Royal United Services Institution. Journal

Publication details, including instructions for
authors and subscription information:

<http://www.tandfonline.com/loi/rusi19>

Aids to Navigation: Stationary and Floating Lights, with a Detailed Description of the Foster Compressed Gas System, as Applied to Light Towers, Buoys, Torpedo and Submarine Boats

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Published online: 11 Sep 2009.

To cite this article: H. G. Huntington (1886) Aids to Navigation: Stationary and Floating Lights, with a Detailed Description of the Foster Compressed Gas System, as Applied to Light Towers, Buoys, Torpedo and Submarine Boats, Royal United Services Institution. Journal, 30:133, 275-299, DOI: [10.1080/03071848609416371](https://doi.org/10.1080/03071848609416371)

To link to this article: <http://dx.doi.org/10.1080/03071848609416371>

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Friday ~~March~~ 5:1886.

ADMIRAL SIR F. DE ~~POPE~~ **McCLINTOCK**, Kt., F.R.S.,
Member of Council in the Chair.

AIDS TO NAVIGATION: STATIONARY AND FLOATING LIGHTS, WITH A DETAILED DESCRIPTION OF THE FOSTER COMPRESSED GAS SYSTEM, AS APPLIED TO LIGHT TOWERS, BUOYS, TORPEDO AND SUBMARINE BOATS.

By H. G. HUNTINGTON, Boston, U.S. America.

"Naviget; hæc summa est."

VIRG. ÆN.

The CHAIRMAN: Ladies and gentlemen, instead of the lecture which was to have been given by Admiral Arthur "On the Results of the Naval Operations in Berekhaven," which has been postponed, we have to-day a lecture "On Aids to Navigation; Stationary and Floating Lights, with a detailed description of the Foster Compressed Gas System, as applied to Light Towers, Buoys, Torpedo and Submarine Boats," by Mr. Henry G. Huntington of the United States. This is a highly interesting subject to many of us, and although few people have had sufficient scientific education and practical experience to be able to grapple with a great deal that is to be said, I yet hope that in the audience whom I have the honour of seeing before me there may be some who are sufficiently acquainted with this matter to raise upon the lecture an interesting discussion. The subject of portable gas is not a novel one at all; it has been raised many years since. When gas is cut off from the generator and highly condensed it becomes conveniently portable, and therefore it is now coming into rapid use for lighting the beacons and buoys along the coasts of this country, and of a good many other countries also. I have no doubt that everyone in this room is aware that the Corporation of the Trinity House is constantly engaged in improving the lights along our shores, and that it has only recently concluded a most exhaustive series of experiments for the purpose of arriving at the proper value, as an illuminant, of gas, of oil, and also of electricity. But besides being valuable as an illuminant in our homes, gas has another peculiar feature,—it contains so much condensed energy in itself that, in this respect, it can be aptly compared with gunpowder. I will not further encroach upon your time, but will now ask Mr. Huntington to read his paper.

From the earliest times the nations of the earth have appreciated the aids to navigation afforded by lights on important headlands as guides to harbours or warnings of dangers.

The first lighthouse in the world was the famous Pharos of Alexandria, of which the ruins may be still recognized. Pliny informs us that it was built by one of the Ptolemies, about 285 B.C. It was of white stone, square, of many storeys, and diminished upwards to a height of 512 English feet. It cost nearly 200,000*l.* sterling. The fires lit in its highest storey were visible, Josephus says, about 30

miles. The Romans had full knowledge of the usefulness of lighthouses, and not only in their own country, but wherever they conquered other nations, did they establish these aids to navigation.

Without following farther the history of lighthouses through the middle ages up to our own time, it may perhaps be suspected that the number of wrecks in proportion to tonnage is greater now than then. This, however, is a simple conjecture that cannot be decided and of no practical importance. Probably no countries in the world possess finer systems of lights than Great Britain and France, yet in these days when all quarters of the globe are constantly visited by the world's commerce, an enormous quantity of wrecks occur that might be prevented were more care taken to protect navigators when in dangerous waters.

Light-vessels with a crew of men aboard, beside their first cost are a large annual expense, and their great bulk renders them dangerous and difficult of management in typhoons, hurricanes, and heavy seas. They have been frequently carried away, dragged from their moorings, or broken their cables, and during absence from the danger they were intended to warn navigators off, disastrous wrecks have occurred. Every landsman knows it is not the open sea the mariner fears, but the approach to land, and in the careful statistics of wrecks by the Board of Trade, we find that in the nine years ending 1883, out of a total loss of 15,569 lives including crews and passengers, only 1,334 occurred by vessels foundering, while nearly one quarter, or 3,580, occurred through strandings. The balance of total loss in this period was made up of collisions, missing or other causes.

We find that out of the total registered tonnage of the same nine years nearly 33 per cent. were totally lost. For example, in the whole number of registered British ships at home and in the Colonies, out of a total registered tonnage of 8,406,251 tons, 2,717,725 were totally lost. At this rate the whole registered tonnage of Great Britain and her Colonies is lost each generation. The country in the end has to bear these losses, and shipowners are heavily taxed in the premiums they are forced to pay for insurance.

In the present depressed state of the shipping trade these burdens are still more acutely felt, for in prosperous times the profits compensate in a measure for such charges, while at present the enormous outlay incident to shipowning makes that business not only unprofitable but ruinous.

Economy and efficiency are the present studies of all Governments and private undertakings, and so convinced have the authorities in this country been of the value of a serious study of various systems, that experiments were ordered by the Board of Trade at the South Foreland, to test the merits of lighthouse illuminants.

Until the present time, no Government has undertaken so valuable, thorough, and exhaustive experiments in regard to the penetrating power of light in all conditions of atmosphere, as these which have been carried out by a Committee of the Elder Brethren of the Trinity House during the past year. In their report we have been presented with most carefully compiled and exact statistics by the first authorities on light

in the country, whose observations extended over so long a period, and were so conscientiously made, that their results may be considered as having successfully answered the problem they were instructed to solve as to the relative merits of electricity, gas, and oil. The general conclusion of all these experiments has, however, demonstrated the utter inefficiency of even the strongest light known to the present time, in a dense fog.

From the above report we learn that on the 17th of May, 1884, from 1 A.M. to 3 A.M., "a thick and homogeneous fog" completely obscured the electric light at 1,900 feet, oil at 1,700 feet, and Wigham's gas at 1,400 feet.

Here we have electricity with a force of 1,500,000 candles, through cylindrical belt and vertical condensing prisms giving only 500 feet better results than Wigham's 108-jet gas through a Mew Island lens, whose illuminating power in a clear atmosphere is put at 59,000 candles, and while the electric light is nearly twenty-five times as powerful as the gas, its powers of penetration in any condition were not shown to be as great in proportion, and Mr. Vernon Harcourt's statement as to the superior penetrating power of gas light over electricity of equal candle power is fully confirmed by these experiments.

It is proposed in this paper to deal more particularly with the question of gas-lighting as applied to lighthouses and buoys, as the report of the Committee has clearly demonstrated, that when properly developed, Douglass's gas burners used, and processes adopted that offer greater economy in its production and greater purity and brilliancy in its quality, gas is destined not only to largely supplant oil, but can be made superior in penetration to equal candle-power electricity, whose first cost and subsequent maintenance exceed in a marked degree the first cost and maintenance of a gas station, as described in this paper.

This is easily seen by referring to the table of comparative cost of lighthouse illuminants prepared for the United States Government, and showing the relative cost of lard-oil, petroleum, and coal-gas.

The only gas besides coal-gas used by the Trinity House Commission was that made from petroleum by a German process, the light from which, on the Metropolitan Underground Railway and on some Continental lines, cannot be considered an unqualified success.

The gas tower used in the experiments at the South Foreland was marked B, the electric light tower A, and the oil tower C. In the C tower gas pipes also were introduced up its centre column, and laid to each trimming stage, so that burners might be readily attached to them, and both different kinds of gas and burners compared with those in B tower.

There were submitted three specimen sets of burners, two of the Douglass pattern, one six-ring $5\frac{1}{2}$ inches in diameter, its flame condensing to $3\frac{1}{2}$ inches in the focal plane, and the other $8\frac{1}{2}$ inches across, compressed to $5\frac{1}{2}$ inches at focus; two of the Siemens regenerative pattern, one producing a flame 10 inches in diameter and 6 inches high, the other a smaller flame 4 inches by 4 inches; and one Sugg six-ring burner, with a cylindrical flame $7\frac{1}{2}$ inches in diameter,

controlled by a cylindrical glass, $8\frac{1}{2}$ inches in diameter and $8\frac{1}{2}$ inches high.

These burners were carefully tested, with the result that the Sugg burner was discarded from the lighthouse lantern because evolving too large quantities of smoke, and the smaller Siemens burner was decided to give too little light to be useful in a lighthouse.

The comparative tables of these burners will be found later on marked B.

But to continue the comparison between gas and electricity, the following table taken from the Trinity House Report and marked A will be found useful. In notes to the next table, not shown here, we find that "for fixed lights in all kinds of weather the gas is generally superior to oil."

TABLE A.—*Showing Comparison of Electric Light by Eye-measurement with highest powers of Gas and Oil, both Revolving and Fixed. The assumed value of the Electric being 100.*

Number of observations in clear weather.		Electric.		Average of recorded values.				Percentage of superiority of			
				Gas. Quadriform 103 jets.		Oil. Triform 6 wicks.		Electric over gas.		Electric over oil.	
R.	F.		R. & F.	R.	F.	R.	F.	R.	F.	R.	F.
33	42	Single..	100	73	61	67	51	27	39	33	46
190	98	Biform..	100	65.25	61	60.25	53	31.75	39	39.75	47
79	23	Triform	100	53	70.5	60.3	68	37	29.5	39.7	32
307	163										
Number of observations in weather not clear.											
29	3	Single..	100	70	60	66.6	72	30	20	33.4	28
126	40	Biform..	100	72	58	63	49.25	23	42	32	50.75
68	18	Triform	100	52.6	51.6	50	46	47.4	48.4	50	54
223	61										

NOTE.—The numbers for the fixed gas and oil lights are at times higher than those for the same lights when revolving. This does not mean that the fixed were better than the revolving lights, but that the standard electric fixed light was not so superior to the fixed gas and oil lights.

The relative power of electricity, gas, and oil in weather not clear, at great distances, is admirably described in the same report.

It appears that at distances under 5 miles, quadriform gas and triform oil were better than biform electric. As the distances were increased the electric light seems to have come to the front. The permanent electric lights are reported as showing up well, although the experimental electric light was so much impaired at the short ranges.

Again on December 6th, 1884, in a fog and drizzling rain, we find that the observations unanimously indicate that triform electric is little if at all better than quadriform gas or triform oil, and that the single electric arc with three machines is much superior to the triform arrangement.

On February 16th, 1885, in a dense fog and very heavy rain, the summary of results by four observers is given as greatly in favour of the single electric light with double current, but although its candle force is so superior to gas and oil, yet we find that its superiority over both is only a distance of 200 feet, not a steamer's length!

Mr. H. B. Dixon's Photometric Experiments.

These were so important and thorough that I venture to quote from his report on the determination of the total light of each illuminant, electricity, gas, or oil, but the general result may be roughly stated as showing but little difference between oil and gas.

The only object of these notes is to demonstrate the advantage of an economical system of gas over oil in saving expense of first cost and maintenance.

Mr. Dixon says the illuminants submitted to trial were:—

A. The De Meritens electric light, with one, two, and three magneto-electro machines.

The carbons used were "solid," "core," and "bundle" carbons.

B. The Wigham gas burners with 28, 48, 68, 88, and 108 jets.

The Douglass argand gas burners with 10 rings and with 6 rings.

The Sugg argand burner with 6 rings.

The Siemens regenerative burners, large and small.

The gas used was canal gas of 20 to 30 candle-power, and oil gas of 40 to 45 candle-power, per 5 cubic feet.

C. The Douglass oil burners with 6 wicks and with 7 wicks.

The Service oil burner with 4 wicks was also tested for the purpose of comparing it with the other illuminants.

A. The Electric Light.

The electric light was tested with the bar-photometer at a distance of 220 feet. Ten readings were made alternately by Mr. Vernon Harcourt and myself. In making the reading no attempt was made to measure the sudden intense flashes of a second or two duration, or the equally brief extinctions of light which occur from time to time with the electric arc. Each reading represents as nearly as may be the average light over a period of 20 or 30 seconds; the mean of the 10 readings gives the average light over a period of four or five minutes.

AIDS TO NAVIGATION:

1 Machine. 40 mm. Solid Carbons.

Results.

1.	8,430 candles.	H. B. Dixon.
2.	9,200 "	A. Vernon Harcourt.
3.	8,880 "	H. B. Dixon.
4.	8,880 "	A. Vernon Harcourt.

8,850 Mean.

1 Machine. 30 mm. Core Carbons.

Results.

1.	9,890 candles.	H. B. Dixon.
2.	10,770 "	A. Vernon Harcourt.
3.	11,640 "	H. B. Dixon.
4.	11,190 "	A. Vernon Harcourt.

10,870 Mean.

2 Machines. 40 mm. Solid Carbons.

Results.

1.	14,530 candles.	H. B. Dixon.
2.	10,660 "	A. Vernon Harcourt.
3.	12,510 "	H. B. Dixon.
4.	13,320 "	J. Sparling.
5.	13,040 "	H. B. Dixon.

12,830 Mean.

2 Machines in quantity. 81 Bundle Carbons.

Results.

1.	11,420 candles.	H. B. Dixon.
2.	18,870 "	A. Vernon Harcourt.
3.	18,630 "	H. B. Dixon.

16,310 Mean.

2 Machines in series. 81 Bundle Carbons.

Results.

1.	13,900 candles.	H. B. Dixon.
2.	13,600 "	J. Sparling.
3.	12,500 "	A. Vernon Harcourt.

13,330 Mean.

These results show that in the photometric gallery two machines do not give double the light of one machine in the electric arc. The

"core" carbons gave a better result than the "solid" carbons. Afterwards core carbons of 40 mm. diameter were obtained, and were used in A tower.

B. Gas Burners.

The Wigham Gas Burner.

The Wigham 108-jet burner was tested with different consumptions of cannel gas with the following results. Each result is given by the mean of ten observations with the bar and with the table photometer.

No.	Illuminating power in candles.	Corrected rate of consumption of gas.	Value of gas.	Duty. Illuminating power per cubic foot of 24 candle gas.
1	2,240	205.3	27.6	6.62
2	2,252	302.0	24.9	7.20
3	2,295	312.4	25.7	6.86
4	2,331	319.5	26.06	6.73
5	2,433	351.4	25.7	6.47
6	2,425	368.2	25.7	6.15
7	1,683	214.8	41.6 (oil gas)	4.52

The highest illuminating power was given with a consumption of 350 feet, the highest duty with a consumption of 300 feet per hour. The burner did not consume oil gas to the same advantage as cannel gas.

The smaller sizes of the Wigham burner were tested with the following results:—

Burner.	Illuminating power.	Corrected rate.	Value of gas.	Duty.
88 jets	1,400	246	25.4	5.38
68 "	992	160	25.8	5.77
68 "	822	150.8	21.8	6.03
48 "	677	112	26.0	5.56
48 "	572	109.7	22.0	5.69
28 "	249	45.2	26.7	5.05

2. The Douglass, Sugg, and Siemens Gas Burners.

The Douglass 10-ring argand burner was tested with different consumptions of cannel gas in the same way as the Wigham 108-jet burner:—

No.	Illuminating power.	Corrected rate.	Value of gas.	Duty.
1	2,323	197.3	27.6	10.20
2	2,591	231.6	27.6	9.73
3	2,619	271	25.7	9.02
4	1,915	136	41.6 (oil gas)	8.12

The illuminating power increases as the rate of consumption is raised from 200 to 270 feet, but the duty is greatest with a consumption of about 200 feet.

The other gas burners were tested with the following results:—

Burner.	Illuminating power.	Corrected rate.	Value of gas.	Duty.
6-ring Douglass ..	825	101.2	27.6	7.02
6-ring "Sugg" ..	853	72.8	41.4 (oil gas)	6.79
6-ring Sugg.....	821	193	22.0	4.61
Large Siemens ..	600	90.1	22.0	7.27
Small Siemens ...	194	39.0	22.0	5.39

The 6-ring Douglass burner gave the best light with a consumption of 100 feet an hour, with oil gas its illuminating power was increased, and its duty but slightly diminished. The Sugg burner evolved large quantities of smoke, which made it impossible to burn it in the lighthouse lantern at its full power. As the smaller Siemens burner gave too little light to be useful in a lighthouse, it was not tried in the experimental tower.

C. The Douglass Oil Burners.

The 7-wick and 6-wick oil burners were tested in a similar manner to the gas burners. The 6-wick burner gave a very constant light, the 7-wick showed greater variations.

Burner.	Mean illuminating power.	Mean consumption of oil per hour.	"Duty" light per gallon per hour.
7-wick.....	917	1 gallon	917
6-wick.....	730	0.625 "	1,168

Similar tests were also made of the larger Douglass burners, and of two smaller burners in the lighthouse service. Although these

burners were not entered for competition, a comparison of their illuminating power with that of the 7- and of the 6-wick may be of interest.

Burner.	Illuminating power.
9-wick	1,785 candles.
8-wick	1,400 "
7-wick	947 "
6-wick	730 "
5-wick	620 "
4-wick	415 "

Taking the average of the measurements made on the clearest nights, the intensity of the beam of each illuminant as a revolving light is given in the following table:—

	Eddystone lens.	Mew Island lens.	Cylindrical belt and vertical prisms.
<i>Gas.</i>	<i>Pyrcs.</i>	<i>Pyrcs.</i>	<i>Pyrcs.</i>
Douglass, 10-ring.....	105	91	
" 6 ".....	92	70	
Wigham, 108-jet.....	..	59	
" 88 ".....	..	51	
" 68 ".....	..	48	
" 48 ".....	..	42	
" 28 ".....	..	33	
Sugg, 6-ring.....	55?		
Siemens (large).....	10*		
<i>Oil.</i>			
Douglass, 7-wick.....	60	49	
" 6 ".....	61	48	
Service, 4-wick.....	55	44	
<i>Electric.</i>			
1 machine.....	..	..	1,250
2 machines.....	..	..	1,500

* This is the illuminating power at the centre of the beam. Owing to the construction of the burner, the edges are much brighter than the centre, so that the cone of light thrown by the annular lens is much brighter at its edges than in the middle. As the lens revolves the observer sees two flashes of bright light, with a dull light between.

These values divided by the previously determined illuminating power of each unaided lamp give the lens-factors for each illuminant:—

TABLE B.

Burner.	Illuminating power of naked light.	Illuminating power through lens in clear atmosphere.				Factor of lens.		
		Cylindrical belt and vertical prisms.	Eddystone lens.	Mew Island lens.	V.P.	Ed.	M.I.	
Electric, 1 machine.....	10,000	1,250,000	..	..	125			
" 2 "	15,000	1,500,000	..	..	100	42.0	37.6	
Douglas, 10-ring, gas.....	2,500	..	105,000	94,000	..	111.5	84.8	
" 6 "	825	..	92,000	70,000	..	..	25.7	
Wigham, 108-jet, gas.....	2,300	..	..	59,000	..	..	38.6	
" 86 "	1,400	..	..	54,000	..	..	48.5	
" 68 "	990	..	..	48,000	..	..	61.8	
" 48 "	680	..	..	42,000	..	..	132.0	
" [28 "	250	..	..	33,000	..	..		
Sugg, 6-ring, gas.....	820	..	55,000	..	..	67.1		
Siemens, gas.....	600	..	10,000	..	..	16.7		
Douglas, 7-wick, oil	950	..	60,000	49,000	..	63.2	51.6	
" 6 "	730	..	64,000	48,000	..	87.7	65.8	
Service, 4 "	415	..	55,000	44,000	..	132.5	106.0	

Shown through annular lenses the smaller flames are far more economical of light than the larger, the larger flames, however, have the advantage of throwing a broader beam and so producing a longer flash than the smaller. But the larger flames have a distinct advantage over the smaller in thick weather, for the light from the large burners is less cut down by haze and mist than the light from the smaller burners.

It is not intended to follow this highly interesting report further in quoting from its detailed statements, but only to add a summary of some of the conclusions arrived at in regard to gas, which seem to be—

First. That for a revolving light, the large flame of gas has a distinct advantage over the small flame of oil as respects the duration of flash.

Second. That gas offers peculiar advantages for producing short flashes by sudden extinction and re-ignition, and also for producing atmospheric thrills, which are of great value in a fog.

Third. That the general result of sky-flashing is not favourable to its adoption.

Fourth. That light for light there is no practical difference between gas and oil flames, seen through the annular lenses of a revolving light, but that four superposed gas lights are a little better than three 6-wick mineral oil burners.

Fifth. That the heat of the Wigham burners in quadriform is a serious objection to this system.

Sixth. That for lighthouse illumination with gas the Douglass patent gas burners are much more efficient and economical than the Wigham gas burners.

Seventh. That the electric light is absorbed more largely by haze and fog than either the gas light or oil light.

The complete inutility of even the strongest lights in thick weather cannot but suggest to the thoughtful inquirer, whether it would not be safer to protect dangerous outlying reefs, shoals, and low coasts by a system of gas-lit buoys burning day and night, with a light 15 feet above the sea, visible in clear weather from 6 to 10 miles, and in a fog distinguishable several hundred feet.

That such lights exist, and can burn continuously from six months to one year, we have abundant evidence in the official reports of the first authorities in the United States on the Foster gas-beacons and buoys, and in the award at the International Fisheries Exhibition, London, 1883, of the highest premium, a gold medal, to the Foster gas-buoys.

There are many parts of the British Empire where navigation is difficult and dangerous, and where light-vessels have been carried away on account of the large surface they offer to the wind and waves.

Intricate channels, usually impossible of navigation by night, could be easily marked by gas-lit buoys painted of distinctive colours, and made visible by reflected light masked by a screen, which would be beneath the buoy-light proper. Such dangerous navigation as the

mouth of the Hooghly River and the passage through its tortuous channels to Calcutta, Bombay Harbour, the Island of Ceylon, the Irrawaddy, and other great rivers, might be rendered safe and navigable on all nights by a judiciously studied system of gas-lit buoys.

Many unprotected islands, shoals, and coral-reefs—the cause of so many wrecks, as the recent loss of the P. and O.'s fine steamer "Indus," and a more recent wreck of an English steamer in the Straits of Bab-el-Mandeb, are but a few examples in a thousand—might be distinctly marked, and the small cost of installation and subsequent maintenance would be but a fractional part of the losses occurring to merchants, shippers, and insurance companies from the wrecks, but now too unfortunately frequent. Lloyd's list of wrecks shows an average of about a hundred a day in all parts of the world, a great proportion of which occur at night, or from uncertainty of position, when a well-devised system of self-sustaining lights would prevent many of such disasters.

The Italian Government, which in marine affairs is now certainly one of the Great Powers of Europe, has shown its appreciation of a system of gas-lit buoys by ordering two of Pintsch's buoys for trial at the entrance to Naples, and by also decreeing an experiment with Foster's system at Genoa in the coming spring, after which it is their intention to place a quantity of buoys in the Red Sea to mark the difficult navigation on approaching Massowah, eventually destined to become a great centre of commerce, as the port of export from Abyssinia and Central Africa.

All Governments are notoriously slow in dealing with new inventions, but the favourable results shown in the United States by the Foster buoys and beacons, and the many awards of competent juries, place this system on an exceptional footing.

I wish it distinctly understood that I do not claim for Mr. Foster the first idea of filling buoys with gas, for as far as most careful investigation of the records show no one prior to Mr. Julius Pintsch, of Berlin, in 1876, ever suggested gas-lit floating lights.

The Trinity House Board have used Pintsch's gas-buoys for some years, but intend experimenting with Foster's buoy, which is entirely novel in construction and contains gas compressed to 40 or 50 atmospheres, while eight is the pressure of Pintsch's buoys.

While convinced of the great advantage to be obtained by a judicious and extended use of gas-buoys, there is still a large field for improved light-towers made of tubes containing compressed gas—thus serving a twofold purpose—to mark headlands and shallow waters, in many parts of the British Empire, and in savage countries where a staff of attendants is impossible, or where, as sometimes occurs on desert islands and the coasts of Africa, there is neither food nor water to be obtained. The respect and awe of savages for a light burning day and night with no visible source of supply, would ensure the safety of such a light in countries where the establishment of a light-station might be dangerous.

There is no limit to the size of these light-towers, and their term of

service when charged could be arranged from one month to one year without refilling, according to strength of light required.

Useful lights giving 200 candle-power naked light or 1,000 candles with optical apparatus, visible 15 to 20 miles in clear weather and consuming $6\frac{1}{4}$ feet an hour, with occultations of 15 seconds each minute, would burn from 10 months to a year.

The manner of supplying detached lighthouses and gas-buoys by a tender on which the gas may be generated and compressed into the reservoirs, is shown by the illustration on the wall.

The device of a bent gas-tube to supplant rubber hose, which burst under the great pressure adopted in the Foster system, is due to Mr. Scott, an assistant light-keeper in Currituck Sound, North Carolina, where ten beacons have been in service since 1880.

With these preliminary remarks as to the utility of the system of compressed gas, I now propose describing in detail certain portions of Foster's Compressed Gas as applied to beacon lights, signals, and buoys.

Rapid advances in the arts and sciences have led to numerous valuable improvements in nearly all branches of industry, but none are more important in their peculiar province than the use of gas for lighting beacons and buoys as applied to the system described in this paper. Practical demonstration has proved that the advantages attending the use of this luminant in preference to oil are as marked when adapted to the lighthouse service as in domestic use, and when to this superiority is added wonderful economy in cost of maintenance, and far greater reliability under trying circumstances, further argument in favour of its general adoption seems unnecessary, though a comprehensive summary of cause and effect is not out of place in this connection, in order that a thoroughly intelligent understanding may be reached.

To render the use of gas available for this purpose it is necessary to compress an immense volume of the fluid into the smallest possible space and to provide a receptacle for its storage, with sufficient capacity to supply a light for an extended period capable of being readily refilled; that shall be as nearly indestructible as possible, and when once charged, the arrangements for its consumption so perfect as to render the light reliable, and independent of supervision until the gas is exhausted.

The economy obtained by petroleum gas over petroleum oil may be demonstrated from Mr. Wooten's report, as General Manager of the Reading Railroad, to the Directors, by which we learn that the saving effected in about two years was sufficient to cover the whole outlay expended on the outfit, a sum of 5,097*l.* sterling. This too in a country abounding in petroleum. The saving of labour in cleaning and trimming the lamps is also a not inconsiderable item when on a large scale.

The distinguishing merits of the Foster system are:—

First.—In an apparatus producing from a most available, plenteous, and low-priced material, a perfectly "fixed gas" of intense illuminating power, which deteriorates neither when subjected to low temperatures nor any degree of compression.

This is of the greatest importance in using compressed gas in the lighthouse service, for the volume which must be stored is in minor proportion to the illuminating power of the gas; 1,000 cubic feet of this gas will give as much light as 200 lbs. of sperm candles, about five times as intense as coal-gas.

Second.—In a compressor equally free from complication and so thoroughly effective, that 3,500 lbs. to the square inch has been attained by it; in this particular lies one of the most prominent merits of the Foster system; for it will be apparent that the advantages to be derived from the use of compressed gas will be increased with the degree of pressure, and the consequent reduction of volume.

This is specially true of the use of compressed gas for lighting beacons and buoys, when the principal object to be attained is to put the largest quantity into the smallest space, in order to reduce the size and cost of storage tank to a point admitting the use of gas pipes or tubes for receptacles, instead of reservoirs made of large plates, riveted or welded together, which are liable to injury from any violent contact, are costly to repair even when it is possible so to do, and with which there is no assurance that they will not become useless at a time when their absence or condition would be fatal to the interests or lives for which they are supposed to afford protection.

The Third prominent feature of the Foster system is the automatic appliance for regulating the flow of gas to the burner, without which the enormous pressure operated by this system would be valueless.

When it is understood that the pressure per square inch in a tank containing forty atmospheres of gas is equal to a column of water about 16,000 inches in height, and that the pressure of gas at the point of consumption should be equal to a column of water seven-tenths of an inch, while the gas in the supply tank is being consumed and the pressure diminished down to the last inch, it will be understood how important is the office of the governor.

This invention, the result of many years of study and costly experiment, is the only *perfect* appliance of the kind yet devised.

The cheapest, safest, and best system of lighting is with petroleum-gas. Its production costs less than coal-gas, is much more luminous, and when properly made, is susceptible to great compression, without material deterioration. The expense of manufacturing gas under the Foster system is equal (lighting power considered) to about one-tenth the average selling price of coal-gas, and in estimating the probable saving by its use it is safe to calculate on this basis. The cost of lighting by this system, as compared with high test mineral oil, is about 40 per cent. less.

Complete works for manufacturing and compressing the gas cost from 1,000*l.* to 3,000*l.*, according to capacity and local conditions. The principal object of compressing gas is to contract its volume to the smallest possible space, in order to carry a long period of supply in receptacles of convenient size, hence it will be apparent that the advantages to be derived from any compressed gas system will be increased in proportion to the degree of pressure operated, and the consequent reduction in volume; in other words, *that system is the best*

TABLE C.—*Comparative Cost of Luminants.*

Order of light.	Candle-power U.S. Light-house Standard.	Consumption of oil per annum.		Consumption of gas per annum.		Comparative cost of luminants per annum.				Percentage increase in cost of oil over the Foster system.
		Mineral oil. Gallons.	Lard oil. Gallons.	Coal gas 14 candle-power. Cubic feet.	Petroleum gas (Foster system). Cubic feet.	Mineral oil at 18 cents per gallon.	Lard oil at 90 cents per gallon.	Coal gas at \$2.00 per thousand feet.	Petroleum gas (Foster system) at \$1.00 per thousand feet.	
First	400	..	938	625,968	125,193	..	\$844 20	\$1,251 93	\$125 19	57½ per cent.
Second	164	..	560	255,762	51,152	..	504 00	511 52	51 15	88½ "
Third	78	270	..	120,312	24,062	\$48 60	..	240 62	24 05	100 "
Fourth	32	137	..	50,000	10,000	24 66	..	100 00	10 00	146 "
Fifth	18	86	..	27,955	5,590	15 44	..	55 91	5 60	175 "
Sixth	12.5	40	..	18,765	3,753	7 20	..	37 53	3 75	92 "
Light-vessel.	18 to each lamp	16 lamps 1,088	..	not practicable	89,120	195 84	..	..	80 12	117 "
Buoys	10.5*	..	..	not practicable	7,324	..	..	..	7 32	

* The buoy light may be increased to the intensity of 50 candles, when necessary.

which produces an equal light for the longest period from a given sized cylinder.

The Foster system as satisfactorily operates forty atmospheres of pressure as others do eight atmospheres, reducing the gas cylinder to one-fifth the size; or, with the same cylinder capacity, giving an equal light five times as long as any other; this is accomplished to such an extent by the Foster apparatus, that receptacles holding the gas under pressure are made of lap-welded tubes, 15 inches in diameter, having heads welded in each end, instead of being made of large plates rivetted together, which, besides being unreliable, are heavy, cumbersome, and expensive.

The cost of operating the Foster system as shown by the foregoing table, is based upon the standard intensity of light and number of hours of service adopted by the United States Lighthouse Department in burning oil, which in all cases necessitates the employment of keepers. The large saving shown is but a small percentage of the actual reduction in cost of maintenance under this system. At stations operating fog-signals and revolving machinery where keepers are absolutely required, the force can be largely decreased. Proper attention to oil lights involves the cleansing of lamps and chimneys, trimming wicks, care and measurement of oil, lighting and adjustment of flame, and almost constant watching while lighted.

The operation of the compressed gas system involves no more care than a simple gas burner in a private house. The governor once regulated, only the required gas can pass to the burner, insuring an unvarying flame until the supply is cut off or exhausted. Fixed lights of the fourth, fifth, and sixth order, having no machinery, or where it is possible to introduce our automatic appliances, and which are accessible by a tender, require no keeper under the Foster system, and the saving thus effected would, in many instances, repay the entire cost of apparatus in from one to two years.

Under such circumstances the lights necessarily have to burn continuously (as is the case with our beacons in Currituck Sound), and an increased consumption of gas results, costing as follows:—

For a fourth order light, about £4 12s. per annum.

„ fifth	„	„	£2 13s.	„
„ sixth	„	„	£1 17s.	„

Where gas is to be supplied to buoys, or to lights placed on permanent structures, it is advisable and most economical to place the generating and compressing apparatus on a "tender," specially designed for the purpose, and as it would only be necessary for the "gas tender" to visit the stations once in six or twelve months, according as provision is made, it would be capable of supplying hundreds of lights. Oil and fuel for one round trip to all the lights could be taken on board at points affording the cheapest market. Proper provision for the storage of oil in suitable tanks instead of in barrels reduces its cost; and by this means the "gas tender" could supply stationary works located at buoy depôts with petroleum.

By this system, compression of the gas may follow immediately

upon its generation, and in such case it is forced at once into the storage tanks provided, the entire proceeding being carried on, regardless of the vessel being at rest or in motion. From ten minutes to one hour, dependent upon the capacity of the beacon-tanks or buoys, would be expended in charging, and if the lights were not very close together, sufficient gas would be generated in the intervals between stoppages at stations to immediately supply the receptacle when reached.

An infrequent visit, possibly not oftener than once in three or six months, to cleanse the lens, which can be done by a resident of the neighbourhood or by a passing tender, will be all the attention required under this system, after the reservoirs have been charged for a stated period, six or twelve months. The absolute necessity for the increase of lights and signals on our waters is well understood, and forcibly illustrated by the almost daily records of destruction to life and property in connection with transportation by vessels, and the intelligence of the age insists upon the adoption of the most perfect, reliable, and economical appliances to the attainment of this result.

DETAILED DESCRIPTION OF THE FOSTER APPARATUS.

The Gas Works.

The cheapness of petroleum and the ease with which it can be vaporized, or converted into a gaseous form, have led to many attempts to use it for the production of illuminating gas. Although some measure of success has attended even the rudest efforts of this kind, yet the great difficulty has been to produce a *fixed gas*, or one which would not smoke nor condense and thus deposit tar and other obstructions in the apparatus used, nor lose its luminosity when subjected to low temperature or great compression, and at the same time keep the latter so simple that a person of ordinary intelligence could manage it.

To those who are not familiar with the process of converting petroleum into gas it may be said that if in the process of conversion too low a degree of heat be used, some portions of the gas produced will be readily condensed, and the gas thus lose its luminosity and form a deposit of coal-tar and other substances in the apparatus. In other words, a certain high degree of heat must be employed to make the gas non-condensable under the ordinary circumstances of its use. On the other hand, if the temperature be too high, the carbon in the petroleum will be deposited in the retorts in a solid form, thus leading speedily to their destruction. Success in the production of petroleum gas is therefore dependent on the regulation of the temperature during the process of gasification. This is difficult to do, for the reason that if liquid petroleum be injected into a hot retort and converted into gas it will absorb an enormous amount of heat in the process of changing from the liquid to a gaseous state. This principle is illustrated in the boiling of water. Under atmospheric pressure water boils at 212°, and the temperature of steam at the same pres-

sure is also 212° . It is, therefore, often thought that to convert water into steam under those conditions all that is required is to heat it to that temperature. But when this has been done we have simply water boiling hot. To convert it into steam we must continue to add more heat, which in the old phraseology was said to become "latent." The quantity of heat contained in a pound of boiling water is 212 units, whereas a pound of steam of atmospheric pressure has 1,178.1 units. In other words, the amount of heat required to convert a pound of boiling water into steam is $1,178.1 - 212 = 966.1$ units, which has been called "the heat of gasification." The conversion of petroleum, or any other substance, into gas, is attended with exactly similar phenomena, that is, an enormous amount of heat is absorbed in gasifying it. To maintain the requisite temperature in the retorts, therefore, they must be heated very hot, which either produces a deposit of solid carbon in the inside, thus impairing their efficiency, or they are rapidly destroyed by the great heat. On the other hand, as already explained, if the retorts be not kept hot enough the product will not be a fixed gas, but will condense and deposit tar in the apparatus.

In this dilemma the resort has usually been to the use of retorts at so low a heat as to be incapable of making a fixed gas, and to use a quantity of air or non-luminous gas to carry the imperfect products to the place of consumption—a practice resulting in great waste, and, although the effect of a very small quantity of air in very rich gas may not be noticed, the admixture of large quantities rapidly destroys the lighting power. So great is this destruction that 1,000 feet of oil-gas which is capable of giving as much light as 200 lbs. of sperm candles, when mixed with 1,000 feet of air, forming 2,000 feet of so-called "mixed gas," will give only as much light as 100 lbs. of sperm. This is of great importance if gas must be compressed and stored in a portable holder, as it must be for beacons and buoys, for the volume which must be stored is in inverse proportion to the illuminating power of the gas.

In the manufacture of petroleum gas, then, the temperature should be regulated so that it will not be high enough to destroy the retorts rapidly, or cause the carbon in them to solidify, and yet the heat should be sufficient to produce a fixed gas with a high illuminating power.

While this process is not confined in its use to the manufacture of gas for illuminating beacons and buoys alone, yet it has the advantage of producing gas of higher illuminating power which does not lose luminosity when compressed, and which will not deposit any tarry or liquid substances in the process of manufacture.

The Foster Compound Gas Compressor.

Two great difficulties attend the compression of gas or air, especially under a high pressure. These are:—

First. The development of "latent" into sensible heat, which necessarily results from compression. In other words, the tempe-

perature of gas is elevated by compressing it, consequently there is a diminution of volume when the fluid afterwards becomes cool.

Second. The loss of effect following an imperfect displacement of all the gas from the pump cylinder at each stroke, which results in a re-expansion of the gas left in the cylinder, thus partly filling it with gas that has once been compressed instead of taking a cylinder full of fresh gas at each upward stroke of the piston. Various attempts have been made to overcome these difficulties, but with only partial success, so that generally it has been concluded that it is better to use comparatively low pressure than to encounter the difficulties referred to.

In order to be able to attain a high degree of compression, Mr. Foster has adopted what is known as the compound principle in the gas compressor. The result is so successful that 3,500 lbs. pressure to the square inch has been obtained, as has been previously stated in this paper.

The Foster Gas-lighted Buoys.

The Foster buoy is composed of a group of 7 or 13 lap-welded cylinders, made without seams or rivets, each cylinder forming in itself an independent water-tight compartment, capable of withstanding heavy concussion from floating bodies such as would prove fatal to those constructed of the large plates now used in other gas-buoys. These cylinders, like those employed in our beacons, are capable of being charged with gas compressed to from 40 to 50 atmospheres, and the supply is sufficient for six or twelve months, according to size and number of gas cylinders. Its subdivision of receptacles gives assurance of buoyancy, even should one or more cylinders receive injury of a character which would cause inevitable loss, by sinking, of any other buoy having but one or two compartments. Each cylinder having an independent check-valve prevents the escape of gas from the other tanks, should any of them be injured.

To practically exhibit the workings of the Foster buoy, one of the structures was on July 1st, 1882, placed in the Delaware River, where it remained burning continuously until October 1st, when, by authority of the United States Lighthouse Board, it was moored near the Fourteen Foot Bank Light Vessel, in Delaware Bay, a most exposed position, and it there remained until November 15th, 1882, when the gas became exhausted. Another experimental buoy was carried down the Delaware River from its moorings in a strong flood, and after a period of several days was found aground in Delaware Bay, with its light still burning, notwithstanding the shocks and knocking about it had received.

The Foster Gas Lighters Beacon and Automatic Fog Signal and Flash Light.

The beacons were first adopted by the United States Lighthouse Department in the latter part of 1880, when ten were erected for lighting the waters of Currituck Sound, N.C. and Va.

Since their introduction numerous and valuable improvements have been made by the patentee, the most novel of which is an automatic fog bell and flash light attachment. The power for operating the machinery is furnished by the rise and fall of the tide acting upon a float inclosed within a water-tight caisson, to which water is admitted in given quantities, and provision is made for the continued operation of the apparatus during "slack water," except for a period of a few minutes.

In this device the light flashes simultaneously with each stroke of the bell, thus enabling the navigator to determine his exact position by timing the interval between the flash and sound signals.

This structure is particularly adapted for marking shoal and dangerous places, and entrances to harbours and rivers, and will operate successfully when there is a rise and fall of 5 feet or over; it may also be erected on shore when pipe connection with low water is admissible.

The Use of Compressed Gas in Naval Warfare for Torpedo and Submarine Boats.

Gas made from petroleum is capable of great compression, and with Foster's compressor as much as 3,500 lbs. to the square inch have been obtained (about 230 atmospheres).

Compressed hydrocarbon can be contained in a very small space for the service it performs. There is absolutely no waste attached to its use. Under proper regulation entire combustion takes place, and consequently there is an absence from smoke, so serious a drawback to all coal-fuel.

With coal we have besides 90 per cent. of loss in solid substance, which is utterly useless, occupies valuable space, and subsequently has to be thrown overboard, entailing much time and labour.

By means of the steam generators which I employ I am enabled to obtain a high efficiency with small boilers or apparatus.

So quickly is water converted into steam that the boilers can make 200 lbs. of steam pressure, while only containing a few gallons of water at a time, therefore even if a coil burst, the damage would be slight.

The water is heated in stages by being split up into thin streams by passing it through spiral or helical coils of pipes, themselves constituting a boiler, or in combination with an annular boiler, formed by placing one dome-shaped shell within another, that would by itself constitute a boiler. Heat is applied by the use of compressed gas passing through atmospheric or other burners, so arranged that the greatest amount of heat may be generated by the combustion of the gas either with air or oxygen, and transmitted in the most efficient manner to the pipes through which water or steam is flowing.

The products of combustion are then collected, and either escape in the usual way or are forced by pressure through an escape valve, combustion in some cases taking place under the influence of a compressed atmosphere.

The advantages I claim for gas over any other substance are its freedom from smoke when properly regulated, its instantaneous ignition and equally instantaneous extinction, its perfect combustion, facility of manufacture, and satisfactory service.

The requisites for torpedo-boats, and especially submarine boats, to render them efficient are great speed, compactness, quick manœuvring, and certainty of action. All machinery is liable to fail, and the power which supplies machinery may equally become exhausted at a critical moment. In any submarine boats when coal is used a certain period must elapse after ignition of the fires has occurred before they can be in full service. With gas we get up steam in a few seconds, either below or above water.

The little American boat "Stiletto," that made 29 miles in 1 hour and 17 minutes, on a gallon of water in a beehive coil boiler, is an example of this principle.

Petroleum is stored in tanks, and can be made much more effective than coal, as its bulk is not wasted. These tanks should be on the supply tender.

I should propose that when a fleet of submarine boats were employed, a tender provided with gas generating apparatus and compressor be used to supply compressed gas to the torpedo-boats. But as this service would probably be more particularly confined to the protection of harbours and estuaries, provision for gas stations is easily made.

An idea has lately been protected for raising steam by the aid of Foster's compressed gas as fuel, with a view of substituting it in the place of coal, more especially when storage dimensions are limited, and when the area of boiler space has to be reduced to a minimum, and it is at present under consideration whether this system may not be advantageously adopted as a motive power for the propulsion of submarine boats. Its primary recommendation is that we can stow sufficient compressed gas in such a vessel capable of providing fuel for a much longer period than will be necessary to remain in action.

Secondly, its storage being of course in sealed cylinders, it is a matter worth consideration that these cylinders can be placed within the space reserved for the reception of water required for sinking purposes, allowing of course for a certain amount of increased space being required in that compartment due to the area of the gas tubes, so that by raising the deck over the water space a few inches, a clear way from fore to aft will be secured for the reception of whatever machinery may be called into requirement.

As of course boiler space is a matter of serious moment in these vessels, it is necessary to provide those which shall have the greatest amount of heating surface combined with the most effective circulating powers, and I am of opinion that a boiler constructed almost entirely of spiral tubes, as previously described, through which water would be caused to circulate freely, owing to the rapidity with which the small quantity of water in the boiler at one time would be raised to steam by the use of suitable burners through which compressed gas

could be supplied at variable pressures, will be a preferable means for obtaining the motive power to that where coal firing is used.

Roughly speaking, without having the particulars of any experiments, and upon the supposition that gas is used from a storage compressed to 50 atmospheres, it is computed that steam will be raised to a sufficient pressure for propelling a boat not less than 60 feet long in a boiler, the dimensions of which shall not exceed 6 feet diameter at its base, and of a height not exceeding its diameter, and that fuel for seven hours firing could be carried in every 50 feet length of cylinders 15 inches in diameter.

We are all cognizant of the usefulness of steam as an agent to be relied upon, and I am strongly impressed with the idea that for purposes where there must not be a suspicion of possible failure, engine power is the only method worthy of consideration.

Colonel J. B. RICHARDSON, R.A. : I should like to ask how the greater absorption of light is accounted for, whether light of one colour is more apt to be absorbed than light of another colour, whether experiments in different lights have been tried with reference to absorption. I should also like to ask whether these cylinders containing gas under very great pressure—a great number of atmospheres—could be used in the Red Sea as is suggested, or whether the great heat of the sun in that sea and in the tropics would not tend to burst them. We are told in the lecture that it has only been tried in New York, and that it is not capable of being damaged by cold. The question of the effects of heat has not apparently been taken into consideration.

Captain CERRIS : I should like to make one remark with respect to the buoy that is exhibited. It is apparent to every seaman that where there are no highlands or high objects serving as landmarks in approaching a river, those buoys have great advantages over the ordinary kind. I should like to know if 45 atmospheres is the utmost limit to which the gas can be compressed, because I have an idea that it might be utilized on rivers in our pleasure yachts.

Mr. RICKMAN : Shall I be in order in asking if the lecturer is aware of a report made by Admiral Rowan, Chairman of the Lighthouse Board of the United States, to the Secretary of the Treasury, dated 16th February, 1883; and also whether he is aware of a report made by the Experimental Committee of the Lighthouse Board of the United States to Admiral Rowan, this report being dated April 23rd, 1884?

The CHAIRMAN : I would also like to ask Mr. Huntington to give us the cost of the gas so much per thousand feet.

Mr. ISOLIS (Secretary to the Trinity House, Tower Hill) : I should like to make an observation or two upon this paper. The Trinity House, as you know, Mr. Chairman, are very much interested in anything approaching to an improvement in lighthouse work, and they will, I have no doubt, have very great pleasure in inquiring into the details of the scheme which Mr. Huntington has put before us. There are, of course, many questions to be asked with regard to the details of such a scheme, but it appears to me, in the first instance, that if he is hopeful of attaining such high powers as are mentioned in the Report of the Committee on Lighthouse Illuminants, he does not fully realize what quantities of gas he will require. Now we have here a 10-ring gas-burner consuming more than 200 feet per hour, and it is the work done by such a burner as that which is dealt with in the Report from which he is quoting. We have here again a 6-wick oil burner, of the type in common use in lighthouses round the coast, consuming paraffin or rape oil. To produce a light of that power we should need a very much more extensive system of supply for gas than is indicated in the paper; and it would be unsafe to assume that by the process described we should be able to secure lights of high power without the attendance of keepers. Nor could we supply them with compressed gas except at an expense enormously greater than that which we are called upon to meet in using oil or gas in the ordinary way. I think that the flame produced in

the burners of the Metropolitan Railway carriages, and which is spoken of rather slightly in the course of the paper, is very much nearer the illuminating power that we shall have at our command by means of the compressed gas system, at all events for some time to come, such a light as we have in a lantern of this kind which is taken off the top of an actual gas-lighted buoy. Consequently, the quotation of those very large powers I think raises hopes that are not likely to be realized. The gas that we have used in gas-buoys at present is distilled from shale or mineral oil, and produces a high illuminating power, in fact with the Douglass burner it was made to beat the canal gas at an experiment at South Foreland, that is to say, it gave a higher illuminating power in the same burner. Another question to be asked is whether the travelling and floating gas works spoken of have yet been brought into action. The lecturer speaks of making and compressing gas as you go along, and of putting it into buoys or landing it into beacons; but I should like to ask, has it yet practically been done? We find that a buoy, lying of course in more or less disturbed water according to the state of the weather, has to be filled with gas by attaching one end of a flexible pipe to the receiver on board the vessel, which receiver is charged with gas to about 20 atmospheres, and the other end to the buoy brought alongside. The gas, passing from the receiver through the tube, rushes into the buoy until the pressure in each is nearly equal, so that we get, perhaps, 10 atmospheres left in the receiver on deck, and 10 atmospheres in the buoy afloat. If the buoy is to be served afloat in this way, the anticipation that we shall be able to make our gas and to compress it direct into the buoy is rather sanguine. If we might hope always to lift the buoy on deck, the process would perhaps be easier; but serving it as we do now, I am afraid we shall not be able to get the pressure spoken of, and consequently shall not attain the long duration of un replenished service which is anticipated for the buoy. As regards the floating structure shown in the drawing, I am not an engineer, and cannot speak with authority, but I am a little afraid that the mode of mooring will be found inconvenient, if not disastrous. We had an automatic buoy with a long tube reaching down far below it into the water, moored in that way in the first instance, and the chafing of the mooring round the part where it was attached was so great that the buoy got nearly waterlogged. In the absence of diagrams, of course we cannot see the process of making the gas. It would have been very instructive to have seen it; of course we shall learn more when the paper is published. One other remark I would make is that the buoy that is said to have come down the Delaware River in the ice without losing its light was a very fortunate buoy. I think it is probable that it was not so much knocked about as at first sight would appear, because one rather important difficulty we have had to overcome is the effect of a blow upon the buoy. A barge running against a buoy in the Thames, or even a boathook struck against it, has been known to put the light out; and that buoy at Sheerness was in the early stages of the experiment put out by the concussion occasioned by the firing of heavy guns. These are some of the questions, founded upon difficulties which have been overcome in the present state of the service in England, upon which some further information is desirable on the present occasion.

Admiral BAINE: In the few remarks I propose to offer on this paper I shall confine myself almost entirely to the question of the automatic fog signal. The impression of most Officers who have been in fogs, or in any circumstances where it is important that they should know their position, has been that it is exceedingly difficult to realize where their position is by the sounds they hear, and I propose to ask the lecturer whether he will be able to inform us what experiments have been made in the United States with reference to two points: one, the best method of getting sound carried through a fog to indicate with reasonable accuracy the locality of such sound: and the second, the best method of carrying any illuminating power through a fog. Of course in lighthouses and in the various structures such as we see here illustrating this lecture there are certain things we can control. We can control the gas, or whatever may be the illuminant that is used; we can control the strength and height of the light, but what we cannot do is to be certain that in any given atmospheric conditions you are able to penetrate to the same distance with that light. I believe it has been ascertained by experiments undertaken by the Elder Brethren of the Trinity House that on days apparently precisely the same, and in

fine clear weather, light is extremely different as regards its power of penetration of the atmosphere. I believe in some cases the same light which on one clear night will be seen a certain given number of miles, on another night, apparently to the eye exactly similar, the light is only seen about one-half or one-third of the distance, and I am under the impression that no very clear explanation has been given as to the cause of this variation. As regards sound, the extraordinary fact occurs that at one time you will find that sound signals will travel and reach the ear at a distance not exceeding 3 miles, which is the ordinary reliable distance, and on other occasions the same sound will reach, I am told, as far as 15 or 16 miles under what appear to be precisely similar conditions. It has also been found that in fogs, in which it is generally supposed that sound does not travel well, it actually travels better than it does in fine or clear weather. It has also been ascertained that mist and snow are conditions of the atmosphere which are favourable for the conveyance of sound through the air. I would like the lecturer to tell us if he knows what experiments have been carried out in the United States upon the subject of sound signals. We know what has been done by our Trinity House within the last ten years, and the series of useful investigations that have been made with regard to this important subject.

Colonel BAYLIS: It has just been observed that the mere concussion of firing guns will extinguish the light. I think it was also said that a boat striking against a buoy, or even a boathook striking it, will put out the light. If that be so I should like to ask whether when a violent sea strikes against the buoy and vibrates it considerably, the light is or can be so protected as to ensure its remaining intact?

Mr. HUNTINGTON: A good many questions have been asked me which I am afraid I am unable to reply to, and some reports, which I have not even heard of, have been referred to in one question. I am first asked if there is anything in the colour of the light with reference to absorption. I think it has been understood that in gas and oil flames the red rays carry much further than any other rays, and that the violet tint in the electric light does not carry so far. With reference to the effect that the heat of the sun might have upon the compressed gas in situations such as the Red Sea, I may say that of course these tubes would be made of such strength as to resist any such extra pressure which might be brought to bear upon them. That is a matter which can be easily arranged. As I have said, I regret that I am not acquainted with the report made by Admiral Rowan in 1883, or the report made to him in 1884. Mr. Inglis has very kindly taken part in this discussion, and has asked some questions with regard to having the gas upon the tender. We have not at present had gasworks upon the tender itself, and the way in which the buoys have been supplied has been, as is suggested, that the reservoir has been put into a scow, and being connected with the buoy, the pressure was allowed to equalize. It is just as has been described, except that the pressure in the tanks was much higher than Mr. Inglis stated. The gas has never been generated in the vessel itself. It was only supposed that that would be a good idea for supplying a great number of lights on inland waters, where you have 50 or 100 lights to serve. It might not be required in this country.

Mr. INGLIS: Do I understand you that you have 45 atmospheres in the beacon, or 45 atmospheres divided by 2?

Mr. HUNTINGTON: We get 45 atmospheres in the beacon. The pressure is much greater in the storage tanks, and it is equalized in the pressure. That is the report we had from the Lighthouse Department of the United States authorities. With regard to the buoy coming down the Delaware I may say I omitted the word "ice" in reading my lecture. The circumstance was told to me, but I am convinced that that statement must be incorrect. No doubt it was a strong flood, and the buoy was carried down in that flood, knocked about, and ran aground, but still the light did not go out. I have quotations from the daily papers speaking of the circumstance. I regret that I am not able to give the information that Admiral Brino asks for with regard to the effect of fog upon the transmission of sound. As to the cost of the gas, it would depend upon the price of petroleum. When petroleum is 4½ cents a gallon the gas would come to 19 cents a thousand feet, including everything. That is the cost in America—a little under 1s. a thousand feet. One man can make and compress 10,000 feet of gas in a day. I have seen it working myself, and have seen

one man do it, and I think that compares very favourably with the results obtained at any coal gasworks.

The CHAIRMAN: I am sure we are all very much indebted to Mr. Huntington for the able lecture which he has delivered on a very abstruse subject. Some parts of it were exceedingly deep. I know I felt that the tide had risen clean over my head. But there are some practical portions of this subject that one can grasp. Moreover, all these scientific matters have to bear the test of practical experiment, and of long-continued experiment. I speak mainly of the light he gets from the gas. The lighthouse authorities always experiment thoroughly upon any illuminant that may be proposed to be used for our lighthouses and lightships round the coast, in order that they may be able to rely upon the work which that illuminant can do. In this connection it may be interesting to gentlemen to examine these burners which are on the table. One is for oil with six concentric wicks. It is the burner which is in common use all round our coasts, and it produces a splendid light, so powerful that in clear weather we only use the three outer wicks. When the weather becomes misty we light up all six, and so we get a very powerful light. Then, we have this still more powerful gas-burner with ten concentric rings of gas. The six-wick oil-burner has been in common use for many years round our coasts. It shows a light equal to about 720 candles, and we can keep it going at an expenditure of half a gallon an hour, costing only about 3d. This is the consumption in foggy weather; it is not above one-half or two-thirds of that in clear weather, when only half the wicks are burning. The oil is very easily conveyed to our lighthouses and lightships.

Admiral FREMANTLE: What sort of oil do you use?

The CHAIRMAN: Paraffin oil, distilled from Scotch shale. From a long-continued set of experiments which we have made at the South Foreland we find, as far as we can arrive at the cost, that we produce a light of 1,000 candles from paraffin oil (such as we use), and allowing for all expenses the cost would be about 10d. per 1,000 candles of light per hour. If we were to use gas produced from cannel coal it would cost us just double that, or 20d. an hour, and Mr. Pintsch's oil-gas comes to something between the two. I am sure that nothing under a series of exhaustive experiments will convince me that the gas which Mr. Huntington has told us of can be produced at such a very low figure as he supposes. If we add to its original cost the expense of conveying it to or making it at out-of-the-way stations where our lighthouses are placed, it would come to something very much higher, and I think very much beyond the cost of the oil which we now burn. Of course the oil produces ample light; quite as strong as is necessary. We have in one lighthouse two of these oil lamps, one above the other—the biform system. We light the second burner in foggy weather, and at a distance beyond a mile and a half it seems like one great light. There are other systems of lighting, with three or four lamps superposed, so that it is easy to produce as powerful a light as is at all necessary. I will not occupy your time any further; but I hope I may, in your names, thank Mr. Huntington for his very interesting lecture.