horizon. Now experience had shown that, in order to secure satisfactory character, the length of this long eclipse ought to be three times that of the short eclipses; the emission of a group demanded, therefore, 2 revolutions of the illuminant for two-grouped flashes, $2\frac{1}{2}$ revolutions for three-grouped flashes, 3 revolutions for four flashes, and so on. In consequence of such conditions: (1) The illuminant would be extinguished over the whole of the horizon, and its light entirely lost during $\frac{3}{4}$ or $\frac{3}{5}$ or $\frac{3}{6}$, and so on, of the time of its action, according as the flashes were grouped as 2, 3, 4, &c. (2) The speed of rotation of the lamp would be double, or two and a half times, or three times, &c., that of the feux-éclairs, accordingly as it gave two or three or four grouped flashes. Now by the experimental law of Bloc, upon which the feux-éclairs were based, the luminous intensity of a light at the limit of its range, multiplied by the duration of its flash, ought to give a constant product. From the experiments of Mr. Charpentier, this duration should be about $\frac{1}{10}$ second, and it was upon such data that the elements of the French feux-éclairs had been calculated. It was, therefore, evident that if the speed of rotation of a feu-éclair was doubled or tripled, in reducing the length of its flashes to $\frac{1}{20}$ second or $\frac{1}{30}$ second, its intensity was divided by 2 or by 3 respectively; and to preserve the same luminous range it would be necessary, in doubling or trebling the speed, to double or treble the intensity of the light. It followed that the proposed arrangement, which entailed speeds two or three times greater than those of corresponding feux-éclairs, would have intensities reduced to half or one-third, if the same burner and optic were employed in the two cases. It was to be remembered, however, that this inferiority was redeemed in part by the development of the optic, which covered a horizontal angle of 180° in the proposed arrangement, while in the feux-éclairs this angle was only 130° for two-flash groups, 72° for three-flash groups, &c. But it was also necessary to take account of the cost of the optic, which, being in proportion to its development, was less in the feux-éclairs when the number of flashes in a group was greater. To these objections it could be replied that it was not impossible to assign to the flashes of the new apparatus the normal length of $\frac{1}{10}$ second by correspondingly retarding the speed of the rotation, or by augmenting, as required, the diameter of the burner. The first method appeared inadmissible, for sailors demanded that flashes should be multi-

Mr. Bourdelles.

Mr. Bourdelles. plied, as much as possible, instead of produced at longer intervals. As to the second, the annual cost of repair would be consequently seriously increased. Although less important, there were other by no means insignificant objections. The revolution upon ball bearings of such heavy apparatus as that proposed would appear highly hazardous. Experience of the system in France since 1896 in the floating light at Calais (Gironde) showed that it introduced a considerable resistance, notwithstanding all the precautions taken for its elimination. It had been decided not to employ it except where no other course was available, as in floating lights with optics so suspended as to be insensible to rolling. But in all other cases rotation on a mercury-bath presented incontestable advantages. Access to the light and to the optic was also easier with the French feux-éclairs of the three first orders. The light could be regulated without the rotation being stopped; it appeared difficult to realize this important advantage in the proposed arrangement. Upon these grounds he could not but conclude that the Authors' arrangement scarcely constituted progress over the system of feux-éclairs inaugurated in France, which appeared more advantageous on account of the greater intensity of the light, security of attendance, and economy in the first cost of instalment and in repair.

Mr. Brebner. Mr. ALAN BREBNER was gratified to find from the Paper that British lighthouse engineers were not allowing themselves to be surpassed, but he could not deny that the lightning-light system originated abroad, nor that he looked in vain for any complete application of this improvement on British coasts. All navigating officers he had met and who had seen the lightning-lights wanted to see more of them, and ascribed to France the foremost rank in coast illumination. It was not generally known that Fresnel was the first to propose mercury flotation, for in 1825 he wrote [1]:— "Je me propose de faire flotter nos appareils à feux tournants du premier ordre dans un bain de mercure au lieu de les faire rouler sur des galets." His death had postponed the carrying out of this proposal till about 1891. The second essential fact turned to account in the lightning-light system was a physiological one, namely, that a flash of light which lasted $\frac{1}{10}$ second produced the full effect on the eye. This fact was first mentioned in connection with lighthouses by Lord Kelvin in 1881,[2] having been

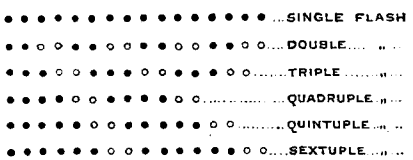
[1] "Œuvres de Fresnel," Tome iii. p. 420.

[2] "Lighthouse Characteristics." Paper read at the Naval and Marine Exhibition, Glasgow, Feb. 11, 1881. "Popular Lectures and Addresses." Macmillan, 1891, vol. iii. p. 405.

experimentally determined and published by Mr. William Swan in 1849.[1] The third feature of the lightning-light system was the use of broad in place of narrow panels of the optic. He had frequently urged the desirability of using panels wider than 45° or 60°, and had quoted the physiological fact in Paris previous to the disclosure of the system, but the use of mercury flotation and the system as a whole had taken him by surprise. It was admirable how, when the French engineers had combined the three essential features into a theoretically correct system, they immediately put it into practice. Splendid, however, as this achievement was, the Authors now offered a further and indisputable advance. With the Hopkinson group-flashing apparatus the more flashes put into a group the more the power was reduced. In the spindle-eclipsing system the power of the flash remained the same whatever the number of flashes; but, admitting for example, that for flashes of 5-seconds' interval a 15-seconds' eclipse was sufficient between the groups, the relative utilization of light would be greater the more the flashes per group. This was manifested in *Fig. 7*, in which the circles marked 5-second intervals and the shaded dots flashes. The spindle-eclipsing system was not applicable to a rock station where the horizon had to be illuminated through 360°; but it was so at any station having a sufficient overland arc, where no light was required; further the eclipsing and re-opening of the light must be effected whilst the beam pointed over the land arc. This indispensable condition observed, the system was seen to be distinct from the Wigham eclipsing-flash system, for in the latter system it was inevitable that the number of flashes per group should vary, whilst in the former no such variation was possible. It might be asked, however, whether it was possible to cut off or re-open the light during the short time the rotating beam pointed over the land arc. As the interval between flashes of a group would be 5 seconds, this would be the time occupied by a complete revolution of the single-beam apparatus. In $\frac{1}{2}$ second then the beam would sweep round an azimuth of 36°. But the land arc in most lighthouses was greater than 36°. Hence there would rarely be less than $\frac{1}{2}$ second

Mr. Brebner.

Fig. 7.



[1] Transactions of the Royal Society of Edinburgh, vol. xvi. p. 599.

Mr. Brebner. of time in which to cut off or re-open the light. He thought the mechanism to accomplish this could be easily devised. He therefore approved of the system proposed and believed it worthy of preference in all new lights. Only by resorting to it could the highest power for a given cost be obtained. In preparing a scheme of lighting for Magellan Straits in September, 1898, presented to the Chilian Government, he had proposed the use of eight spindle-eclipsing lights, which, although similar in everything except the eclipsing gear, gave four distinct characteristics. Ten years ago a six-sided revolving light was an exceptionally powerful single light, and the same in quadriform a *ne plus ultra*. Now he held that for any given order a single spindle-eclipsing apparatus would be at all times more effective than a six-sided apparatus in quadriform, whilst the cost of the former would be only two-fifths of that of the latter. The large diameter mercury basins shown for Cape Leeuwin and Lundy Island lights constituted a marked improvement on the original French designs. He had designed them so since 1893. In 1896 he had been called on to design a new first-order light for Curaumilla, near Valparaiso, the former light having been wrecked by an earthquake. He used a six-sided all dioptric apparatus floating on a mercury-bath almost identical with that shown for Cape Leeuwin, but with a different arrangement of lifting-jacks, and with a crown of guide-rollers above the apparatus. Since the light was shown on 1st January, 1898, several earthquake shocks had occurred, with the result that small quantities of mercury had been jerked out of the basin, but without the least damage to any of the optical or mechanical parts.

Mr. Kenward. Mr. J. KENWARD thought that in attempting to discredit the old but still widely current forms of dioptric revolving apparatus, the Authors raised no objection as to the periods of light and darkness that was not equally applicable to those of the feux-éclairs. The mariner needed a recognizable distinction which must vary considerably, and it was by no means yet certain that flashes might not be so frequent in occurrence and so brief in duration, as to confuse him as much as when they were fewer and slower. The speed of rotation had been gradually accelerated of late years, and a flash every 2 minutes would no longer be tolerated. But this was due not so much to any defect in the signal itself as to the immense acceleration in the speed of ships. It was stated in the Paper that wherever the feu-éclair had been adopted it had commended itself to the approval of the maritime world. This might be strictly true of the Hopkinson group-flashing system, but it was hardly true of the feu-éclair, even

taking "the maritime world" in the narrowest sense. For he had heard nautical opinions of a very different character, and had been informed on excellent authority that the duration of the flashes would be increased beyond the orthodox $\frac{1}{10}$ second in future French lights, to the weakening *pro tanto* of the estimated intensity. He should be disposed to take the judgment and the practice of Trinity House in this matter as of the greatest value. The feu-éclair was a useful addition to the resources of the light-house engineer, but it was yet on its trial, and ought not to be allowed prematurely to displace older and well-tried forms. As regarded intensity, it was needful to determine by the photometer what was due to the enlarged panels, what to the speed of rotation, and what to a third factor of a purely physiological kind. This last could only be well performed at sea. Various estimates of candle-power were quoted in the Paper, some being too obviously empirical, especially when the electric light was in question, as when an intensity of 30 millions or 35 millions was attributed to a light. The British lighthouse authorities had been unable, after some years' enquiry, to determine the intensity of any electric light on the British coasts, and were content to describe them in the Admiralty lists as "very powerful." With regard to the Authors' improvements on the feux-éclairs, there was undoubted merit, but these could hardly be regarded as novel. Lenses of high vertical angle were well known to lighthouse authorities, and to Messrs. Chance; and, under the name of holophotes, single panels had often been used. The South Stack subsidiary light was a holophotal quadrant of 700 millimetres radius, of 45,000 candle-power, designed by Dr. Hopkinson, and was, so far as he knew, unique. The totally reflecting dioptric mirror was the perfected work of Mr. J. T. Chance. Whenever the nautical conditions called for it, the vertical angle had, equally with the horizontal, been extended to the highest limits, but this was not new. The eclipsing device of the Authors was ingenious, and should be received as an additional expedient for producing periodic occultations which had been produced in other ways by Mr. Wigham and Messrs. Chance. The mercury flotation was without doubt an admirable arrangement where a high speed was to be attained with heavy or even with light apparatus. It was the finest mechanical adaptation to light-house work, as the group-flashing system was the finest optical one. The Authors gave the intensities of the hyper-radial light as derived from Mr. Allard's formula. The proper way of comparing the economical value of lights was to include the interest on the cost of the tower, and the annual maintenance, in the list

Mr. Kenward.

Mr. Kenward. of expenses, and so to obtain the cost of each unit of illumination in each case.

Mr. Matthews. Mr. T. MATTHEWS observed that the Authors apparently based their remarks on the assumption that the intensity of the beam of light issuing from a lighthouse was the first and main consideration. The more important question was, however, the character of the light, taking into consideration its geographical position in relation to the characters of the already existing lights in its vicinity. This matter having been determined by experienced nautical advisers in consultation with their engineer, the duty of the latter was then to design such an optical apparatus as should produce the greatest intensity possible for the character desired. In advocating the feux-éclairs system the Authors remarked:—"It is curious that England, the greatest mercantile country, should here lag behind the rest of the world." The desirability, or otherwise, of reducing the length of the flashes produced by dioptric apparatus in the Trinity House Service had for a considerable period received the close attention of the Elder Brethren; and, in addition to visiting, accompanied by himself, some of the most modern lights on this system on the French coast, they had carried out several series of experiments with the object of satisfying themselves as to the shortest flashes which should be produced, regard being had to the all-important point of the reliability of the character of the light, and thus its usefulness to the mariner. As a result, a dioptric apparatus had been installed in a lighthouse recently erected on the north end of Lundy Island, producing the following character, viz., flash $\frac{2}{3}$ second, eclipse 2 seconds, flash $\frac{2}{3}$ second, eclipse $16\frac{2}{3}$ seconds; total period, 20 seconds, and giving an intensity in the beam of 121,500 candles; and a second apparatus precisely similar in character had since been erected at St. Mary Island, a little to the north of the entrance to the Tyne. Careful observations of both these lights had been made by the Elder Brethren and their officials, and opinions had been ascertained of masters of vessels navigating in these waters, with the result that, after further experiments, the Elder Brethren had deemed it desirable, in the interest of the mariner, that the dioptric apparatus now being constructed for the proposed lighthouse on the foreshore at Beachy Head should produce flashes of slightly increased length as compared with those at Lundy and St. Mary lighthouses, and with a diminished long interval of darkness, although they fully realized that a slight loss in intensity would follow. Moreover, the lights recently constructed and now in progress on the French coast had, or would have, longer flashes

Mr. Matthews.

than those advocated when the lightning-flash lights were first adopted there. No definite rule could, however, be laid down for the length of any flash from a lighthouse, although it should be understood that, with single-flashing lights, the length should exceed that of double flashing, double flashing should exceed that of triple flashing, and triple flashing should exceed that of quadruple flashing, &c., the length of the flash in all cases being in proportion to the intervals of darkness. He appreciated the statement of the Authors on p. 135 as to the new lights at Cape Leeuwin (Western Australia), Cape St. Blaize, and Great Fish Point (Cape of Good Hope) having met with complete success. The mariner would, indeed, be ungrateful if he did not highly value such installations, considering that these dangerous positions had previously been entirely unmarked. He concurred in the view that, sufficient power being granted, the fixed light was, from the point of view of visibility, the light *par excellence*, and it seemed only reasonable to argue therefore that, in the case of flashing lights, the greater the proportion of light to darkness, the greater their efficiency, provided that the necessary intensity be obtained. In the first of the three apparatus referred to in Table I, the proportion of light to darkness with the hyper-radiant apparatus would be three times that of the feux-éclairs, in the second instance four times, and in the third twelve times, thus showing that the larger apparatus had a distinct superiority over the smaller one of the same candle-power. A slowly revolving light could be made to produce flashes every 5 seconds by simply rotating it at a greater speed. Attention was directed by the Authors to a further development which they had designed for quick or lightning-flashing lights, by which they claimed to be enabled to produce any character which might be desired, and at the same time the maximum intensity for such character, and, as an example, the Casquets was mentioned, and the argument advanced that the present power of that light was only one-ninth of that which would be produced by an apparatus composed of a single panel of 180° with 180° of mirror, as illustrated by Fig. 4, Plate 5. (This illustration did not, however, agree with the foregoing description, as two panels, instead of one, were shown.) There must, he thought, be a mistake in this calculation, as a dioptric mirror could only be credited with intensifying the beam of the light about one-third. The beam would, therefore, be approximately 6 times instead of 9 times. Comparison was also made between the existing light of the Casquets and the system now proposed. The character of the present light was as follows, viz., three flashes every

Mr. Matthews. 30 seconds; thus:—flash $2\frac{1}{2}$ seconds, eclipse $2\frac{1}{2}$ seconds, flash $2\frac{1}{2}$ seconds, eclipse $2\frac{1}{2}$ seconds, flash $2\frac{1}{2}$ seconds, eclipse $17\frac{1}{2}$ seconds, the light being thus visible for $7\frac{1}{2}$ seconds during each period of 30 seconds, and the duration of the short interval of darkness being equal to that of the flash. With the apparatus proposed by the Authors, however, the character would be as follows, viz., flash 0·1 second, eclipse 4·9 seconds, flash 0·1 second, eclipse 4·9 seconds, flash 0·1 second, eclipse 19·9 seconds; total period, 30 seconds, the light being thus visible for only $\frac{3}{10}$ of a second during each 30 seconds, and the duration of the short intervals of darkness being 49 times that of the flash. It would readily be seen from the above-mentioned characters which light would be of the greater utility to the mariner. When the light at the Casquets was first exhibited, the duration of the flash was shorter than at present, and it was to meet the wishes of the mariner that the length was increased. This light was visible through 360°, and he did not understand how the system proposed by the Authors was capable of producing the correct character throughout the circle. The beam of light from the apparatus they suggested must always be pointing in some direction when the occulting cylinder fell or rose, and the character would, therefore, be interfered with over a certain arc. In instances where there was a blank arc, there would be no such objection, as the cylinder could be made to rise and fall when the beam was in that arc. On page 135 it was stated that hyper-radiant apparatus were established at Round Island and Bishop Rock; Spurn should be added to this list. He did not agree in the suggestion to mount an apparatus on spindles or bearings about which it was to revolve, as indicated on Fig. 4, Plate 5, for it was not preferable to the method now adopted. It would be seen from a glance at the illustrations, and bearing in mind the importance of the apparatus being rotated with the least possible vibration, that the greater bearing surface with the present system must be of advantage. The apparatus introduced at the north end of Lundy Island was the first instance where, with the lens rotated on a mercury-float, the light-keeper was enabled to stand on a fixed platform inside the former. Realizing the fact that the burners in the Trinity House service were of greater intensity than any others, and the importance of maintaining their flames at their maximum powers, he was induced to design the apparatus on this method, in preference to that prevailing in the French and other services, where the keeper was rotated with the lens, the latter system being, in his opinion (if the light be properly maintained)

attended with considerable risk. He thought the saving in favour of feux-éclairs shown in the Authors' Tables of cost was in excess of what would be realized in actual practice. Mr. Matthews.

Messrs. D. and C. STEVENSON thought the Authors' necessarily brief outline of the history of the evolution of the characteristics of lighthouses would convey the impression that nothing had been done towards shortening the periods or shortening the duration of the flashes of light in Great Britain till 1875, if not till 1890, when Mr. Bourdelles proposed a flash of $\frac{1}{10}$ of a second, to which lights he gave the somewhat sensational name of feux-éclairs; that in fact periods of 1 minute and flashes of 3 seconds' to 6 seconds' duration formed the universal practice in this country. This was not the case, as in Scotland, even so long ago as 1848, there were several lights with a period of 5 seconds, the duration of the flashes being less than 1 second. In 1862 a first-order dioptric light of 1 second duration had been erected, and in 1883 a light was established in Scotland with a flash of only $\frac{4}{10}$ second. The Authors were mistaken in supposing that the hyper-radiant apparatus, proposed by Messrs. Stevenson in 1869, was introduced to meet the exigencies of the group-flashing light. It was designed with a view to take full advantage of the large burners introduced by Mr. Wigham and Sir James Douglass, and was equally applicable with any other size of apparatus to be used with a short flash or feux-éclair character if desired. That the flashes emitted by a lighthouse apparatus should be as short as was consistent with distinct vision was obvious; but in trying to attain this object the French lighthouse authorities had exceeded practically safe limits. There was a wide difference between experiments in a dark quiet laboratory and observing lights from the bridge of a vessel in bad weather, when the light of the mast-head and the side light was thrown back to the eye by the reflection from particles of rain, mist, or snow, the tops of cresting waves, or masses of spray. In such cases it was obviously desirable that the light should be longer on the eye than $\frac{1}{10}$ second. The transient $\frac{1}{10}$ second flashes might easily be missed in such circumstances, especially when the observer was near the limit of visibility of the light. Again, the time necessary for full impression on the retina was dependent on the strength of the light falling on the eye, and, therefore, when the light was weakened by passing through mist or rain, a longer duration of flash was necessary to secure its producing any impression on the retina, and so insure its being observed by the sailor. Experiment showed that, instead of the brilliancy of a light increasing as a lens was made to revolve more and more rapidly— Messrs. Stevenson.

Messrs. Stevenson.

as the Authors stated—the brilliancy decreased in proportion with the increase of the speed of rotation, until, when the speed became so rapid as to form a continuous effect on the retina, the power of the apparatus became reduced to that of a fixed light with cylindric refractor. Apart altogether from the photometric power of the whole apparatus, the influence of the extent of illuminated surface was to be considered in securing a longer range in hazy atmosphere. Even the Authors did not appear to have the courage of their opinions, for they recommended that on British coasts—in the meantime, at all events—the flashes should be reduced to $\frac{1}{5}$ second, not to $\frac{1}{10}$ second. Further, lights showing flashes of only $\frac{1}{10}$ of a second duration involved the use of too short a period of darkness between the groups to give sufficiently pronounced character to the light. The impossibility of adjusting and tending the burner without stopping the revolution of the apparatus, owing to its high speed, was also a great practical objection to the small sizes of feu-éclair apparatus. The character of the light was destroyed while this was being done, and, if it occurred at a critical moment for a vessel, might be productive of disaster. It was an axiom in good lighthouse engineering that a light should never, even for a moment, show anything but its true character. It was stated by the Authors that many commanders, after for the first time passing a feu-éclair, had given unsolicited testimony to their appreciation of it. Something more than seeing these lights for the first time—possibly in fine weather—would be desirable before such testimonials could be accepted as of value, though no doubt the new light appeared much better than the light they had been accustomed to see from the same lighthouse. As to the commercial aspect, if the same power and efficiency could be obtained by the smaller apparatus, they would be less costly, but this could not be admitted. To compare the costs of the apparatus producing the same candle-power by the use of feux-éclairs and certain other forms of apparatus, the Authors gave Tables, in which they used Mr. Allard's formula for calculating the candle-power. But the results thus obtained were not comparable, for Mr. Allard's method was not applicable to the calculation of intensities with large burners in small orders of apparatus which was necessary for the feux-éclairs system, the result being that the feux-éclairs were credited with a relatively higher candle-power. The use of a larger burner than the apparatus was suited for gave no more effective power or flash than a small burner in a suitably-sized apparatus. The most powerful oil light on the French coast was a hyper-radiant of 220,000 candle-power (French

measurement), and not a feu-éclair, and this power would have been doubled had three panels instead of six panels been used. The costs given in the Tables for feux-éclairs lights were underestimated, and the comparison of cost instituted by the Authors between the Armen incandescent gas feu-éclair light and a hyperradiant apparatus was not complete, as there had not been included in the cost of the former the expense of erecting a gaswork and compressing machinery, nor of the additional maintenance and attendants necessary for working the plant. With reference to the development of the feu-éclair system proposed by the Authors, the eclipsing shade was open to all the objections above alluded to. Further, it would, for example, in the case of a three-flash light, show in certain arcs four flashes in place of three flashes, and this rendered its adoption inadmissible, except, perhaps, in certain special geographical situations. At Tarbetness and Lundy Island it could not be employed, as the Authors suggested, to show the present characteristics of these lights ;[1] and, indeed, for any group-flashing light of fast period the system was inapplicable if a satisfactory duration of the short and long eclipses were to be maintained. Further, the difficulty of attending to the burner, with the proposed system of eclipsing, obviously was greatly increased, especially as the burner and glass chimney were much longer covered by the shade than uncovered, making it impossible to attend properly to the burner without stopping the apparatus, and, therefore, showing for a time a false light. The temperature of the burner also would be greatly, and possibly dangerously, increased. Again, it would be necessary that the eclipsing shade and the revolutions of the apparatus should absolutely synchronize, and that the clockwork should run with a regularity which in practice was unattainable.

Messrs. Stevenson.

THE AUTHORS, in reply to the Correspondence, remarked that they had never had any intention of reducing the flash below $\frac{1}{10}$ second ; they had been content to accept that fraction as, for all practical purposes, an irreducible minimum. It was the basis of their system, and they had so regulated the speed of rotation as to secure always this duration of flash at least. They desired to make it especially clear that by the regulation of the speed of revolution in the manner indicated the full power of the apparatus was obtained, and here was the gist of their contention ; the apparatus was one of the greatest possible power, in no way

The Authors.

[1] Not on account of absence of dark arcs, but the periods of light and dark are inadmissible with a spindle eclipser.

The Authors. enfeebled by being split into group-flashing panels. The Authors were not at all sure that there was an overwhelming mass of evidence in support of Mr. Bourdelles' statement that sailors demanded that flashes should be multiplied, instead of divided, as much as possible. They would point to one circumstance, which appeared to run counter to it. In the French and English list of lights many apparatus might easily be found which had never been objects of complaint, and yet their flashes were numerically few, slow in following one another, and in point of power not to be compared with the spindle-eclipsing mechanism. The Authors noted, however, that other correspondents were here at variance with Mr. Bourdelles. For example, Mr. Kenward stated:—"The mariner needed a recognizable distinction which must vary considerably, and it was by no means certain that flashes might not be so frequent in occurrence and so brief in duration, as to confuse him as much as when they were fewer and slower"; while Messrs. Stevenson objected that "Lights showing flashes of only $\frac{1}{10}$ second duration involved the use of too short a period of darkness between the groups to give sufficiently pronounced character to the light." As to ball bearings, it had been demonstrated that railway-carriage axles run on ball bearings travelled hundreds of thousands of miles without other attention than oiling. The weight of a large spindle-eclipsing apparatus would be considerably less than that borne in the case of a railway-carriage. The conditions were, moreover, totally different where a floating light was concerned, so much so that the Authors were of opinion that no deductions could be drawn from the working of ball bearings under such circumstances. If this standard, laid down by Mr. Kenward at the close of his interesting remarks, were accepted for the economical value of lights, the spindle-eclipser would most certainly be found to take the foremost place; in other words, to be the cheapest light. The Authors certainly had no intention to assume that "the intensity of the beam of light issuing from a lighthouse was the first and main consideration," as Mr. Matthews understood them to do. The first and most prominent excellence of this new system they stated in the list of advantages claimed by them for it was its greater characteristic distinctiveness. Mr. Matthews' view did not appear clear, as on the question of the character of the lights, he observed:—"This matter having been determined by experienced nautical advisers in consultation with their engineer, the duty of the latter was to design such an optical apparatus as should produce the greatest intensity possible for the character desired." It was natural that

the engineer should, under all the circumstances, regard the determination of the experience of nautical advisers as flavoured with infallibility, but it might not be so obvious to independent experts, and lighthouse engineers had some dim glimmering at least of the consequences which would be likely to ensue if mariners generally were allowed to select lights and settle their suitable characteristics. Usefulness would suffer, even if there was a gain on the side of the antique and picturesque. Indeed, this might be seen in the coast illumination of the River Tyne. Of the apparatus established at the north pier in the year 1895, the upper light was of the fourth order green, the centre fifth order white, the lower sixth order red. They were all fixed, and placed vertically one above the other. To add to the effective symmetry of the whole, there was the feu-éclair on St. Mary's Isle, at the entrance to the Tyne, the flashes of which mariners declared to be of too short duration. If the nautical authorities of the district had been consulted, this courting of disaster might have been avoided. It had been observed by Mr. Matthews that he appreciated the statement that the new lights at Cape St. Blaize and two other southern promontories met with complete success, adding:—"The mariner would indeed be ungrateful if he did not highly value such installations, considering that these dangerous positions had previously been entirely unmarked." The latter part of this sentence was based on a partially erroneous conception of the facts. Cape St. Blaize was not a new light, it was not formerly unmarked, but had a fixed light. Similarly, Mr. Matthews was not quite accurate when towards the close of his observations he stated:—"The apparatus at the north end, Lundy Island, was the first instance where, with the lens rotated on a mercury float, the light-keeper was enabled to stand on a fixed platform inside the former." Lundy, where the light was exhibited in 1897, was not the first example of a fixed platform with a mercury float, though it might have been the second; the first was Cape Leeuwin, from the design of one of the Authors, where the light was exhibited in 1896. The Authors also found it difficult to agree with the argument that because a fixed light be the best, the flashing light which had the greatest proportion of light to darkness was the best. However, this involved complex considerations, for which there was no space in the present reply, since the matter was not quite so simple as it might appear to be. As regarded the comparison of the candle-power between the Casquets and a third-order apparatus, the Authors considered that if Mr. Matthews would carefully investigate the power of the beam given from one panel of the apparatus

The Authors.

The Authors. employed at the Casquets, and that of a third-order holophote light with 180° of mirror, he would find that the figures given by the Authors were fairly correct. The Authors had nowhere stated that a triple flashing spindle-eclipser could be installed at an all-round light. On the subject of the inapplicability of the Authors' system to all-round lights, on originally designing this form of apparatus, they kept in view the fact that there would be a certain difficulty in applying group-flashing apparatus to all-round lights, although with single-flashing lights it did not exist. But in any case, as compared with lights which had a dark arc, the number of those which showed light all round the horizon was very small; and with group-flashing lights where there was a dark arc, it was not possible that a false characteristic should occur. It was remarked in one passage of Messrs. Stevenson's criticism :—"Even the Authors did not appear to have the courage of their opinions, for they recommended that on British coasts, in the meantime, at all events, the flashes should be reduced to $\frac{1}{5}$ second, not $\frac{1}{10}$ second." The Authors' point was that the seamen should be educated up to $\frac{1}{10}$ second. Their actual words were :—"The Authors are of opinion that a further reduction of the length of the flash from 2 seconds to $\frac{1}{5}$ second, and as the mariner became accustomed to the innovation, carrying this reduction further to the limits of complete perception, would be universally approved." Messrs. Stevenson appeared to labour under a misapprehension on another matter of perhaps more importance. They stated :—"The impossibility of adjusting and tending the burner without stopping the apparatus owing to its high speed was also a great practical objection to the small sizes of feux-éclair apparatus." It was no more necessary to stop this apparatus to tend the burner than to attend the damper. As for the criticism of the views of commanders after for the first time passing a feu-éclair, the Authors might remark that there was a not unreasonable prejudice in favour of first impressions.

Prominence had been given to a theme which was not altogether novel, viz., the presence of the large burners in the small apparatus. The Authors, like most persons who have given attention to the subject, were here in accord with that opinion. It was, however, a mistake to suppose that the candle-powers given by the Authors were adduced from apparatus in which large burners were employed. Again, the Authors could not accept without qualification the assertion with reference to the comparison of the light at Armen and a hyper-radiant. The comparison instituted, they ventured to point out, was simply between the apparatus and

accessories of the two installations, and beyond these limits in their comparison the Authors had no intention of going. As to the objection that the costs given in the tables for the feux-éclair were under-estimated, the Authors would remark that the figures were specially prepared for them by a leading firm of lighthouse manufacturers on the Continent, and there could be no dispute as to the trustworthiness of such a source of information. As to the contention that the spindle-eclipser apparatus could not be employed at Tarbetness and Lundy Island, the Authors would refer to the Admiralty list of lights, where it would be seen that at Tarbetness the light was obscured by the land, and that at Lundy Island it had a dark arc, and therefore the spindle-eclipser apparatus was applicable in both cases. In conclusion, Messrs. Stevenson observed that, "It would be necessary that the eclipsing shade and the revolutions of the apparatus should absolutely synchronize." As a matter of fact they did absolutely synchronize, both being worked from the same clock, as was the case, for example, with the ordinary hour and minute hand. The Authors feared that an important point had been largely passed by, namely, the great efficiency of this form of apparatus through its combination of power of beam with distinction of characteristic, such distinction not having hitherto been obtained without a large sacrifice of power. The Authors.