THE IAN HARDY SERIES

BY

COMMANDER E. HAMILTON CURREY, R.N.

Each Volume with Illustrations in Colour. 6s. nett.

Ian Hardy's career in H.M. Navy is told in four volumes, which are described below. Each volume is complete in itself, and no knowledge of the previous volumes is necessary, but few boys will read one of the series without wishing to peruse the others.

IAN HARDY, NAVAL CADET

"A sound and wholesome story giving a lively picture of a naval cadet's life."
Birmingham Gazette.

"A very wholesome book for boys, and the lurking danger of Ian's ill deeds being imitated may be regarded as negligible in comparison with the good likely to be done by the example of his manly, honest nature. Ian was a boy whom his father might occasionally have reason to whip, but never feel ashamed of."—*United Service Magazine.*

IAN HARDY, MIDSHIPMAN

"A jolly sequel to his last year's book."—*Christian World.*

"The 'real thing.' . . . Certain to enthral boys of almost any age who love stories of British pluck."—*Observer.*

"Commander E. Hamilton Currey, R.N., is becoming a serious rival to Kingston as a writer of sea stories. Just as a former generation revelled in Kingston's doings of his three heroes from their middy days until they became admirals all, so will the present-day boys read with interest the story of Ian Hardy. Last year we knew him as a cadet; this year we get *Ian Hardy, Midshipman.* The present instalment of his stirring history is breezily written."—*Yorkshire Observer.*

IAN HARDY, SENIOR MIDSHIPMAN

"Of those who are now writing stories of the sea, Commander Currey holds perhaps the leading position. He has a gift of narrative, a keen sense of humour, and above all he writes from a full stock of knowledge."—*Saturday Review.*

It is no exaggeration to say that Commander Currey bears worthily the mantle of Kingston and Captain Marryat."—*Manchester Courier.*

"The Ian Hardy Series is just splendid for boys to read, and the best of it is that each book is complete in itself. But not many boys will read one of the series without being keenly desirous of reading all the others."—*Sheffield Telegraph.*

IAN HARDY FIGHTING THE MOORS

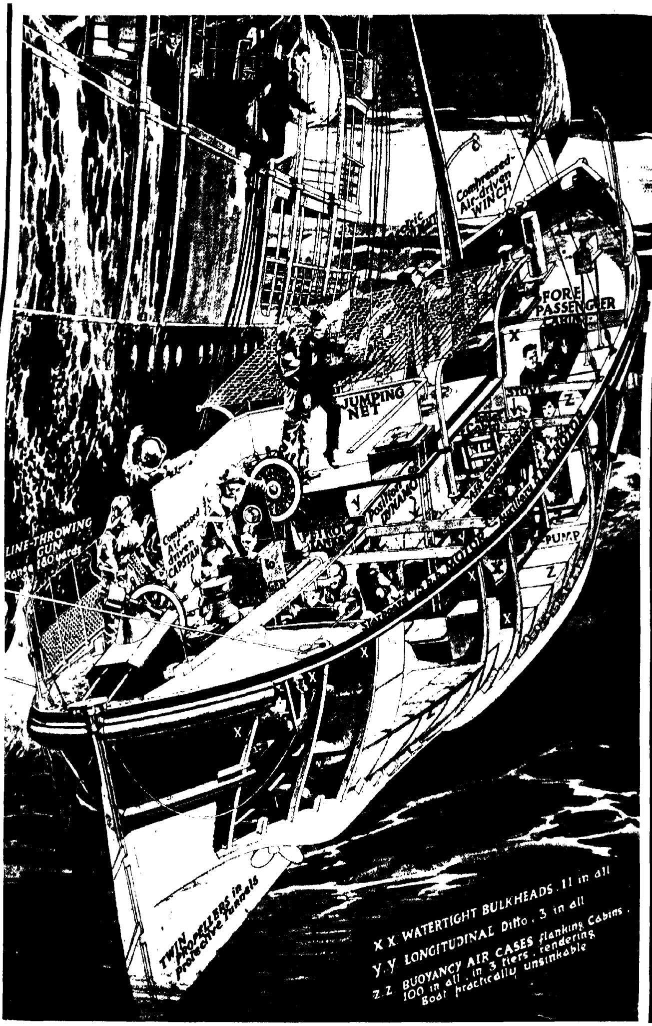
By writing this series the author is doing national service, for he writes of the Navy and the sea with knowledge and sound sense. . . . What a welcome addition the whole series would make to a boy's library."—*Daily Graphic.*

"The right romantic stuff, full of fighting and hairbreadth escapes. . . . Commander Currey has the secret of making the men and ships seem actual."—*Times.*

"By this time Ian Hardy has become a real friend and we consider him all a hero should be."
Outlook.

SEELEY, SERVICE & CO. LIMITED

THE ROMANCE OF
LIGHTHOUSES & LIFEBOATS



A Rescue by a Barnett Motor Lifeboat

These large lifeboats, which are 60 feet long, are each provided with a net amidships, into which the shipwrecked people can jump. They also have searchlights, cabin space for fifty passengers and a gun capable of throwing a line to a vessel in distress. They are driven by two 75-horse-power motors.

THE ROMANCE OF LIGHTHOUSES & LIFEBOATS

AN INTERESTING ACCOUNT OF THE LIFE-SAVING APPARATUS & APPLIANCES USED IN GUARDING AGAINST THE DANGERS OF THE SEA, INCLUDING A DESCRIPTION OF LIGHT-SHIPS, ROCKETS & SUBMARINE SIGNALLING

BY

T. W. CORBIN

AUTHOR OF
'THE ROMANCE OF SUBMARINE ENGINEERING'
"MECHANICAL INVENTIONS OF TO-DAY"
&c., &c., &c.

WITH 42 ILLUSTRATIONS & DIAGRAMS

London
Seeley, Service & Co. Ltd.
196 Shaftesbury Avenue
1926

PRINTED IN GREAT BRITAIN

CONTENTS

LIST OF ILLUSTRATIONS

CHAPTER I

THE LIGHTHOUSE

THERE is something very romantic about a lighthouse, attracting the interest of every-one. Probably that is because of what it suggests. Without our realizing it, it calls up thoughts of wild, stormy nights, dangers and perils, endurance and heroic deeds. The stately column which often supports the light appeals by its simplicity and grace to our sense of beauty, and there is about it a sugges-tion of strength and reliability, qualities very dear to the British nature.

The sea coasts of the world are dotted with lights. Dangers of various sorts are marked by them. Wherever he goes the sailor finds lights for his guidance, but they do not all serve quite the same purpose.

When a mariner is crossing the ocean he notes his course by various means. The compass helps him, for one thing. Observations of the sun and stars give him still more accurate information ; and now he has the wireless direction finder. But even when he has done his best with these he only knows that he is somewhere near a certain point. So as he approaches land by night he looks eagerly for a light. Presently one comes up over the horizon. Watch in hand, he times its flashes, their duration and the duration of the intervals between. Thus he recognizes it; he knows for certain what particular light it is. He takes the bearing of it with his compass and steers accordingly.

MAXIMUM DISTANCES BEYOND WHICH A LIGHT CANNOT BE SEEN BECAUSE OF THE CURVATURE OF THE EARTH'S SURFACE.

Height in feet.	*Distance in miles.*	*Height in feet.*	*Distance in miles.*
10	8·06	120	17
20	9·57	150	18·01
30	10·72	200	20·66
40	11·69	300	24·31
50	12·55	400	27·38
60	13·32	500	30·09
70	14·03	600	32·54
80	14·7	700	34·72
90	15·32	800	36·89
100	15·91	1000	40·72

Now he begins to know exactly where he is. If he can pick up another light and get the bearing of that also he will know his position still more definitely.

Lights of this kind are called "making" lights, because they are the ones which a sailor first sees when he is "making" the land, as he calls it. They are always large and powerful and raised as high as possible, so that they can be seen at the greatest possible distance.

The earth having a curved surface, the height of the light makes a considerable difference to the distance at which it can be seen. On page 18 is given a small table showing how far off lights of various heights can be picked up. This, of course, is not a question of the brightness of the light, but simply depends upon the shape of the earth.

With the fast steamers of to-day this becomes more and more important, for supposing a light be first seen by a ship when 20 miles away while she herself is travelling at 20 miles an hour, there is not much time left in which to correct her course, should that be necessary.

Examples of "making" lights are the Lizard for ships approaching the south of England from the south and west; Fastnet Rock, off the west coast of Ireland, which is usually the first thing seen on this side by transatlantic ships; Cape Race, for the mouth of the St. Lawrence, and Navesink at the entrance to New York Harbour.

In addition to these are the lights which mark some particular danger, such as the famous Eddystone. They go by the name of "warning" lights.

Then along a coast such as that of the English Channel are a chain of lights, mostly on headlands, which lead a ship along. "Coasting" lights, these are termed, and on a well-lighted coast there is, on a reasonably clear night, always one in view.

There are, of course, some lights which really perform a double function, and so may belong to two or more of these classes.

Besides these are the "leading" lights which lead vessels up channels or into harbours, and the "port" lights which mark the ends of piers, jetties, etc.

A few moments' thought will show anyone that in order to fulfil all these various purposes there needs to be a wide range of lights available varying in size and therefore in candle-power.

The size of a light is denoted by the size of the "optical apparatus," the assemblage of glass lenses and prisms by which the light from the lamp is controlled. Each light is described as belonging to a certain "order" according to the distance from the centre of the lamp to the lens.

All the large and important lights are of the "revolving" type, which means that they show a series of flashes in place of a steady light, which effect is produced by causing the "optical apparatus" to revolve inside the lantern.

Some of the minor ones show a steady unvarying light, and others again, among the small fry, are "occulting," that is to say the light varies as in the revolving lights, but in their case the effect is produced by alternately covering and uncovering the lamp or by turning up and down the gas supply.

The duration of the flashes and the duration of the intervals between them constitute the "character" of the light, by which it is known from its fellows.

THE LIGHTHOUSE

There are many positions where a warning light is necessary, and yet it would be almost impossible to erect a lighthouse. The Goodwin Sands, for example, are a terrible danger to shipping, as is proved by the number of wrecks which, despite all possible precautions, occur there every winter. Nowhere are lights more needed, but to erect a lighthouse upon those treacherous sands, if not impossible, would be at least extremely difficult and costly. In such cases the obvious thing is to have a floating lighthouse, to mount the lighthouse lantern, or something similar, upon a ship, which can be anchored upon the spot. Hence we arrive at the lightship.

The light upon a lightship is usually small as compared with those on shore, but the tendency appears to be in the direction of larger and larger lights even upon lightships.

No doubt the lightship has grown from just an ordinary small ship with a lamp hung up upon a mast. With time and experience the shape of the vessel itself has changed from that of the ordinary ship : it has become more specialized ; and in like manner the light itself has developed from a small simple contrivance hoisted up on a pole to something which resembles a small lighthouse standing upon the deck of the ship.

The lights of lightships are many of them occulting, and some are even revolving, like the greatest lighthouses. They are supplemented also with fog-signalling apparatus of various sorts, not to mention wireless telegraphy for sending information ashore, calling for aid when necessary, and generally supervising the traffic.

The lightship man, in some cases, appears to play a part somewhat similar to that of the policeman who controls the traffic in a busy street. He is more in the stream of traffic than is his comrade of the lighthouse, and if he sees a ship running into danger or causing danger to others he has signals by which he can make his presence, and his opinions too, known to the offenders.

Some of the smaller lightships are so contrived that they can be left unattended for considerable periods. These may perhaps be regarded as large buoys, but in many respects they are really ships.

Of buoys there are of course an endless variety, from a can or barrel to most elaborate and beautifully made contrivances which show a light like a miniature lightship, and in some cases have an automatic fog-horn whereby they send forth sighs and groans with every motion of the water around.

Quite apart from the light, however, many of the lighthouses—the towers upon which the lights are supported—are marvellous feats of engineering. The tower upon a headland near some populous town, of course, is not much different from any ordinary building except for its shape; but the tower upon an isolated rock, covered by the sea possibly, at every tide, with "no room to move," is quite different.

The erection of such a structure is a very costly business which calls for the utmost possible care, ingenuity, and courage. Yes, courage, perhaps more than all. The courage of the soldier is not more striking than that of the man who undertakes the responsibility for devising a tower upon an isolated rock. It is not the danger of being washed off during the progress of the work that he need fear. Reasonable prudence can provide against that. It is the danger of making a mistake, an error of judgment, which may possibly throw the work back a year, double the cost or lead to a badly built, unsafe tower.

In designing a structure of this kind many of the points are merely a matter for calculation, but there are others in which right can only be distinguished from wrong by the personal judgment of the engineer. And unless his reputation is to be ruined he must choose the right every time. So, when you look at a lighthouse tower upon an isolated rock, just give a thought to the man who had the courage to put down upon paper the best way to attack and overcome the enormous natural difficulties involved in building it.

Then think of the men whose duty it is to look after the lightships and the isolated lighthouses. Those on the shore lighthouses, of course, have a fairly comfortable time, but think of the others. The writer remembers many years ago chatting with a man who was one of the attendants upon a lighthouse on Lundy Island, in the Bristol Channel. His home was in Cardiff, and he said that the lonely life in the lighthouse so affected his nerves that when he periodically visited his home he was afraid to cross the street. That is just a little incident, but it calls up a striking picture of the life upon the lighthouse.

All these subjects will be enlarged upon in subsequent chapters.

CHAPTER II

TRINITY HOUSE

THE British are a most extraordinary people, particularly in their methods of governing themselves. The British Constitution itself is an absurd mixture of illogical, nonsensical, unscientific ideas. If an intelligent observer from another planet were to drop down in the British Isles to investigate these matters, he would report to the effect that he had found a strange people with ridiculous, stupid ideas of government far inferior to anything to be found upon his home planet, where, no doubt, everything is systematic, orderly, and methodical.

But if he stayed long enough he would add as a postscript: "In spite of what I have said above, British methods seem to work remarkably well."

The explanation of this strange state of things is that when we want to set up an authority to carry out some national duty we much prefer to find some old existing institution and adapt it to what we want rather than make a new one.

An excellent example of this occurs in regard to the lighthouses, lightships, and buoys around the coasts of England and Wales.

TRINITY HOUSE

When the greatest maritime nation of the world suddenly awoke to an interest in its lighthouses and lightships it did not, as most other nations would have done, set up a new Government department to do the work. It found an old semi-private guild of mariners, established no one knows when, or by whom, already doing the work to some extent, and it forthwith gave them greater powers, linked them up, for financial purposes, to the Board of Trade (a Government department), and told them to get on with the work. And, as usual, this patched-up illogical contrivance has ever since worked most efficiently, so that the lighting arrangements around the coast of England and Wales, the Channel Islands "and Gibraltar," leave little to be desired.

Of early history this wonderful guild has none, for the simple reason that all its records were destroyed in the Great Fire of London in the year 1666, or, if any escaped, they were finally demolished by another fire in the year 1714 which destroyed their headquarters.

The first thing which we know definitely is that in the year 1514 the King of England, Henry the Eighth, gave a Charter to a guild of mariners, pilots, and others interested in shipping, who were in the habit of meeting apparently in the church at Deptford-Strond, in the county of Kent. Deptford-Strond is identical with the densely populated Deptford of to-day, one of the "metropolitan boroughs" which now constitute the County of London, but at that time it was no doubt an isolated village on the banks of the

Thames, just the place where the seafaring men who used the "London River" might be expected to congregate.

The guild comprised women as well as men ; indeed, the wording of the Charter is " men as well as women," as if the women members were taken for granted, but it was necessary to mention the men. The sisters or women members appear to have died out in the early stages.

In the charter the body is described as the " Guild or Fraternity of the most glorious and undividable Trinity and St. Clement of Deptford Strond." Its chief duty was the provision of pilots for ships entering and leaving the Thames. There is a tradition that they had a kind of depot for pilots also at Leigh in Essex, which is borne out by the fact that a number of old "brethren" are buried at Leigh, in St. Clement's Church. Deptford was said to have provided outward pilots, and Leigh those for inward-bound ships.

In addition, however, to this practical duty of organizing a pilot service for the Port of London, the guild also administered a number of charities for the benefit of seafaring folk. They helped mariners who for any reason, such as illness or injury, might be in distress; they looked after sailors' widows and orphans.

In the year 1520 we see the beginning of a real national Navy, and as part of the new arrangements the Dockyard and Stores at Deptford were placed under the control and supervision of the Trinity " Brethren."

In 1556 we find a new name used, "The Corporation of Trinity House of Deptford Strond."

Queen Elizabeth gave the Corporation power "to erect sea-marks" and to license watermen on the River Thames. In doing this the Queen describes them as a "Corporation of the chiefest and most expert of masters and governors of ships incorporate within themselves, charged with the conduction of the Queen's Majesty's navy royal."

It is evident from this that the Corporation was already, in the time of good Queen Bess, becoming a power in the land. Otherwise the supervision of the Navy, such as it was in those days, would not have been placed in their hands.

It seems doubtful, however, if their control was a very real thing, for there was the Lord High Admiral, who evidently had great powers and rights of his own. For example, this official had the right to anything that he could make by the sale of ballast dredged up from the bed of the Thames. He was also empowered to erect beacons and lay down buoys and recoup himself by levying dues upon shipping.

These rights do not appear to have been interfered with by the decree of Elizabeth just referred to, since in the year 1592 the Lord High Admiral of that day, none other than the Lord Howard who fought the Armada, still possessed them. In reading the history of those times one is saddened by the cupidity and selfishness of so many of the leading men, but in Lord Howard we have an honourable exception. Although the rights must have been a source of much profit, he arrived at the very right and patriotic conclusion that it would be better for the country if they ceased to be in the hands of any single man. He therefore proposed that he should surrender them to the Queen with the strong recommendation that she in turn would pass on both duties and profits to the Corporation of Trinity House.

This was done, but corruption was still at work, and in spite of what the Queen had done there went on for the next forty years or so a battle royal between the Trinity House and private individuals who persuaded the monarch of the time to give them a "patent" authorizing them to erect a lighthouse somewhere and, of course, levy tolls upon ships.

It seems to us ridiculous, but was in accord with the corrupt administration of those days. A man would think of a spot, not always a suitable one, where there was an excuse to put a light. He would then go to the court and through some influence or other obtain a patent allowing him to do this, and to levy tolls upon ships passing it, which tolls were collected on his behalf by the Customs. The grant of the patent was always accompanied by a payment to the King, which alone is a significant fact. The King made money out of the grant, the patentee made more, and the mariners may or may not have been benefited.

There was one honourable exception to this in the person of Sir Robert Killigrew, who first built a light upon the Lizard. It was erected and maintained for some time entirely at his own expense, assisted by some of his friends, and his aim seems really to have been the preventing of shipwrecks rather than his *own profit.*

The dues were collected at the various ports by the Customs officials, and the patentees had power to seize ships or exercise other pressure in the event of people being unwilling to pay.

All this was a flagrant violation of the arrangement made in Queen Elizabeth's time, but it was made legal by certain lawyers' quibbles.

This state of things continued until the year 1637, when as the result of a lawsuit it became evident to the Trinity House authorities that they had better acquiesce in the competition of private lighthouses. It should be made quite clear that they do not appear to have contested this point for any selfish reason, but simply because it appeared to them, as apparently it had to Queen Elizabeth and Admiral Howard, that the public would best be served if all lights were under one control.

But although they were not the sole owners of lighthouses they had some of their own, and they had a wide range of duties also. Anybody or any Government department who wanted to know anything about nautical matters seems to have appealed to them.

They had charge of Deptford Dockyard and the Naval Stores Depot at Deptford. They designed ships for the Navy or inspected those bought ready built. Provisions, tackle, and ammunition for the Navy had to pass their inspection. Buoys and beacons (daylight) had to be placed and maintained by them. Pilots could not work except with their certificate, an arrangement which still exists. They had the right to appoint Consuls at Leghorn, Genoa, and several other places in the Mediterranean. They provided charts and maps for the Navy, recommended men for officers' commissions in the Navy, in times of stress they even had to impress men for the Navy. In lawsuits referring to shipping they had to attend and advise the judge, as in fact they do to-day.

And with all these responsible duties they remained a private guild of men interested in the sea, who served very largely in an honorary capacity. As examples of men who served their fellow-men for very small reward, if any at all, these old Brethren of Trinity House set us all a magnificent example. With such a tradition behind them it is not surprising that the King himself is to-day proud to be one of the "Elder Brethren," while Gladstone and several other Prime Ministers have made the uniform of an "Elder Brother" their dress at State functions.

During the Commonwealth the charter of the Corporation was cancelled, to be renewed again at the Restoration.

At some time unknown the headquarters of the Corporation were transferred from Deptford to Stepney or Ratcliffe, on the north of the Thames. This was evidently for the sake of convenience, the new house being much more accessible from the City than was Deptford. In the year 1660, doubtless for the same reason, they moved into the City itself, to a building in Water Lane very near the Trinity House of to-day.

During the Plague they sought refuge temporarily at Deptford, and soon after, in the Great Fire, the Water Lane premises, with all the old documents, were entirely consumed. Rebuilt, these buildings were again destroyed in 1714, and in 1798 a final move was made to the beautiful building upon Tower Hill which is one of the gems among the London buildings now. It is interesting and fitting that the old Trinity House should have as a close neighbour the magnificent modern quarters of the Port of London Authority, who now perform many of the duties relating to the port which in days gone by fell to the older body.

The contrast between the small but ancient home of the ancient guild, whose foundation is lost in the far-off centuries, and the tall commodious offices of the new "authority" created in 1909, is very striking.

According to the charter of James the Second, there were to be a Master, four Wardens, eight Assistants, and eighteen Elder Brethren. It was this charter which brought the Corporation formally into existence again after its suspension during the Commonwealth, and it was provided that the first set of officers should be nominated by the King, after which vacancies should be filled as they occurred by the votes of the Elder Brethren, as was done in the old days. The effect of this was to make the body a more courtly one than it had been before. During this period the mastership fell upon two occasions (it was an annual office) to Samuel Pepys of Diary fame. Through his influence his brother John Pepys, was appointed Clerk to the Corporation, an office which he appears to have filled with only moderate success. Under these conditions the periodical banquet assumed a very important place in their proceedings.

The other famous writer of a Diary, John Evelyn, mentions the fact that he attended some of these banquets. In one case it appears to have been due to his father-in-law having made a generous gift to the Corporation for their charitable work, a gift which Evelyn seems to have regretted somewhat, thinking possibly that it would be so much the less for his wife to inherit. It occurs to the writer, however, that John Evelyn may have done business with the Corporation in gunpowder, which he manufactured in those days at the village of Godstone in Surrey.

As the nominees of the King died out the membership of the Corporation gradually became more and more what it had been before—practical master-seamen, shipwrights, pilots, and other experts in nautical matters. Through their sterling worth and self-sacrificing labours the Corporation regained that character of solid wisdom and reliability which carried it through so many centuries to the honoured position which it occupies to-day.

This practical ability was shown in the year 1797, when there was a mutiny among sailors in the ships of the Navy, known as the Mutiny at the Nore. The Elder Brethren themselves went down to the Nore and removed the buoys so as to make London more safe. In 1803, when again there was a risk of trouble, they took strong and quick steps which made London safe from attack.

In 1836 by Act of Parliament the Corporation was empowered to acquire all the private lighthouses and work them under their own supervision as a national service. This they now do, raising the necessary funds by means of dues levied upon the ships which benefit by the lights.

In order to obtain this control they had to buy out the old " patentees " who had the private lighthouses, and in many cases huge sums had to be paid, showing what vast sums the old private owners had extorted from the shipping community. As an example, there was an old rickety building masquerading as a lighthouse upon Smalls Rock off Milford Haven. For the right to take this over, Trinity House had to pay £170,000, after which they had to spend £50,000 on a proper lighthouse.

They have to submit their accounts to the Board of Trade, and the latter department have some say in all matters involving considerable expenditure. Subject to this supervision they carry out these important national duties on their own responsibility.

The lights around the coast of Scotland come under the control of the Commissioners of Northern Lighthouses, with offices in Edinburgh; while those of Ireland are cared for by the Commissioners of Irish Lights from Dublin, but over these minor bodies the Trinity House has some sort of control.

In addition to these authorities, a number of local ports have their own lights. The writer remembers years ago seeing the imposing lighthouse upon the Great Orme's Head near Llandudno and taking it for granted that it was a Trinity House light. It came quite as a shock to learn that it belonged to the Mersey Harbour Board, the reason being that its chief purpose is to guide ships approaching Liverpool.

In the same way, the borough of Preston, to name only one example, controls a number of lights for the use of shipping entering and leaving the river Ribble.

Thus there are many lighting authorities altogether in the British Isles, but for importance and historical interest the Corporation of Trinity House outshines them all.

CHAPTER III

THE SOURCE OF LIGHT

THE early beacons were no doubt just bonfires lit upon the shore. The earliest lighthouses of which there is any record had fires of wood. The historic tower upon the island of Pharos was said to be 100 feet high, and its fire fed with oak logs. The light was altogether 590 feet high, and out of common humanity one hopes that there was a prehistoric lift for taking the fuel to the top.

Later on coal displaced wood for this work, as it did in so many other spheres, on account of the rapid consumption of the forests.

Then followed candles. The famous Eddystone light was lit with candles, first of tallow, then of wax. It hardly seems worth while to have built that costly tower, and to have replaced it after two catastrophes, in order to hold aloft such a miserable glimmer as that.

But that, of course, is a case of "relativity," although not of the Einstein variety. We have nowadays lighthouse apparatus which can throw a ray estimated at over a million candle-power, and it is in relation to such things as that that the little group of candles in the old Eddystone seems so feeble. No doubt they did good work in their time.

The next step, after the candles, was the oil lámp which came into use about the beginning of the nineteenth century. Sperm oil was the fuel employed, followed by colza or other vegetable oils, and finally, in 1871, by petroleum.

Gas burners, with coal gas, oil gas, and acetylene, are all brought into the service in different places, according to the local conditions, and electric light has also been used.

Acetylene has a great future before it, particularly for untended lights, and will probably be used more and more because of its brilliant light and the ease with which it can be generated or stored in steel bottles. Where the lighthouse is on the shore with a town near, ordinary town gas with an incandescent mantle has evident advantages.

The same may be said for electric light, but it is in fact little used except for small lights in ports and harbours where the convenience and cleanliness characteristic of electric light outweigh its disadvantages.

It is with no disrespect to that very competent body the Corporation of Trinity House that the author ventures to mention here a matter which came under his own notice. He was holiday-making in the Isle of Wight and visited the St. Catharine's Point lighthouse, which is one of the few important ones where electric light is installed. To satisfy an inquisitive small son, he got a glimpse of the machinery in the little generating station close by, and to his astonishment saw a dynamo the like of which he never expected to see outside a museum. It was one of the very oldest type. It evidently did its work all right, and probably its only fault would be a somewhat lower efficiency than a modern machine, but it was evidently installed a great many years ago.

At one time the arc light was thought to be the coming light for this purpose and it was put in in several places besides the St. Catharine's Point light, but there are certain drawbacks to it. One is that as it works the point of one of the carbon pencils (just where the light is formed) gradually burns away, causing a slight change in the position of the light and throwing the beam slightly out of its proper direction. Another drawback is the colour of the light. White light, as we all know, is made up of a mixture of light of different wave-lengths. There is, in fact, an infinite variety of wave-lengths in white light, and on passing through the tiny globules of water which constitute fog the rays are deflected from their naturally straight course more or less according to their wave-length. Those of the longest wave-length (which form red light and the other colours adjacent to red) are bent less than those of shorter wave-lengths, which give us the bluish tints. The result is that in a fog the blue and bluish rays are flung about in all directions so that only a very small proportion falls directly upon an observer's eye. This occurs to a much less extent with the red and reddish rays, consequently more of these get through to the observer. In other words, red light penetrates fog much better than blue, so that a light like that from the electric arc, which contains an unusually large proportion of the bluish rays, is particularly unsuitable for use in a lighthouse. But the greatest objection of all is—it costs too much. Other systems give at least as good a light at smaller cost.

Of the oil lamps employed there are three distinct types. In one the oil is sucked up from the container into the burner by the capillary action of the wick, just as happens in the ordinary domestic lamp. Indeed, these lamps are little more than common domestic lamps specially designed for the purpose and specially well made. The wicks are generally round, and there are often several placed concentrically. Two is common, and in the old days as many as ten wicks were needed for a large light.

Another type is called the " constant level " lamp. It is essentially much the same, except that the oil comes down a pipe from an elevated reservoir, so that a slight weight of oil is always forcing the supply to the burner. The reservoir is supplied from a second reservoir in such a manner that it is always filled up to the same level, and so the pressure is kept precisely the same.

In the third type the oil is forced into the burner by air-pressure produced by a pump.

The most important lamp of all, since it looks as if in time it might displace all the others, depends for its light upon the heating of a mantle, like the well-known incandescent gas light. This, however, is incandescent oil, for the fuel is fed into the lamp in its liquid form, to be changed by the lamp itself into gas and then burned in the mantle, thus combining the clear, compact, steady light of the incandescent mantle with the portability and safety of oil.

This form of lamp is as remarkable for its simplicity as for its efficiency. The oil is stored in an air-tight vessel in which a space is left for air. Into this space air is forced by a pump until a pressure of about 65 pounds per square inch is reached. Meanwhile, a small starting lamp supplied with methylated spirit is lit in order to heat up the " vapourizer " which is in the lower part of the lamp itself.

The vapourizer being sufficiently hot, which occurs after about six minutes, the oil is liberated by opening a valve and is forced by the air pressure up a tube. Entering the hot tubes which form the vapourizer, the oil is changed into vapour which emerges through a fine hole into a mixing chamber, where it mingles with the correct proportion of air, on the Bunsen principle, to give perfect combustion. Hence it rises through a screen of fine gauze, above which it burns with a very hot, clean flame.

This flame is used to heat a specially made mantle, and the result is a steady and intense light.

From the mixing chamber a small quantity of the vapour is drawn off to a Bunsen burner which maintains the requisite temperature in the vapourizer, so that the methylated spirit is only required at the commencement.

Those who are familiar with the working of a " Primus " stove will perceive that here we have the same principle applied in a slightly different way.

Not only does this form of lamp give a fine light, but it is astonishingly economical. In its largest size, the mantle of which is 110 mm. in diameter, the size which is used with the largest apparatus, the oil consumption is only 3 pints per hour. The intensity of the light is 3000 candle-power.

Three other sizes are also used, with mantles 85, 55, and 35 mm. in diameter respectively. The largest size is sufficient for the largest revolving lights.

Perhaps it would be well at this point to clear up what may seem at first sight rather puzzling. It has just been said that a lamp of 3000 candle-power is sufficient for a large lighthouse the light from which, it is stated elsewhere, may exceed a million candle-power. How can that be?

The explanation is this: Candle-power does not denote the total quantity of light, but the intensity at some particular point. We judge the candle-power of anything by the quantity of light which falls into our eyes. Taking the case of a single candle, the light of which spreads in all directions, we see only a very small fraction of its light at any one moment, and that small fraction is the standard of brilliancy—that is, one candle-power. Now suppose we place a mirror behind it; we probably double the quantity of light which falls into our eyes, with the result that we are getting light of 2 candle-power from a single candle. By adding a lens in front we can bring still more light into our eyes, thereby obtaining an intensity of several candle-power, yet still we are only using the light from one candle.

Thus, by taking the light from a 3000 candle-power lamp and condensing it with the optical apparatus into a beam we magnify the intensity up to a million or over. We do not add to the light; we only increase that amount of it which falls upon a given point.

We may thus sum the matter up: For large lights the oil-vapour lamp stands pre-eminent; for smaller lights, those oil lamps where the oil is supplied to the burner under pressure are probably the favourites; while for smaller ones still the ordinary wick lamp serves.

The latter, in spite of its feebler light and because of its simplicity, plays a useful part even in large lighthouses as a standby, for service in case the main lamp should through any accident go out of order. Under these conditions it is of the utmost importance to get the reserve lamp into operation very quickly, and for this reason it would be hard to beat the simple self-contained portable contrivance with no mechanical complications.

All the above applies to places where the lamp has constant supervision, but there are many places where lights are placed which have to be left untended for months at a time. Untended lightships are coming more and more into use, but besides them there are hundreds, if not thousands, of beacons and buoys which, while quite important in their way, have but very occasional human attention.

At one time the favourite burner for these unwatched or "permanent" lights was the Wigham burner, which was designed to obviate the necessity for trimming the wick. Those who have any experience of domestic oil lamps will realize how important a matter this is. No ordinary oil lamp will burn satisfactorily unless it be trimmed and the charred part removed from the end of the wick every day. Clearly, then, if a lamp is to burn without attention for weeks and possibly months, something must be done to avoid charred wicks. In this ingenious contrivance the burning of the oil takes place not at the end of the wick, but somewhere in between the ends, and the wick is kept slowly moving. Thus the flame gradually creeps along the wick, not remaining long enough at any one spot to cause charring. With such a lamp it is only necessary to see that enough oil is supplied; it "trims" itself.

Another type of lamp which has been installed in permanent lights of minor importance has a wick of carbon which requires no attention.

The two systems which between them hold the field to-day, however, are not oil lamps at all, and consequently the charred wick trouble does not arise. Both are based upon the use of gas, with or without the aid of a mantle.

The first of these is "compressed oil gas." The gas is forced by pumping into steel cylinders or into chambers provided for the purpose in the hull of an unattended lightship or the body of a buoy or in the base of a beacon. If steel bottles are used, the compression can be done ashore and the cylinders simply dropped into place and connected up when convenient.

Otherwise, the supply vessel which periodically visits the lights must be provided with pumping apparatus so that the gas can be passed through a hose pipe.

The gas itself has to be manufactured ashore in a specially constructed plant.

The gas is stored under high pressure, but is liberated through a pressure regulator, a kind of automatic valve which lets it slowly out, just fast enough to maintain the proper pressure (quite a low one) at the burner. The regulator is perfectly self-acting, so that as the pressure in the storage reservoir falls it lets the gas out a little faster and at the burner the pressure is always just right.

There are cases where the expanding force of the gas as it falls to the lower pressure is made to drive the occulting apparatus. More often, however, the gas after leaving the reservoir traverses a contrivance called a flasher, which alternately stops it and releases it, or, in other words, turns the light up and down, thereby giving the light its "character."

This oil gas works excellently with an incandescent mantle.

Acetylene is even more convenient than compressed oil gas. It can not only be carried about in cylinders and liberated for use in the manner just described, but it can actually be made on the spot. A self-acting and self-regulating gasworks can be installed inside a buoy and there left to look after itself for months at a time.

It is dangerous to compress acetylene as is done with other gases, but if the cylinder for holding it be filled with coke or other suitable porous material saturated with acetone, the acetylene when under a moderate pressure becomes dissolved in the acetone. When the pressure is released it comes out of solution. In this dissolved state it is quite safe. So cylinders of dissolved acetylene can be taken about freely and placed in any small light, just as can be done with cylinders of oil gas.

But, as already pointed out, it goes " one better " than the oil gas, since it can often be made on the spot and used straight away as it is made.

The material, as many cyclists and motorists know, is a substance called " carbide of calcium," which, so long as it is kept dry, is perfectly inert and harmless. Consequently it can be carried about freely in air-tight cans and drums.

To produce the gas it is only necessary to bring this substance into contact with water. There are two ways of doing this : some generators bring the carbide to the water ; others bring the water to the carbide. Each has its advantages ; but in the case of a generator which, like those we are considering, has to be left for long periods, simplicity and freedom from mechanical complications make the water-to-carbide method by far superior. The only working part, then, is the water itself. It runs in and meets the carbide. How much gas is formed depends upon the area over which carbide and water are in contact, and if it be generated too rapidly the gas forces some of the water back again, pushing it out of contact with carbide until a state of equilibrium is reached, when the apparatus settles down to make just that amount of gas that is required and no more.

What is left after the water and carbide have acted upon one another is simply lime, a perfectly clean and harmless substance which can be thrown away anywhere.

As with oil gas, so with acetylene, the character can be given to the light by the action of a flasher.

Of course, a light is only needed on the average for sixty hours out of every hundred, and a lamp which burns continuously therefore wastes 40 per cent of its oil. In these unattended lights there is no one to extinguish the lamp at daybreak or to light it again at night. A clockwork mechanism might be contrived that would turn a gas-lit lamp on and off at certain times, but there is a much better thing than that.

It is called the "Chance Light Valve." It consists of two glass bulbs supported one at either end of a balanced beam, and connected together by a glass tube. The bulbs are partially filled with a volatile liquid such as ether, and while one of them is left transparent, so as to reflect or transmit light, the other is blacked, so as to absorb it.

Now, light has a certain heating effect, and the result is that when there is any light about the blackened bulb becomes slightly warmer than the other, because it keeps the heat which it receives, while the other throws it off. At night both are at about the same temperature.

Since the ether only about half fills the bulbs the space above the liquid contains ether vapour, and at night there is about an equal quantity of the liquid in each bulb. As soon as light begins to fall upon the apparatus up goes the temperature of the black bulb and down goes that of the other, causing more vapour to be generated in the former and some of the existing vapour to be condensed in the latter. With any considerable amount of light the liquid will wholly pass into the bright bulb. Thus, by the extra weight of liquid at the one end of the beam, the balance is upset, one end of the beam is depressed, and this motion, actuating a simple series of rod and lever, turns off the gas supply, all but a small by-pass.

When evening comes, the temperatures of the two bulbs gradually reach equality again and the beam tips back, turning on the gas once more.

The apparatus is exceedingly simple and therefore very unlikely to get out of order. It is mounted under a strong glass shade (with a pointed top to prevent birds from roosting upon it) and, deriving its motive power from the daylight itself, it turns the gas up and down daily with the regularity of a most conscientious attendant.

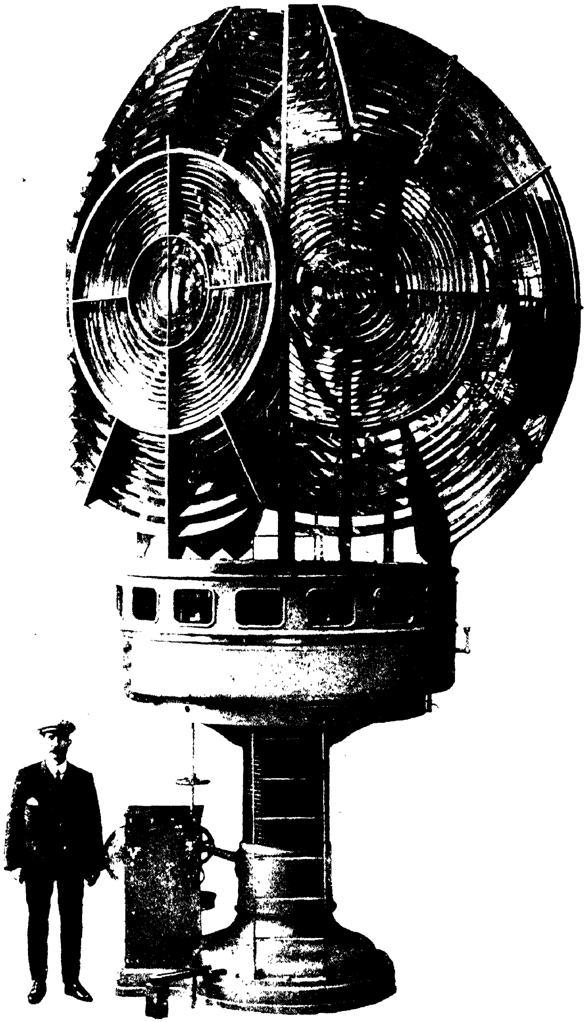
Akin to this beautiful instrument is the " flasher " already referred to, which turns the gas off and on automatically with such regularity and reliability that it can be trusted to maintain the " character " of a light for long intervals without human supervision.

Externally it is quite uninteresting. All one sees is a gun-metal vessel with one or two short pipes connected to it, but inside it are two very beautiful contrivances. It consists of two chambers, one above the other, the burner being usually placed on the centre of the uppermost. The gas first enters the lower chamber, which acts as a regulator of the pressure, ensuring that at whatever pressure the gas may come from the generator or reservoir it shall enter the upper chamber at one pressure only—the correct one.

Its action is similar to other pressure regulators, but may be described briefly. Across the chamber, near its upper surface, there is stretched a diaphragm of leather pressed downwards in the centre by a spring. The gas enters at one side, and filling the chamber lifts the diaphragm. This movement is caused, by a simple series of levers, to close the valve which controls the entry of the gas. The exit of the gas takes place through another orifice in the side, and it will be seen after a moment's reflection that when gas is flowing through this apparatus it will always issue from the outlet with a steady practically unvarying pressure.

For if the pressure at the outlet should increase, it follows that the pressure inside will increase too and raise the diaphragm, thereby closing the inlet. Or, to put it another way, the diaphragm so regulates the ingress of the gas that it maintains a steady flow at the outlet.

Now we are ready to transfer our interest to the upper chamber, where we find a similar leather diaphragm. The gas passes up from below through a



A HUGE LAMP

The marvellous arrangement of lenses and prisms which enables the lighthouse to send out its guiding flashes, with the mechanism for turning it. Made for "Chilang" Lighthouse, China.

tube and enters through a valve at one side, which valve can be very finely adjusted by means of a screw. Upon this screw much depends.

As in the lower chamber, the gas as it fills the vessel raises the diaphragm. This diaphragm, however, does not act directly upon the outlet valve, but moves for some distance before it does anything at all. It then causes a lever to tip over suddenly and open the outlet valve fully all at once. The gas then rushes out to the burner, is lit by the by-pass light, and the mariner sees a flash.

With the outlet of gas the pressure falls more or less quickly inside the apparatus, with the result that the diaphragm descends again and, after moving a certain distance, tips the lever back again, completely closing the outlet and extinguishing the light.

The duration of the flash depends upon how long it takes for the pressure in the upper chamber to fall and the diaphragm to move from the "turn-on" position to the "turn-off" position. That depends upon the size of the inlet as compared with the outlet; hence the importance of the screw adjustment already mentioned.

The duration of the period of darkness between flashes will depend upon the pressure of gas at the inlet, for the greater that be the faster will it come in and the quicker will the diaphragm be raised to the "turn-on" position. That, however, is also provided for by a screw adjustment. The spring which presses upon the lower diaphragm can be set to press more or less strongly as required. If the pressure of the spring be increased, the gas will lift the diaphragm more slowly and vice versa.

Thus, by the operation of these two adjusting screws the " flasher " can be set to give just the right number of flashes per minute and of the right duration. The flashes can be set for any duration between a fifth of a second and 4 seconds and the dark intervals from 2 to 20 seconds, or even longer.

CHAPTER IV

THE LANTERN

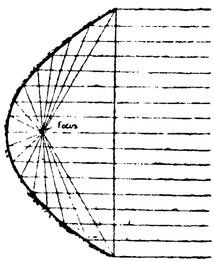
NO sooner had the old beacon fire given place to a lamp than it became evident that something else was needed.

Light naturally spreads from its source in all directions except for that small area where it is obstructed by the burner itself. Now, it is easy to see that in the case of a light intended to be seen out at sea, all those rays from the lamp which tend upwards are perfectly useless. They might help a man in an aeroplane, but they would miss the eyes of the seaman altogether. So, in the case of a naked lamp, we can write down 50 per cent of the light as useless right away. Of the remainder, probably half would fall upon the floor of the lamp chamber or the ground or water at the foot of the lighthouse, too near in to be of any service for navigation. That means another 25 per cent of the whole light. Thus, without calculating carefully, we can see that with a naked light not more than 25 per cent of the light produced would serve any useful purpose.

When we think, too, of those lighthouses (the great majority) which stand upon the coast with land behind them, we see that of that remnant of 25 per cent probably one-third would shine over the land.

From this fact arose the idea of gathering the light together and then throwing it in the required direction, and the first device employed was a mirror.

One is apt to think just at first that such a mirror should be spherical, but whereas a spherical mirror would catch some of the light from a lamp and throw it in one direction it would make a very fan-shaped beam instead of the compact concentrated beam



A PARABOLIC REFLECTOR.

which is required. The rays from it would be dispersed too much.

Fortunately there is another kind of curve called a parabola which answers much better. If a lamp be placed at the focus of a mirror ground to this particular curve, the rays of light which fall upon it are all reflected straight out, parallel to each other, so that they form a solid parallel beam. This will be quite easily understood from an inspection of the above diagram.

Unfortunately, however, this is only true theoretically, because the focus of the mirror is a point and only one spot in the flame can possibly occupy that point. All other parts of the flame are more or less out of focus, and the rays from them therefore diverge more or less from the parallel.

This "divergence" due to the size of the flame is a matter of importance which will be referred to again later on.

As early as 1763 lamps with parabolic reflectors were employed in the Mersey; while in 1784 they were installed by the French, who were pioneers in the art of lighthouse construction, in the fine lighthouse which still stands at Cordouan, near the mouth of the River Gironde.

The mirrors of those days were usually made of metal with a silvered reflecting surface. Such are still used for a special reason upon some lightships, but after a period of about thirty years they were superseded by an infinitely better arrangement, made of glass.

For this the world is indebted to an eminent group of French men of science, notably Augustin Fresnel, who lived from 1788 to 1827.

His invention was the use of glass prisms to direct the light instead of metal reflectors, the advantages being (1) that by that means he could catch the rays and direct them in a more complete and perfect manner than with a parabolic mirror; (2) that the glass required less cleaning than the tarnishable metal; and (3) that less of the light was absorbed in passing through the glass than was absorbed by the mirror.

Everyone is familiar with the action of a lens or bull's-eye upon light. Who has not played with a small lantern with a rough plano-convex lens at the front and knows from his own experience that the glass concentrates the light more or less into a solid beam? Good bicycle lamps, too, have lenses because of which they illuminate the road immediately in front of the front wheel in a manner which is impossible when the front is merely flat glass.

Railway signal lamps, too, are fitted with similar lenses so adjusted that they collect the rays and throw them in a beam upon that part of the line where they will best strike the eye of the engine-driver.

So it is evident that some of the light from the lighthouse lamp could be collected into a beam by a lens and thrown downward and seaward into the eyes of the mariner. But to serve its purpose the light from a lighthouse must be visible many miles away—much farther than is necessary in any of the illustrations just mentioned. A railway engine-driver requires to see his warning light a few hundred yards away; the mariner needs to be warned of danger or guided upon his way at distances of many miles. Therefore something better was needed for the lighthouse than the simple lens which serves for the railway signal.

The difficulty with the lens is that it suffers from a trouble called spherical aberration. This trouble can be reduced, but it cannot be entirely cured. Photographers are familiar with it. If you wish to get a picture with your camera quite clear and sharply defined all over, you "stop down" the lens, as it is termed. This means that you throw more or less of the outer part of the lens out of action by reducing the hole or aperture in front of it. If you watch upon the ground-glass screen of a camera while the "aperture" in front of the lens is gradually reduced, you can see the details round the edge becoming more and more clearly defined.

That shows us that the exact centre of the lens is free from the trouble, but that it increases as we proceed towards the edge.

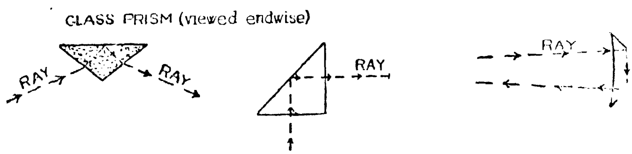
Of course, the camera deals with light coming in, whereas the lighthouse apparatus deals with light going out; but the principle is the same, and just as the outer parts of the camera lens disperse the light somewhat, causing the photograph to be blurred, so a single lens, if used in a lighthouse, would disperse the outward-going light and cause much of it to pass in useless directions.

The photographer knows that with a well-designed and well-made lens he can work with a much larger aperture than is possible with a cheap lens, the reason being that in the former the effects of spherical aberration have been reduced to a minimum. Even with the best lens, however, it is still present to some extent.

Now, Fresnel's idea was to place a big lens in front of the light in order to catch the rays which would otherwise fall upon the sky above or upon the ground at the foot of the lighthouse and to throw them seawards, but he knew that in a sufficiently large lens the spherical aberration would cause a lot of light to be lost. So he made a small lens and around it set a number of glass rings triangular in section so that they constituted circular or ring-shaped prisms. Each of these caught the light which fell upon it and diverted it in the desired direction. The shape necessary was carefully calculated for each ring, and each was carefully ground to the correct form so that the spherical aberration did not occur.

The centre lens was constructed as if it were a larger lens with the outer part cut away, so that in it too the aberration was not large.

Many readers will no doubt be familiar with the action of a three-sided piece of glass or prism, but for those who do not the following diagrams will be helpful.



DEFLECTION OF LIGHT THROUGH A PRISM.

Light passing into glass at an angle is diverted from its straight course ; and the same thing occurs (though the opposite way) when the ray leaves the glass. The amount of the "refraction," as it is called, depends upon the angle at which the ray pierces the surface of the glass. By carefully shaping the prism and correctly placing it in the path of the ray it is possible to guide a ray of light into almost any direction.

The method of guiding the rays by *reflection* is termed scientifically, "catoptric," and the other method where the rays are bent or *refracted* by glass prisms is called "dioptric." We shall see presently that prisms can be used to reflect as well as to refract, and when reflecting prisms are used as well as refracting ones, the term applied to the whole apparatus is "catadioptric."

Fresnel's first apparatus was fixed at Cordouan, where, thirty years earlier, the first large reflector had been placed.

All honour must be given to the French authorities who first took in hand seriously the question of lighthouse illumination, and to the scientific men whom they employed. Equally should we honour, however, the group of British scientific men who took up the work on this side of the Channel, and who have left an indelible mark upon the history of the lighthouse.

Of these one may mention Sir G. B. Airy, the Astronomer Royal from 1835 to 1881; the great Michael Faraday, who was the Consulting Optical Expert to Trinity House; and, perhaps most important of all, Sir James Chance and Messrs. Robert Alan and Thomas Stevenson. The last-named gentleman, it is interesting to note, made us all his debtors in another way by giving to the world his son Robert Louis. One seems to think that *Treasure Island* may owe something to the wanderings of the elder Stevenson, in his capacity of lighthouse engineer.

Let us, then, look at the lighthouse apparatus as, owing largely to the efforts of these eminent men, it exists to-day.

Upon the top of the tower is a circular room, known as the "lantern." The lower part of the encircling wall is composed of iron plates bolted together, in which are formed cunningly devised air ducts, to ensure an ample supply of fresh air to the apartment while protecting apparatus and attendants alike from draughts even in the most boisterous weather.

Above this is a glazed portion, the glass being held in a metal framework the bars of which are usually set spirally so that the panes are diamond-shaped. It is found that bars thus set on a slant interfere with the light less than vertical ones would do. Above this is a dome-shaped roof and ventilator.

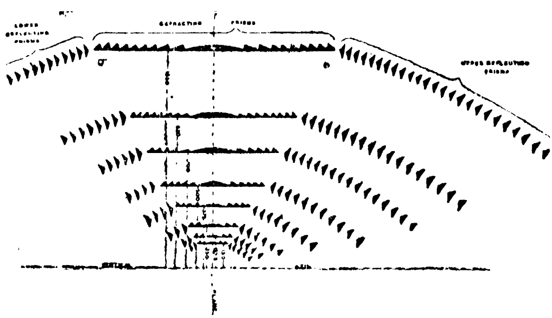
In the centre of this apartment there stands a round iron table or pedestal, sometimes supported upon a single central column of iron, but in the larger sizes upon a group of columns.

Upon the centre of the table there stands a stool upon which the lamp is carried. The lamp is so arranged that, while it can be easily got at by the attendant, or in the event of a breakdown can be quickly removed to make way for the "stand-by" or reserve lamp, it is always firmly held in its correct position. This, it may be remarked, is most important, because the movement of the lamp by a tiny fraction of an inch is enough to throw the beam of light out of its proper angle and so cause it to miss the watchful mariner whose eye it is intended to catch.

Upon the table and round the lamp-stand is a strong ring of cast iron with a kind of circular rail on its underside, so that it can be turned round easily upon a ring of rollers mounted upon the table, the rollers keeping it steady and perfectly concentric all the time.

Above this circular ring is a gun-metal framework roughly the shape of an old-fashioned beehive, but having, in fact, a number of flat faces.

This is known as the optical apparatus, or more briefly the "apparatus," for in this framework are carried the lenses and prisms which collect the precious light as if it were gold, letting not a single ray escape which can possibly be gathered in, and



HOW THE LENSES AND PRISMS ARE ARRANGED.

then flinging the whole in a solid beam, or a series of solid beams, out upon the water.

Each of the flat sides of the apparatus is called a "panel." In the centre is a single lens, flat on the inside and convex on the outside. Around this are several complete rings of glass such as were described earlier. Above and below these, again, are other prisms which form segments of circles all concentric with the lens. Higher still and lower still are other prisms of a kind only briefly mentioned as yet. Their purpose is to reflect light and not to bend it.

It seems strange at first sight to think of reflecting light by means of bars of the clearest glass, but the truth is that a glass bar, properly arranged and properly presented to the rays, reflects light better than a metal reflector.

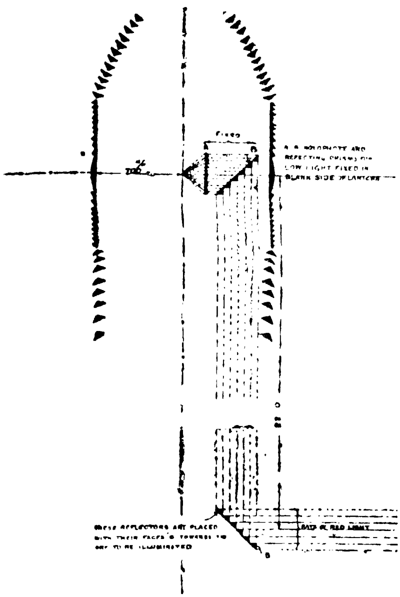
Taking a general survey, then, of a panel, we see the lens or bull's-eye in the middle, refracting lenses around, above and below it, and reflecting prisms above and below them.

The bull's-eye and the refracting prisms catch and bend seawards the light which passes the lamp in a direction somewhere near the horizontal; the upper reflecting prisms reflect that which would otherwise be lost in the roof or upon the sky; and the lower reflecting prisms that which would otherwise fall upon the floor of the lantern or too near the foot of the tower.

If the lighthouse is upon a headland where it only needs to show a light a little more than half of the whole way round, an additional frame of prisms is placed upon the table, inside the main apparatus, in order to catch those rays which but for it would fall upon the blind or landward side.

What these prisms do with the light they thus intercept depends upon circumstances. One very usual arrangement is to fling them straight back into the flame of the lamp, thereby adding to its brilliance. Another is to send them off in a new direction to serve some useful but subsidiary purpose.

An example of this is to be seen at St. Catharine's Point in the Isle of Wight, where the backward rays are caught and thrown down through a hole in the floor, then deflected by another set of prisms into a horizontal direction and through a small window in



LANTERN AT ST. CATHARINE'S POINT, ISLE OF WIGHT. SHOWING HOW RAYS, OTHERWISE WASTED, ARE DIVERTED TO A USEFUL PURPOSE.

the side of the tower. Here they serve as a warning to keep ships off some particular local danger.

We must now notice one particularly important feature of the "apparatus."

The basis, as we have seen, is a cast-iron ring which runs upon rollers forming, as it were, a turn-table.

Attached to this ring is another one, also of iron, which dips into and nearly fills a cast-iron ring-shaped trough. This trough is supported upon strong brackets attached to the columns of the pedestal.

Now, the trough contains mercury, the quantity of which is so adjusted that the iron ring floats and just lifts the apparatus off the rollers. The rollers remain, to ensure that the apparatus shall be steady and to keep it central, but the whole weight of the apparatus actually floats upon the mercury. So valuable is this mercury float in reducing friction that the heaviest apparatus can be pushed round by one finger. When it is mentioned that an apparatus may weigh as much as ten tons, this fact becomes quite startling. Ten tons moved by the pressure of one finger!

Now that is not simply an interesting mechanical contrivance. It is one of the keys to the marvellous efficiency of the modern apparatus. Let us see how that comes about.

First let us enquire why the apparatus is thus mounted so as to turn round. The light from the lamp, as we have seen, goes off in practically all directions. By means of lenses and prisms that which would go upwards to the sky and that which would go downwards too near the foot of the tower, and that which would fall upon the land, is all captured and thrown seawards. The lenses and prisms might be, and sometimes are in "fixed" lights, so arranged as to throw it out in all directions horizontally. In other words, the light may be spread out horizontally over a full circle of 360 degrees. Suppose, however, that the lenses and prisms are so made as to gather it up into four beams each covering an angle of 10 degrees, or 40 degrees altogether. Then each beam will be *nine times as bright* as the diffused light spread over the 360 degrees.

With such an arrangement, however, the light would only be visible at certain points upon the horizon, in between which there would be darkness. So the whole apparatus is made to revolve, and each beam illuminates every part of the horizon in turn.

On a slightly misty night the beams of light from a "revolving" light can be seen radiating from the lighthouse like the spokes of a wheel. On a clear night the beams are invisible except when viewed endwise, so that a mariner standing upon the deck of his ship and looking towards a "revolving" light sees each beam when, and only when, it is pointing directly at him. Hence the effect upon his mind is a flash of light every time a beam comes round.

Advantage is taken of this to give to each light that particular character which enables mariners to tell which is which. The same thing could be done by making the light still, and moving a shutter in front of it so as to cover it and uncover it at intervals, or if the source of light be gas by turning it up and down, or by switching it off and on if it be electric. This is actually done in some small lights, but in the big ones it is much better to adopt the revolving optical apparatus since it simultaneously gives the character and increases the brilliance of the light.

Now to return to the mercury trough. Suppose a light the character of which is four flashes per minute. It might have eight panels and be rotated once every two minutes. The available light will then be divided up into eight beams. Next, suppose that we find a means by which we can drive the apparatus twice as fast—once every minute instead of once every two minutes. We can then get our four flashes by means of four panels instead of eight. *And each beam will be twice as strong.* Thus the faster the apparatus can be rotated the greater the economy of light, or, to put it another way, the brighter can we make the flashes with the same expenditure of oil.

The motive power for driving the apparatus round is human. In those lighthouses which are on the land it might be possible to utilize some other source of power, but on isolated ones it would be difficult. A simple clockwork mechanism wound up by the attendant on duty every few hours is found to be the most convenient.

So the problem is to turn quickly the heavy mass of the apparatus, weighing anything up to ten tons, with a very limited supply of power. What a boon, then, is this mercury trough with its almost entire absence of friction.

The trough is so constructed that it can occasionally be lowered a few inches for cleaning. When that is done the rollers for the time being take the weight. A plug in the trough enables the mercury to be drawn off easily.

Reference was made just now to the dispersion of the light which is caused by the size of the lamp flame.

DASSEN ISLAND LIGHTHOUSE, CAPE OF GOOD HOPE

This lighthouse, 80 feet high, is built of cast-iron plates, bolted together.

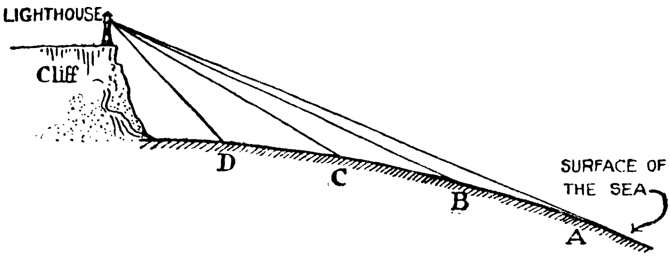
This is to some extent an advantage because a certain amount of dispersion is necessary. If the beam were too narrow it would pass an observer too quickly and he would see only a sharp flash almost like a flash of lightning. The objection to that is that a mariner would not have time to get its bearing. It is of great importance that a navigating officer when he picks up a light should be able to take its exact bearing by his compass. If the flash be too momentary he cannot do this with any accuracy, so it must not be too brief.

In the same way, if the beam were too shallow, it might show upon the horizon, but be invisible to a ship closer in.

It is generally arranged to throw the beam so that it shows from the horizon to a point about a mile from the lighthouse (the latter varying according to local conditions), and gives a flash of not less than one-third of a second duration.

Upon this matter a great amount of care is expended. At the works where the apparatus is made, each piece of glass is put into the frame separately and patiently adjusted with great accuracy. The framework is set up and levelled just as it will be later on in the lighthouse itself. Then a mark is set up some distance away at such a height that a line from the centre of the lamp to the mark will slope downwards at precisely the same angle as will a line from the centre when in the lighthouse to the horizon. It might be thought that the method of adjustment would be to set up a light inside the frame and to watch from the distant mark while a man adjusted the position of the glass. As a matter of fact, the opposite is the way adopted and found most satisfactory. A man places his eye at the spot where the lamp will be while another adjusts the piece of glass. When the observer sees the mark perfectly clearly through the glass he knows that it is right. Thus each piece is put in and adjusted separately.

But all are not set for the horizon. The conditions for each light are carefully thought out and the light from certain parts of the apparatus is sent to the



This Diagram shows how the Curvature of the Earth Limits the Extent of the Light.

horizon, while that from others goes to the nearer regions, the idea being to show the brightest light upon the horizon (that is to say, the greatest distance away), the intensity fading away as one approaches, thus as far as possible equalizing the effect throughout the whole region illuminated.

The divergence of the rays, as will be seen, is wasteful of light if too great ; but, on the other hand, it must not be too little. When the source of the light is small in relation to the size of the apparatus (as in the case of the electric arc), it may even be necessary to set some of the glass parts so as to increase it, but generally they are set with a view to reducing it to the required extent. This is mentioned just to show the extreme care with which the whole apparatus is made in order that not a ray may be unavoidably lost.

Nearly all large lights are revolving, and many of the smaller ones. Among the latter, however, are to be found a number of " fixed " lights, particularly for guiding ships into harbour. Some show light all round or nearly so, prisms and reflectors being arranged so as to save the light which would otherwise be lost upwards or downwards, or backwards.

In others the light is gathered into a comparatively narrow beam so that it shines brightly to a ship when on its proper course, but fades away as soon as it strays off it. Or there may be a coloured beam on each side of the white beam. This result is accomplished by a number of vertical prisms which concentrate all the light into a single beam the two outer thirds of which pass through coloured glass.

Here again we may see an example of the thought and care given to these matters. In passing through coloured glass some light is lost. The prisms are therefore so arranged as to give to the coloured sectors that amount of extra light which will make them shine as brightly as the white sector. Further, to emphasize the passage from the white to the coloured beams the edge of each coloured sector nearest to the white is given extra light. Thus the unwary skipper who strays from the path of safety finds himself immediately warned by an angry red glare on one hand or a fierce green on the other.

The early revolving lights all gave single flashes at regular intervals. This was only natural, for the designers instinctively made the panels all the same size and arranged them symmetrically. There is a description written early in the history of the revolving light in which the apparatus is described as an octagonal drum. Such a drum, rotating at a uniform speed, would give eight flashes for every revolution, all equally spaced. The only character possible under those conditions was the length of the flash and the length of the interval between flashes. True, variety could have been introduced by varying the speed of rotation, but for mechanical reasons that was out of the question.

In the year 1874, however, Dr. John Hopkinson, an eminent man of science and manager of the works of Messrs. Chance Brothers, near Birmingham, invented what is now called the "group flashing" system. He arranged the panels in an unsymmetrical manner so that, instead of a regular series of single flashes, there is produced a series of groups of flashes with a comparatively long interval between the groups. Thus there may be two flashes in quick succession followed by a longer interval, then two more flashes, and so on. Another arrangement is three quickly, then a longer interval before the next series of three. Other combinations are possible, but these two will illustrate the idea of them all.

At one time character was given to a light by means of colour, some of the flashes being, for example, red. There was, however, and always will be, the objection to that, that red glass weakens the beam. It cannot be otherwise since red glass owes its colour entirely to its power of stopping all light except red. It was hard, therefore, to make the red beam and the white beam of equal visibility at a distance, and in any case much light was lost.

Moreover, the power to penetrate fog varies, red being in this respect superior to white, so that if the red and white beams are balanced exactly for clear air, the red will be visible farther in a fog, and the light, seen from a distance, will not show its true character.

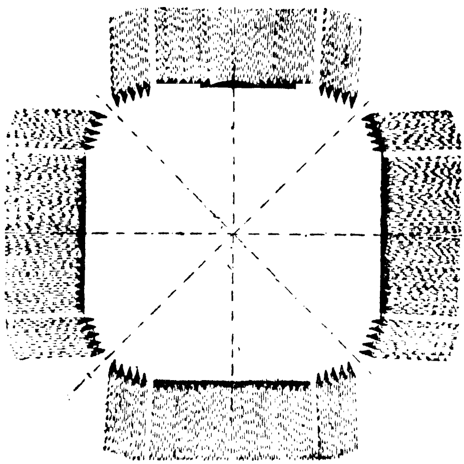
Another method of giving a distinctive character to a light which used to be employed but which is rarely used now except in small cases is to make it "fixed and flashing." In this some of the prisms are fixed, in order to throw a steady unvarying beam; while others revolve, so that the effect when viewed from afar is a steady glow of moderate power which brightens up periodically. This, again, suffers from the serious drawback that from very far off or in hazy weather the steady glow may be quite invisible and only the flashes seen, thereby producing not a "leading" light, but a "mis-leading" light.

Clearly, then, it was far better to keep to equal beams of white light and give the character by varying the spacing of them.

The difficulties in the way were immense. The obvious thing would have been simply to make some panels smaller than others, but that would have varied the intensity of the beams.

Dr. Hopkinson was, however, a great mathematician, and this is largely a question of mathematics. After much labour he succeeded in working out the

Single Flashing Apparatus
(Four Panels).

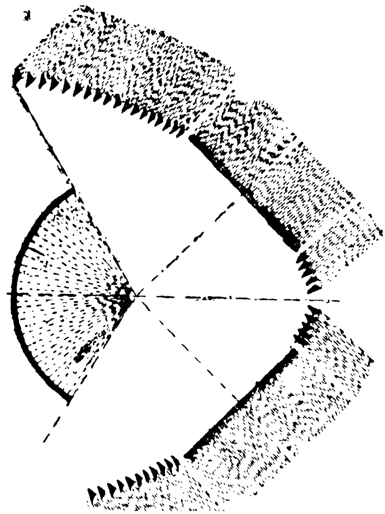


precise form and positions for the lenses and prisms which would give groups of flashes instead of single ones ; would give equally intense beams ; and would involve no loss of light.

The diagrams on pages 70–74 will show how he succeeded in solving this very difficult problem.

In the case of small lights it is sometimes more convenient to give character by opening and closing a shutter, the light remaining steady all the time. The usual form of shutter is a revolving cylinder with holes cut in it. This envelopes the lamp and is rotated upon a vertical axis by clockwork. The lamp becomes visible whenever a hole comes opposite to it. In other

Double Flashing Apparatus (Two Panels and Mirror).



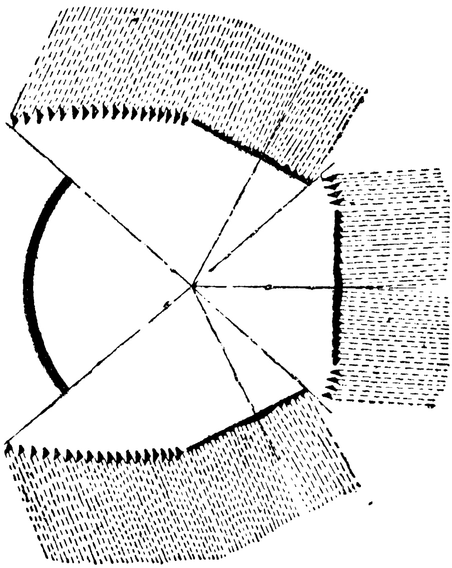
cases the shutter goes up and down. It is wasteful of light because when the shutter is cutting off the light the lamp is still burning, and it adds nothing to the brilliancy of the beam as the revolving apparatus does.

In other cases of the same sort the source of light being gas, the flame is turned up and down by clock-work. This clearly is less wasteful of light.

Lights which are made to give flashes by means of shutters or by turning the gas off and on are called "occulting" lights.

The "clocks" which operate lights are in the

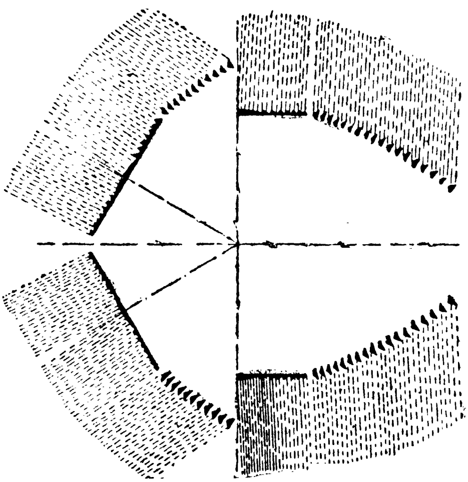
Triple Flashing Apparatus
(Three Panels and Mirror).



larger cases driven by a falling weight, and in the smaller by springs. They are of no particular interest in themselves, being conventional clockwork mechanism robustly made. A device such as an electric bell is arranged to give warning when the time is approaching for winding them up.

Before leaving the subject of the lantern and the arrangements connected with it there are a few smaller details worthy of mention. The ventilation is carefully provided for in order to prevent the condensation of moisture upon the glass. A gallery runs round the outside to facilitate the cleaning of the windows on the outside.

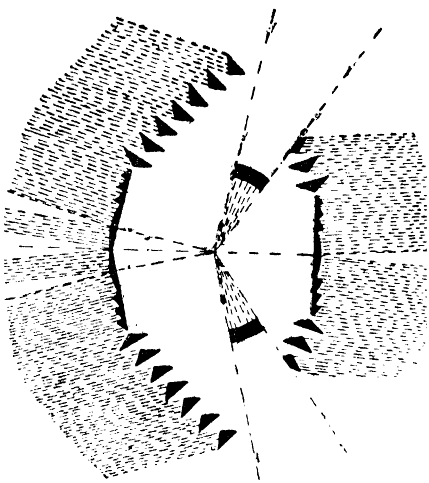
Quadruple Flashing Apparatus
(Four Panels).



An interesting feature of many lighthouses, too, is the provision for saving the lives of birds. Attracted by the light, hundreds of birds fling themselves against the glass, becoming thereby stunned. If left to fall helpless to the ground they are often killed outright, so a large wire screen is spread out horizontally just below the light. Upon this the insensible birds fall without doing themselves further harm, and there they lie until the effect of the blow has passed off, when they are able to fly away.

One very simple but exceedingly important part of the equipment of the lantern remains to be mentioned; that is, the blind. If the sun were allowed

Apparatus showing a Double Flash followed by a Single Flash.



to shine upon the lenses and prisms they would act as a huge "burning glass," and the unfortunate lamp at the focus would receive a concentrated beam of sunlight of such intensity that it would quickly be melted.

The following is a list of the various orders of apparatus, with notes, giving an idea of the purpose for which each order is suitable :—

Order.	Focal Distance (that is, the distance from the centre of the Lamp to the Lens).	Purpose
Hyper-radial.	1330 mm.	Where great range is required and where fogs are prevalent.
Meso-radial.	1125 mm.	Not often used.
First.	920 mm.	First-class lights with average conditions as to fog.
Second.	700 mm.	For lights of less importance or places less liable to fog.
Third.	500 mm.	
Fourth.	250 mm.	Chiefly used for ports and harbours.
Fifth.	187 mm.	
Sixth.	150 mm.	

The question may occur to the minds of some readers as to why the " apparatus " need vary so much in size. The reason is that the " apparatus " must bear a relation to the size of the flame or whatever the source of the light may be.

Common sense tells us that the power of the " light " must depend, to commence with, upon the power of the flame, mantle, or whatever the rays come from in the first instance. That, in turn, is to some extent a question of size. Roughly speaking, to get more light one has either to increase the size of the flame or mantle or to group several together, which is much the same thing.

Then, in order to deal with the rays from a large flame or mantle a large panel is required. Hence the size of the apparatus has to vary with the source of the light.

Attempts have been made to produce " lights " of sufficient brightness with apparatus of less diameter than those given above, the purpose being to reduce the diameter of the tower. The " Fastnet " is an example of this. It is of the kind called bi-form. The apparatus is a two-storey arrangement, there being two sets of panels exactly alike ; one set exactly above the other. Two lamps are used, one at the focus of each set of panels, and the lenses and prisms are so set that the beams from the upper merge together with those of the lower one.

There is also an example in France of a twin apparatus, where two apparatus are set side by side upon a kind of turn-table. The advantage of this is not very apparent, and although many years have elapsed since it was made, it still remains unique.

Another question that a reader may wish to ask is the candle-power of these great lamps. That will best be answered by reference to the examples given in the following pages.

CHAPTER V

THE BUILDING OF MODERN LIGHTHOUSES

WE have already spoken of the two great examples from which the modern rock lighthouse originated, namely the Eddystone of Smeaton and the Bell Rock of Robert Stevenson. We have also noticed a more modern instance in the new Eddystone of Sir James Douglass, and before we go further it will be interesting to note the influence of the Douglass family upon this matter.

Just as the Scotch lighthouses are largely associated with the Stevenson family, so the English ones owe much to the Douglasses. First there was Mr. Nicholas Douglass, who entered the service of Trinity House in 1839, and who supervised several works of great importance. Then we have his more famous son, Sir James Nicholas Douglass, who was responsible for the present Eddystone and numerous other famous erections, his brother James and his son William. All made their mark in the history of the lighthouse.

It is no slight upon the memory of the first Mr. Douglass to say that he was fortunate in entering the service just when he did. His appointment almost coincided in time with the taking over of the private lights by Trinity House. Many of these old lights seem to have been in a deplorable condition. As has been explained already, they were run as money-making ventures, and in many cases, at all events, the aim of the owners was to get as much out of them as possible and to spend as little upon them as need be.

Necessarily, the view of Trinity House was quite different. The very reason for their existence was to benefit shipping, and the fine tradition of usefulness which they had built up during centuries of activity was enough to prompt them at the earliest possible moment to rebuild many of the old towers and to instal better and more powerful lights, as well as to add new lights to those already existing.

Thus a great programme of lighthouse construction was commenced, and the ability of Mr. Douglass and his sons found its opportunity.

At that time, Trinity House did not possess a chief engineer of their own, but made use of the services of Mr. Walker, an eminent consulting engineer of the time, who made the designs which were afterwards carried out by the Trinity House staff. On the death of Mr. Walker in 1862, Mr. James Douglass was appointed Chief Engineer to devote his whole time to the work. On the completion of the new Eddystone tower this Mr. Douglass became Sir James.

One of the most interesting of the works carried out during this period was the erection of a lighthouse upon the Bishop Rock off the Scilly Islands.

The position of these islands, as will be seen by a glance at the map, makes them if unlighted a source of reat danger to ships. Many fine vessels have been wrecked upon them, and thousands of valuable lives have been lost. Previous to about 1847, however, there was only one light upon this dangerous group, that at St. Agnes. Here there was a stone tower erected as far back as 1680. Originally the light was a coal fire, but in 1790 a revolving light was installed, specially interesting as the first revolving light in Great Britain.

The Bishop Rock is so called because in shape it resembles a bishop's mitre. It is covered at high water, and there was only just room enough upon it for the base of the tower.

Because of the difficulties inevitable in any work upon such a tiny rock, particularly when exposed, as it is, to the roughest of weather, it was originally decided to place a framed structure of iron upon it rather than a stone tower. Mr. Walker designed this structure; three years of work was expended upon it, and it was actually ready in 1850 to receive the lantern when an exceptionally heavy storm swept it away entirely.

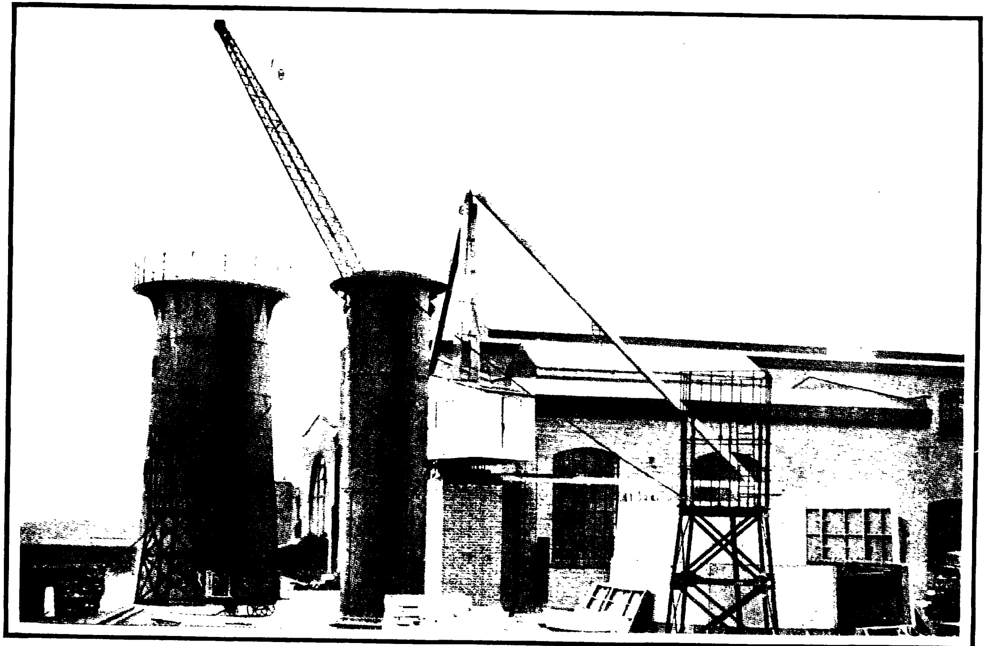
Needless to say, this catastrophe caused great disappointment to all concerned, particularly to the eminent engineer who had been responsible for the design, but careful consideration showed that no blame rested upon him, that the forces to be met and overcome at this exposed outpost of Great Britain were such as defied all estimation, and that the only thing to be relied upon was actual experience.

So a much stronger and heavier structure, this time of granite, was proceeded with.

Even this, however, was not permanently satisfactory, so that in the year 1882 it had to be strengthened. The truth seems to be that even after the destruction of Mr. Walker's structure in 1850 no one realized the tremendous force of the waves at this exposed spot. After the completion of the first tower it was found that huge solid blocks of granite were at times broken as by the blow of an enormous hammer, and a bell weighing six hundredweight was torn from its fixings even at a height of 100 feet above the surface of the water. Extra iron ties were introduced and the structure was vastly strengthened, but even then was not satisfactory, so that, at last, it was decided to surround the original structure with another layer of granite, largely increasing the base, strengthening the shaft of the tower, and adding hundreds of tons to its weight. At the same time a cylindrical base was formed, according to the plan which Sir James adopted in the present Eddystone. At last the force of the ocean has been conquered, and the tower seems perfectly safe. It now stands firm and steady under the severest shocks which the waters are able to administer, holding its light 146 feet above high water. From its base upon the rock for about 70 feet it is solid masonry.

Another notable erection of the same period is the tower on the Smalls Rock, 18½ miles off Milford Haven.

The old structure at this point has already been



By courtesy of

BUILDING LIGHTHOUSES

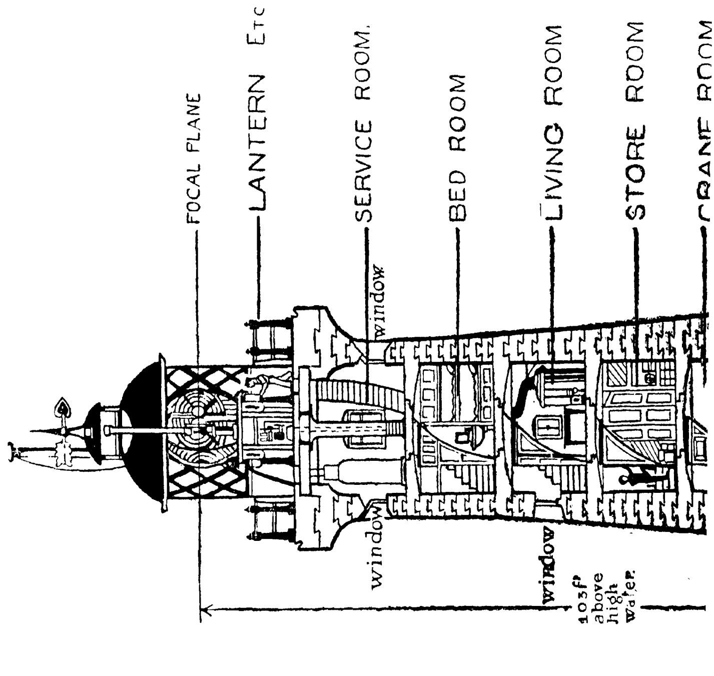
Steel towers may be built in this

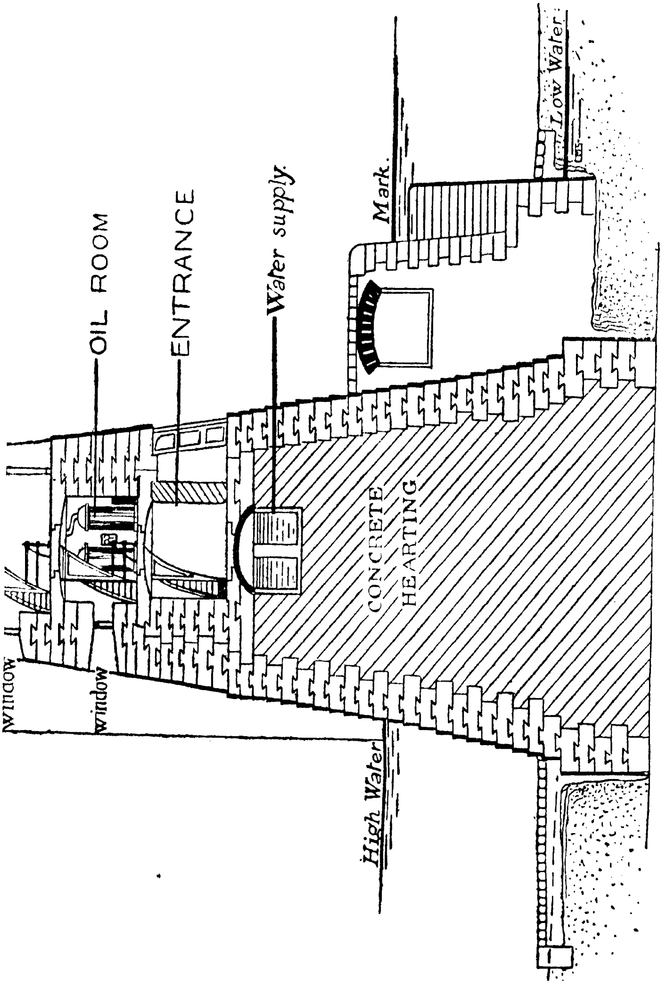
referred to. It was erected in 1776 and consisted of a cabin of two stories supported upon eight legs. The rooms were so low that a tall keeper could not stand upright. The legs were, it is true, of sound British oak, but for all that the whole affair was so unsteady that a bucket of water if left upon the floor would spill some of its contents because of the movement, while inexperienced keepers suffered from sea-sickness.

A rather ghastly tale is recorded of this old lighthouse, On one occasion one of the two keepers became ill and died before aid could be summoned. It is hard to picture what must have been the feelings of his comrade who had to keep the light burning day by day with the dead body of his friend close by. It is now the custom to have never less than three men on an isolated lighthouse.

Speaking of the rocking of a lighthouse when struck by the waves, it is interesting to note that there is usually a plum-bob hanging inside the tower from the centre of the ceiling of one compartment, the point of the " bob " being just above a mark upon the floor below. This makes it a very easy matter to see that no permanent change takes place in the position of the tower, for should it incline ever so slightly to one side the point of the " bob " would move away from its mark.

The procedure in building these towers always follows along the same general lines. First the rock has to be prepared to receive the lowest layer of stones. Exactly what is done depends upon the nature of the rock, but generally it is hewn or chipped away into


FOCAL PLANE
LANTERN ETC
SERVICE ROOM.
BED ROOM
LIVING ROOM
STORE ROOM
CRANE ROOM
window
window
window
window
103 ft above high water



SECTION OF LIGHTHOUSE.
Showing the interlocking of the blocks of stone.

steps upon which the granite blocks may be laid. It is generally considered unsafe to use explosives in this work, lest in blasting away the superfluous rock the main rock itself should be damaged. Fortunately, exposed reefs are of very hard rock, since, if they were not so, the sea itself would have cleared them away ages ago. Pneumatic drills such as are used by miners for breaking up quartz and other hard rocks, operated by compressed air from an attendant steamer, are sometimes employed.

It is usual to carry the foundations down a little lower than the surface of the rock, and the cavity so formed fills up in many cases at every tide. This sort of thing makes the earlier stages very tedious, since it means that work can only be done when low tide and fine weather coincide, and then many of the precious moments have to be spent in pumping out the water before work can be commenced.

To deal with this difficulty some such measure is adopted as that which was employed at the Eddystone, a wall being built round the site of the tower. This fills, of course, at times, but it results in the working periods being considerably longer, as it keeps the rising tide away. To save time in pumping, the enclosure thus formed is sometimes divided up into sections so that all the pumping power can be concentrated upon one section and that cleared quickly.

A wall of this description constitutes what engineers call a "coffer dam," that is to say, it is a dam in the form of a coffer or box. Sometimes it is built of bricks set in "quick-setting" cement. Another method is to use bags of cement, which are just laid one on the top of another like large bricks. This mode of construction is very quick, and therefore suitable for cases where the interval in the early stages is very short. The cement in the sacks sets into very hard lumps, and enough exudes through the sacking to bind them all together very securely.

It will be seen that for lighthouses in rough seas it is essential that the site should be uncovered for a short time at low water, but there are cases on Lake Superior where, the water being less rough and the site conveniently smooth, it has been possible to lower down upon the ground an iron casing from the inside of which the water could afterwards be pumped, thus permitting a lighthouse to be founded upon ground under water.

Naturally, work upon the lower parts of a lighthouse is usually abandoned in the winter because of the short days and the prevalence of rough weather. During the summer the men engaged have to be continually near at hand, so as to take advantage of every available moment. There have been cases where a part of the reef afforded a site upon which accommodation could be erected for the men, as was done for a time at the Bell Rock. In others a neighbouring islet has given them a temporary home. In most instances they live upon a suitable vessel anchored in the vicinity. This has the advantage that when a spell of unsuitable weather sets in the ship can steam away and give the workers a change ashore.

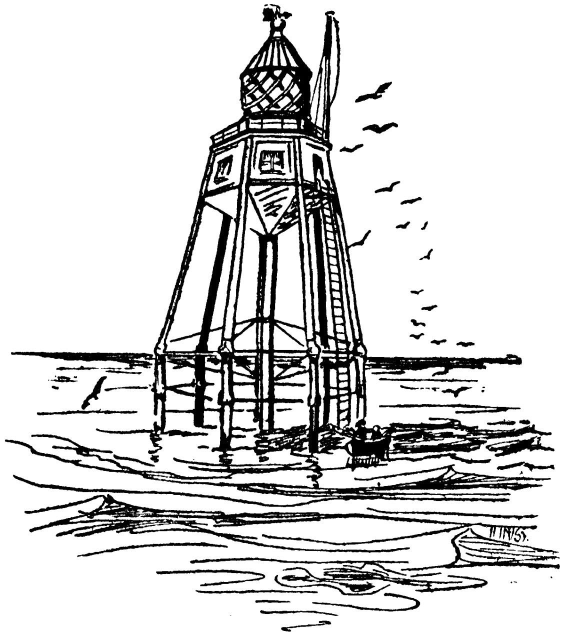
The stones are always carefully prepared in a workyard at some convenient spot on the land. They are correctly shaped and fitted together, and each is marked to show the position for which it is intended, so that all that is necessary upon the rock is to drop it into its place.

A somewhat unique arrangement was made for the construction of the present tower at Beachy Head. The old light was upon the top of a cliff, but it was found that at that altitude it was often obscured by fogs which did not exist lower down. The new one, therefore, is at the foot of the cliff, about 200 yards seawards. It is a fine tower of granite about 100 feet high and is founded upon the chalk foreshore. To commence with, timber piles were driven in and a wooden staging formed well above high-water mark. Then a steel cable was stretched from the cliff above to this stage, and along it both men and material were hauled between the workyard upon the cliff and the scene of action below.

Some of the smaller towers have been constructed of concrete made by mixing sand and shingle with Portland cement. This is only possible, however, in sheltered positions, as a heavy sea might destroy the whole thing before the concrete has had time to set.

Upon sand banks in sheltered positions screw-pile lighthouses are sometimes placed, such as that on the Maplin Sands, in the Thames estuary. They are light, "spidery" structures, not only strong because of the material of which they are made, but durable because of the comparatively slight resistance which they offer to the waves. The narrow round surface of the pile throws the water aside and suffers little shock itself.

A screw pile is an iron tube with a screw thread of one or two turns formed upon its lower end. The



A PILE LIGHTHOUSE.

This type of lighthouse is often used on shifting sands, etc.; the piles are screwed into the sand.

screw is inserted in the sand, and the pile is then turned round and round so that it bores its way in just as a carpenter's screw does into a piece of wood. The sand packs very tightly round it, and this, together with the screw end, makes it very firm and reliable. Piles of this kind are largely used in the construction of seaside piers. When a number of them have been put in they are braced together with steel rods placed diagonally between them. For lighthouse purposes a little group are placed around a central point with their upper ends inclined together, and upon the top a platform is fixed with the lantern upon it. The whole group of piles, with the platform and the diagonal bracings, constitute a combination of lightness and strength which it is hard to equal.

Towers ashore are sometimes formed of cast-iron plates bolted together at their edges. The plates are so formed at the foundry that they constitute segments of a cylinder, their edges are planed straight, and all that has to be done on the site is to place them in position, one at a time, and connect them with bolts passing through holes made for the purpose.

As we have seen already, it is the practice to make a rock lighthouse solid for some considerable way up. The entrance is generally at the top of this solid part and is reached by a ladder formed of gun-metal rungs cemented into the masonry. Gun metal is used for this because it is less affected by the water than iron.

The rooms inside are circular and are generally all the same size, so that the walls diminish in thickness with the height. The room immediately below the lantern is called the "service" room, since it is there that the business of tending the light is largely carried on. Below it come a bedroom, living room, rooms for general storage and for oil.

Access to a room is generally gained from the one below by means of a light iron staircase or ladder.

The actual building of rock lighthouses is full of examples of danger bravely met. In some places an occasional wave of huge size will come along even on an apparently calm day. What shall we say of a party of men taken by surprise by such a wave who just hung on while it passed over them and then went on with their work? Or can anyone relate a finer example of fortitude than that of the party who, through a sudden roughness of the sea, could not be taken off from the Bishop Rock, but had to spend hours partly immersed in water clinging for dear life to holdfasts fixed in the rock until such time as the elements permitted their rescue?

A curious thing happened to Mr. William Douglass when working upon the Eddystone, which shows that the sea can be kind as well as cruel. He was engaged upon the task of taking down the upper part of Smeaton's building when something caused him to slip, and he seemed doomed to be struck to death upon the rocks below. Just at that moment, however, an unexpected wave struck the base of the tower and a great mass of water came up to meet him, so to speak. This broke his fall and carried him away from the rocks and out to sea, so that, being a good swimmer, he easily gained a point of safety quite unharmed.

CHAPTER VI

THE EDDYSTONE LIGHTHOUSE

IN the history of the isolated rock lighthouse the Eddystone plays a commanding part. First, utter and tragic failure attended the attempt to light this exposed reef; then success followed by failure; then success, followed again—though after a longer interval—by failure, led up to the substantial structure of to-day. Whether or not the present tower will outlast its immediate predecessor time alone will show. Since its builders had the accumulated experience of three previous towers to assist them besides the improved methods and materials which had since become available, it is probable that the present one will stand for a great many years. It is conceivable that before this tower shows any signs of weakness some new method of warning, such as is suggested by the "wireless lighthouse," may have rendered it useless.

A glance at the map of England will show that the Eddystone Rocks occupy a position peculiarly dangerous to shipping. There is a wide bay, near the centre of which lies the town of Plymouth, with its large and lovely harbour. At one horn of the bay is Start Point and at the other the Lizard, and the

Eddystone Rocks lie on an almost straight line between them.

It follows, therefore, that a ship rounding either of these points and making for Plymouth might easily, if unguided, run on the Eddystone reef; while ships going to or from London and the many other large ports to which the English Channel is the entrance, in passing between the Lizard and the Start would be even more likely to run upon these treacherous rocks.

In the old days this danger was so great that ships would keep well to the south in order to avoid the Eddystone, and in so doing some ran upon the equally dangerous rocks which guard the Channel Islands.

In other words, this little group of rocks is so placed that it is probably more dangerous to shipping than any other in the world. If one were to search the map for a spot on which to place a danger to the shipping of all nations it would be hard to find a better one than the Eddystone Rocks.

An interesting story is told which shows that a King of France at all events realized this fact. While the second tower was being built we were at war with France, and a privateer swooped down upon the rock one day and made the workmen prisoners. When the French King—Louis the Fourteenth—heard of this, he at once had them liberated and sent back, on the ground that they were engaged upon a work which was needed not by the English merely, but by all mankind.

In the year 1696, then, a certain "mercer and country gentleman" named Henry Winstanley obtained the right to place a lighthouse upon the Eddystone Rocks and, of course, to collect appropriate fees from passing ships.

He appears to have been a most extraordinary man. It is related of him that he played strange tricks upon the visitors to his house. A slipper, apparently left carelessly upon the floor, when accidentally kicked caused a ghost to appear; an innocent-looking armchair would embrace and hold a person who chanced to sit upon it; while a seat in his garden would mysteriously transport its occupier into the middle of a lake. How he accomplished these remarkable feats we are not told, nor do they seem to have much bearing upon the building of a lighthouse, unless it be on the principle that a man who is ingenious in one way will probably be equally so in another.

Anyway, he set to work to construct his lighthouse, an undertaking which occupied him for four years.

It should be mentioned that the rocks are almost entirely covered at high tide and there is not a great deal of room at low tide, so that work thereon is confined to very brief intervals at low tide. Moreover, owing to its exposed position, even these intervals are often of no use, since it is impossible to land upon the rocks except in fine weather. The very name "Eddystone" testifies to the turbulence of the waters around.

The consequence of all this was that in the first season little was done beyond making twelve holes in the rock to receive the foundations.

During the second season, however, the tower was carried up to a height of 12 feet. It was constructed of wood bound together with iron bolts and straps. The base was 14 feet in diameter.

During the third year the height rose to 80 feet, and in the fourth to 120 feet.

In appearance this tower seems to have resembled a Chinese pagoda more than anything else. To our eyes, accustomed as we are to the simple graceful tower of to-day, the pictures of Winstanley's tower seem fantastic in the extreme. The lower 20 feet is said to have been of solid timber. It was octagonal in plan, with many windows and embellishments. About two-thirds of the way up there was an open gallery. It was as if the tower stopped at that height, terminating in a flat platform around which vertical timbers arose carrying the upper part of the structure.

It was finished in 1700 and survived for three years. In the year 1703 there was an exceptionally heavy storm, and when it was over the people of Plymouth were shocked to see that the rock was bare, the tower having entirely disappeared. It so happened that Winstanley had himself gone to the tower shortly before this to superintend certain necessary repairs, so that when the catastrophe happened he was there and perished with his structure.

As if, however, to remind people of the need for a lighthouse at this spot, a fine ship, the *Winchelsea*, returning from Virginia, was wrecked there very soon after, and in 1706 the Brethren of Trinity House got an Act of Parliament empowering them to erect a light themselves or to lease the right to someone else who was willing to undertake the work. They granted the lease to a certain Captain Lovet.

The first thing this gentleman had to do was to find a man capable of designing a new tower and supervising its construction. To-day this would be an easy matter, since we now have a large number of men who have made engineering their profession and who have devoted their lives to the study of engineering problems. There were no professional engineers in the year 1706, however, and so recourse had to be made to a man whom we should nowadays call an amateur.

John Rudyerd was a silk mercer who had a shop on Ludgate Hill. A Cornishman by birth and of very humble origin, he had made his way in the world by hard work and sterling character. It is said of him that if he undertook to do a thing you might be sure that he would do it. If he could not do it he said so to commence with. Thus, when he said that he would undertake to build a new Eddystone Lighthouse, he was believed, although till then his engineering had been of a simple order, largely for his own amusement. Considering the conditions in which he had to work, he was remarkably successful.

Timber was again chosen as the best material. It was thought that stone would never stand the buffeting of the waves. Probably this inclination towards timber was due to the association of certain shipwrights whose services Rudyerd had enlisted. All ships at that time were of timber, and it is not surprising, therefore, that the shipping fraternity should put their faith in that which they already knew could be relied upon.

Rudyerd discarded all ornamentation, all corners, all such fancy ideas as open galleries and made his tower just a simple cone. He made his base, too, larger than Winstanley had done, increasing it to 23 ft. 4 in.

The lower part was formed of strong sound timbers laid crossways and fixed together by the best methods known to the shipbuilders. To give weight, large stones were placed in the spaces between the timbers, but they were solely for the sake of weight and the timber alone was relied upon for strength. The base was fastened down to the rock by iron rods let into holes and fixed by molten pewter being run in around them.

The whole of the outside of the tower was covered by a skin formed of vertical timbers like the "skin" of a ship of that time.

For nearly fifty years this tower stood up against the wildest storms, and it might have stood much longer but for its destruction by another foe—fire.

The source of light was candles, and the ventilation of the lantern appears to have been somewhat deficient, with the result that one night in 1755 the keepers found that the candles had set the roof ablaze. In spite of all they could do, the fire spread downwards until they were driven by the falling of red-hot bolts and molten lead to abandon it altogether and take refuge upon the rock. Fortunately, the state of the sea permitted them to do this and they were rescued, except one who met his death in a most curious way. It appears that this man was standing near the foot of the tower looking upwards with his mouth open, when some molten lead fell and he actually swallowed it. The mention of so ghastly an incident as this can only be justified on account of its exceeding strangeness.

So that was the end of Rudyerd's tower. It had a far more glorious career than its predecessor; it was not unworthy of the excellent stone tower which followed and which may be regarded as the father of all modern rock lighthouses.

By 1755 Captain Lovet had passed away and his lease had come into the hands of others whom we need not name, but whom we can refer to for convenience as "the proprietors." These gentlemen were faced with the problem of getting someone to rebuild the tower, and still there were no professional engineers available. So they applied to the President of the Royal Society for advice.

Now, the Royal Society is a body which was founded by Charles the First for the advancement of science. It holds meetings periodically to listen to and discuss papers read by various members. Many of the greatest discoveries have been given to the world in the first instance by a paper read before the Royal Society.

Among the members at that time was a man called John Smeaton, by trade a maker of scientific instruments, who had impressed his fellow-members by several interesting papers which he had read. It seems a far cry from delicate scientific instruments to a massive lighthouse tower, but Smeaton's general ability appears to have impressed the President to such an extent that he recommended him as the man to rebuild the Eddystone. Events proved it to be a very happy choice. Smeaton did for the lighthouse tower what Watt did for the steam engine—he brought it almost to perfection at a single step and left little for his successors to do except to make minor improvements in detail.

Smeaton was a Yorkshireman, having been born near Leeds in the year 1724. He was more fortunate than Rudyerd in that his father was comfortably off and was able to give him a good start in life. It was first intended that he should follow his father's profession—the Law—and he actually came to London to commence his studies. His heart was not in it, however ; his love was for things mechanical, and he kept writing urgent letters home begging to be allowed to follow his natural bent.

The father was evidently a wise man, and as soon as he was convinced that the inclination towards mechanics was not a passing phase, but a permanent element in the boy's character, he gave way. The great difficulty in the way was that there was no engineering profession at that time. Engineering—what there was of it—was a trade, and the only way to get into it was as a simple workman. So young Smeaton "got a job" in a very humble capacity in a workshop where scientific instruments were made. He quickly got on and was soon able to dispense with the allowance which his father made him. Later on, he was able to acquire a small workshop of his own and become an employer. It was during this period that he impressed the Royal Society by his descriptions of the improvements which he had effected in the instruments which he made.

He was only thirty-two when, in the year 1756, he started upon the task which has made his name famous.

The first question to be decided was the material. Up till then it had been held that timber was essential and that stone could not possibly withstand the force of the waves. Rudyerd's tower, having stood for nearly fifty years, proved that timber at all events could form a tower of sufficient strength, but it also showed the danger which a timber structure ran from fire.

Reference has been made already to the courage necessary when dealing with large engineering problems, and here we have a striking example. A young fellow of thirty-two is faced with the necessity of deciding between wood and stone. General opinion favours wood and condemns stone; a wooden tower has already stood for fifty years; stone has never been tried. Suppose he used stone and the tower fell, as Winstanley's did. His would be the entire blame. Plenty of people would be ready to say, "I told you so." If he made a mistake in using stone, thousands of pounds would be lost besides human lives.

Most men, in these conditions, would have said, "Let it be of wood; we know that will stand and we must take precautions against fire." *That would* have been the safe course. Smeaton took the other. He believed in stone, he had the courage of his convictions, and in consequence his name will live in history as one of the great engineers of all time.

As regards shape, he decided that Rudyerd was right in making it conical; but taking an oak tree as his model he spread out the base somewhat, making a graceful easy curve from the foundation up to the truly conical portion of the tower. His reason for this was as follows:

If you wish to avoid being knocked over by an approaching body there are two alternatives open to you. One is to brace yourself up and endeavour to stop it; the other is to deflect it to one side and let it pass. The second requires much less strength than the first.

Let us now picture to ourselves a wave—a huge wall of water—advancing towards the comparatively slender tower of the lighthouse. Because of its rounded surface, much of the water is thrown aside and passes on, the tower sustaining merely a "glancing" blow. That water, however, which strikes the pillar near its vertical centre line is actually stopped; it flings its whole weight straight at the tower. This effect is naturally most pronounced near the foot where the wall of water is thickest and heaviest, and the idea of the spreading base was that the upward curve would tend to deflect this water upwards so that some of its energy might be expended harmlessly in an upward direction. As we shall see presently, Sir James Douglass found this to be a mistake. It is one of the few points where Smeaton's design has been improved upon.

Except for a spiral staircase up the centre, Smeaton made the first 35 feet of his tower as nearly as he could a solid mass of stone. Portland was the kind of stone chosen, and the blocks were so shaped as to interlock with one another on the principle of the "dove-tail" joint used in carpentry. In addition to this adjacent stones were joined by pegs or "trenails" of oak. Holes were bored in the stones and the trenails driven in, and it is said that the fixing was so good that a trenail would pull in two rather than pull out of the hole into which it had been fitted. Then, again, each stone had grooves cut in it, exactly opposite similar grooves in adjacent stones, and into each pair of grooves a pair of oak wedges were driven, one wedge having its point upwards and the other downwards, so that together they formed a solid mass of oak, keying the two stones together.

The stones were roughly shaped at the quarry, but finally finished in a yard established for the purpose at Plymouth. Here the shape of the stones was carefully marked out upon the floor and the stones made to fit, every one, before being taken to the rock, having been carefully tried against its neighbours. Each one was, of course, marked to ensure its being set in the correct place. The sketch on page 82 shows how the stones were shaped so as to interlock.

Above the solid part there were four rooms, one above another, and on the top of all the lantern. The total height was 90 feet.

This tower stood for well over a hundred years. Indeed, there seems to have been no reason why it should not be standing complete and in full use at this moment but for a very unfortunate circumstance.

It was in the year 1877 that Sir James Douglass, then the Engineer-in-Chief to Trinity House, in addressing the British Association, let out the news that the famous Eddystone Lighthouse was to be taken down. To many of those who heard him, this was a very sad announcement. Smeaton's feat in building this tower so successfully of a new material and by new methods, with little past experience to guide him, had long been looked upon by engineers with intense admiration. Moreover, the profession of Civil Engineer had begun to develop about Smeaton's time, and he was looked upon with a kind of affection as practically the "founder of the profession."

The fact that the structure was unsafe was no reflection upon his memory, since it was the reef itself which, having been to some extent undermined by the sea, had become shaky. At times of heavy storm the pillar shook, but it was at the foundations that the movement took place.

Various measures had been taken, before this announcement, in the endeavour to save it. For instance, it was found that the waves, thrown upwards by the curving base, struck a stone cornice round the base of the lantern with great force, so that cornice was reduced as much as possible in size. Various efforts were made, too, to anchor the base down, so to speak, to the sounder, uninjured part of the reef, but it was all of no use. The only remedy was the drastic one of a new tower, upon a new site.

And that brings us to the last chapter in this interesting story. In 1878 there was laid the first stone of the present tower, to the designs of Sir James Douglass, then the Engineer-in-Chief of Trinity House.

It stands some 100 feet or so away from the older tower ; it has a larger base and is considerably higher, so that the light in the lantern can be seen several miles farther away. Its foundations are even lower than the lowest tide, at a spot chosen with a view particularly to its solidity and freedom from any probability of undermining by the sea.

In general design it follows largely that of Smeaton, but there is one interesting difference. Smeaton, as has been said, copied an oak tree. In this he was not quite correct, for the forces which assail an oak tree act somewhat differently from those which a lighthouse has to withstand.

The enemy of the tree is the wind, which acts most strongly upon its branches, and it has in the course of ages adapted itself to this condition. It has developed a spreading base, which gives its roots a strong grip upon the solid earth. The force of the wind blowing upon the upper parts of the tree causes what the engineer calls a "bending moment" at every point all the way down the trunk to the ground, and this moment increases until it is at its maximum just above the roots. Hence the trunk of the tree steadily increases in strength from the top downwards, and so we get the tapering trunk with the spreading base at the ground level.

Now the waves which attack the lighthouse act most strongly at the base, not at the top. As has already been pointed out, the curved surface of the tower tends to throw the water to either side and the curve at the bottom tends to throw the water upwards but with it all the heaviest blows inevitably fall at the base of the tower.

Moreover, the upward deflection of masses of water is not so desirable as at first sight it seems to be, since they do not rise vertically, but at an incline towards the tower. Thus, being thrown upwards from below they strike the tower higher up, which is a more vulnerable spot.

So Sir James Douglass was bold enough to make a new departure. In spite of the weight which attached necessarily to the opinion of Smeaton, he discarded the spreading base and substituted a cylindrical base. The tower therefore stands upon a cylindrical mass of granite 44 feet in diameter and 19 feet high above high water. From the upper surface of this the spreading base commences, the curve dying away into a cone as it rises.

The effect of this is that at the base, where the blows of the waves are heaviest, there is a solid heavy mass capable of resisting them, and the tendency for the water to be thrown upwards is much reduced, so that the mighty blows against the side of the tower higher up are obviated. There was much discussion about this at the time, but experience has shown Sir James to be right, and the cylindrical base is now the established practice.

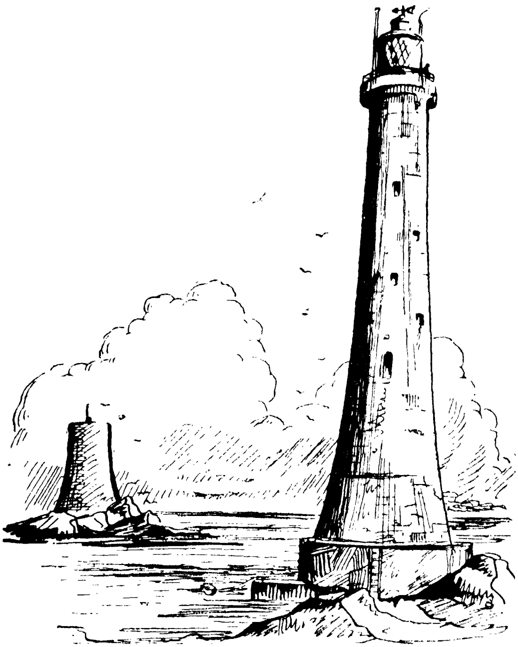
As compared with Smeaton, Douglass had many advantages. For example, the material for the third tower had to be taken out to the reef in herring boats, or " busses," as they are termed locally, propelled by sails. That for the fourth went out in a twin-screw steamer. This fact alone must have made a great difference in carrying out the work. In the early stages of a job like this it is often impossible to work at all except for two or three hours at each tide, and not then if the weather be at all bad. Hence the great necessity of being able to get men and materials to the spot quickly and at the very moment required. It is easy to picture the distress of Smeaton and his staff when the moment arrived to go to the rock and they saw their little sailing boat with its precious load of material arriving late, or perhaps not at all, because of contrary winds. How they would have appreciated a handy little steamer.

In order to avoid the long journey to and fro—the Eddystone is 14 miles from Plymouth—Smeaton had a " buss " anchored near the reef to which the working party could repair and spend their idle intervals and from which they could pass quickly to the rock whenever circumstances made it possible. Douglass was able to improve considerably upon this arrangement. He had his little steamer to run between the work and the base of operations, thereby saving much time and giving the men much more liberty.

Another advantage which the later engineer had over his predecessor was in the cement available. The complicated system of interlocking stones adopted by Smeaton has been described, as well as the arrangement of wedges and trenails, of which, by the way, the number ran into thousands. All this was necessary since no better cement was available than lime. Smeaton spent much time and thought in selecting and testing various kinds of lime to find out which would best suit his purpose. Before the last tower came to be built Portland cement had become available.

This material is made in many parts of the world, most of all in the valleys of the Thames and Medway. It consists of chalk and clay ground together, then baked in furnaces into hard lumps which are afterwards ground to a very fine powder. If this powder be mixed with water and then allowed to dry, a chemical action takes place which binds the particles together so firmly that they form a mass like very hard stone. Moreover, they are able to fix themselves to adjacent stones equally firmly, so that Portland cement can bind stones together so strongly that they become for practical purposes like one stone. This is far more than can be said of any kind of lime.

So Douglass adopted a very simple form of dove-



THE OLD AND NEW EDDYSTONE LIGHTHOUSES.
The old tower, seen on the left, was finished in the year 1759 and replaced by the more modern structure in 1881.

tail arrangement. Each stone was formed with a dovetail-shaped ridge three inches high along its top surface and down one end. The other end and the bottom surface had a corresponding groove The projections on one stone fitted into the grooves in its neighbours. The joints were then filled with cement, and in a very short time the stones were as if they had been one.

It is probable that the cement alone would have been sufficient, but the advantage of the dovetails was that they held the stones together, in spite of the onslaught of the waters, while the cement was setting.

The foundations being below " low water," it was necessary first to build a coffer-dam or circular wall upon the rock in order to protect the foundations from being completely flooded at every tide. Inside this protection the surface rock was cut away until a layer was reached strong and firm enough to hold the tower.

No blasting was allowed for fear the concussion should weaken the rock, but the pneumatic drill as used by miners proved a very useful tool. The compressed air for working the drills came through a flexible pipe from the attendant steamer.

The lowest of the blocks were tied down to the native rock by bolts made of gun metal cemented into both stone and rock and also fixed by having their ends split and then spread out by a wedge when in position.

The granite of which the tower is built came part from Cornwall and part from Scotland.

The height to the centre of the light is 133 feet, enabling a beam to be thrown 17½ miles. Except for a small central space forming a water tank, it is solid up to 25½ feet above high-water mark. The entrance is at this level and is reached by a ladder formed of gun-metal steps built into the side of the tower.

Above the solid portion are nine circular rooms, access from one to another being by iron ladders inside the tower.

The last stone was laid in 1881, the whole of the 4668 tons of granite having been laid in position in about two years. The cost was £59,250.

CHAPTER VII

THE BELL ROCK LIGHTHOUSE

MOST middle-aged or elderly men will have painful memories of this famous lighthouse, having been forced, at the point of the cane, so to speak, to learn Southey's famous poem, "The Inchcape Rock." This poem—a very beautiful one when learnt of one's own free will—tells how a dangerous rock was furnished with a warning bell by the good "Abbot of Abobrothock," which bell was removed in sheer malice by a certain pirate, Sir Ralph the Rover, with the result that he himself was wrecked upon it and lost his life. Because of this bell the Inchcape Rock came to be called familiarly the Bell Rock, the name which is commonly used for it to-day.

It is situated off the east coast of Scotland, almost opposite the Firth of Tay, about 11 miles from the town of Arbroath. It is very small—it was only just possible to find a space large enough to hold the tower—and is so low in the water that very little of it can be seen even at low tide. The Eddystone Rocks were bad enough, but it has been said that, whereas the Eddystone Rocks were barely covered at high tide, the Bell Rock is barely uncovered at low tide.

Because of its nature and position, therefore, it formed a great danger to shipping, for which reason it was eminently a place for a warning light. A light there was desirable for a further reason, however. In time of storm the mouth of the Tay forms an excellent harbour of refuge to which ships can run for safety, and a light on the Bell Rock greatly simplifies the task of steering into this desirable anchorage.

The presence of a light, therefore, not only mitigates the danger of this rock, but changes it into a means of reaching safety.

There seems to have been much discussion about the desirability of erecting this light, but the matter was practically settled by the occurrence in 1799 of a terrible storm which wrecked no less than seventy vessels along that coast, many of which could no doubt, had there been a light, have reached safety in the Firth, in addition to which one large vessel at least was believed to have gone to pieces on the very rock itself.

At this stage in the narrative we must introduce the name of Robert Stevenson, the founder of a veritable line of lighthouse experts, a line which still continues, and of which Robert Louis Stevenson was a member.

This gentleman must not be confused with another eminent engineer, Robert Stephenson, the son of George Stephenson who made the first successful locomotive, and who was himself a great railway engineer. The two are often confused, but the names are not spelt quite the same.

Robert Stevenson was born in Glasgow in 1772.

Owing to the death of his father and uncle, his mother was left in somewhat difficult circumstances, causing her to move to Edinburgh in order that Robert might go to an orphanage there.

Later his mother married again, her second husband being a Mr. Thomas Smith, of Dundee. This gentleman was of an ingenious turn of mind, not exactly a professional engineer, since professional engineers had then hardly come into existence, but a very able man in engineering matters.

About that time a body was established in Scotland called the Board of Northern Lighthouses, the duties of which were to supervise the lights on the coast of Scotland. There do not appear to have been many lights at that time and those there were were private ones, as was the fashion of those days. The idea was, apparently, for the Board to consider if further lights were needed beyond those provided by private enterprise and, if so, to arrange for their erection.

The Board consisted of the Lord Advocate, the Solicitor-General, the Mayors of certain seaport towns, and the Sheriffs of those counties of Scotland which were situated on the coast. It was founded in 1786. Mr. Thomas Smith was appointed engineering adviser. His stepson assisted him and eventually succeeded him.

In the course of his duties Stevenson prepared designs for a stone tower on the Bell Rock, following on the lines of Smeaton's Eddystone tower. The latter was still the only example of its kind. To use his own expression, " Smeaton's narrative of the erection of the Eddystone was the only text book on the subject."

He was not content to follow slavishly, however, even so eminent a man as Smeaton. He made his tower nearly half as high again—100 feet as against 68 feet. He made his solid for 21 feet above high water as against Smeaton's 11 feet. But the most important improvement of all was in the floors.

Smeaton's floors, which divided the tower up into rooms, were constructed on the arch principle. Now, the strength of an arch depends upon the rigidity of its supports. Whenever anyone walks over an arch bridge his weight tends to push the supports apart. Smeaton's floors were really domes, but domes are nothing else than circular arches, and the same principle applies. So the floors in a tower such as a lighthouse, if made in the form of domes, actually tend to burst the walls outwards. Smeaton took a lesson from Wren in this and buried strong iron chains in grooves round the floors, so as to take this stress and prevent any tendency to push the walls outwards. Wren had done this for the dome of St. Paul's.

Stevenson made use of larger stones, the edges of which he built into the walls, and these he so connected together inside that the floors, instead of being somewhat of a source of weakness, became actual sources of strength, tending to bind together and so strengthen the structure.

He also improved upon Smeaton's method of dovetailing the stones, achieving the same strength by simpler and easier methods.

The entrance door he placed near the top of the solid part, and above it he formed six chambers.

The Act of Parliament authorizing the erection of this tower by the Board was passed in 1806, but without finally fixing upon the design. Stevenson was still a young man and there was only the Eddystone by way of precedent, so the Board were not quite easy in their minds about it. They therefore called in the advice of Rennie, another of the early civil engineers, to consult with their own man. Rennie's opinions confirmed those of Stevenson in almost every point, and the work was put in hand.

The chief difficulty was the lowness of the rock. It was only possible to work an hour or two at a time, and that only in fine weather. In the first season the amount of work done amounted only to the equivalent of 13½ ordinary working days of 10 hours. In the second, things were a little better, but the equivalent was only 22 days.

To commence with, a ship was taken out and anchored at a convenient spot near the rock. This was to act as a lightship and mark the rock, and at the same time to form a depot where the men could live and so avoid too much travelling to and fro—we must remember that this was before steamships had become available.

Then, upon the rock itself, steps were taken to construct a timber beacon, a two-story building supported upon strong vertical timbers, the chief purpose of which was to form a refuge or barrack for men engaged upon the work.

The beacon was started in 1807. In 1808 they got seriously to work and succeeded in excavating the pit upon the surface of the rock to receive the foundations. They also got the foundations up to ground level.

The next year (1809) the masonry was carried up to 17 feet above high water. In 1810 the masonry was finished and the lantern fixed ; while in 1811 the light was first shown.

Some of our experiences during the War are recalled by an incident which happened to Stevenson while he was preparing himself for this great work. At the request of his Board, he arranged a tour of visits to various lights in England, in order that he might compare them with those under his charge in Scotland and see if there were any lessons to be learnt from them. Having just visited several on the Cornish coast, he was making his way to the nearest conveyance to get on his journey, when a little party of men met him and proceeded to arrest him. They thought he was a French spy.

They had carefully compiled a detailed list of the lighthouses that he had visited and the questions which he had asked about tides, currents, and so on. They appear, indeed, to have had a far better case against him than that against many who were accused of being German spies in our own time.

At his request he was taken to the nearest magistrate, where he showed his papers, but this poor man seems to have been too frightened to do anything except to refer the matter to the bench of magistrates in a neighbouring town. Off Stevenson had to go, therefore, to the town, where, of course, he was liberated, with many apologies.

One of the great difficulties which faced these early lighthouse engineers was the lack of suitable lifting tackle. To-day there is an almost endless variety of cranes in existence. Should a modern engineer require a crane for a special service, he has only to send out a few post cards to firms who specialize in this kind of machinery, and in two days he will be inundated with well-illustrated descriptive catalogues giving him a wide range of machines from which to choose. A few hours later representatives of these firms will commence to call upon him until he will almost wish he had not sent out so many post cards. Each of these gentlemen will be prepared to give expert advice. If, after all, he does not find exactly the thing that he needs, any one of them will be pleased to design him something specially adapted for the purpose.

Stevenson had no such help. He had to design his own cranes, and in the two types which he used at the Bell Rock we find the beginning of two kinds in wide use at the present time.

Smeaton had been content to use "sheers," a very old device well known to seamen. This consists of two strong timbers placed together so that they form an inverted V. Their lower ends are fairly wide apart; their upper ends are lashed together. The pulley blocks through which the lifting rope runs are lashed to the point where the two timbers join.

Such a structure is not stable, of course, without a third support. Sometimes this takes the form of a third timber, making the whole a tripod, but more often it is a guy rope. It is set slanting in one direction so that the weight tends to pull it over, and this tendency is resisted by a strong rope pulling the opposite way, the two forces together resulting in a stable condition.

One of the difficulties in the use of this appliance on a rock lighthouse is that to be effective the guy needs to be anchored a long way back, so that its position is nearly horizontal. The nearer the rope approaches to a vertical position the less effective does it become. On a small rock it may be impossible to get a suitable anchorage for the guy. Further, its range is limited. It is all very well for lifting things off a cart, for example, and, after the withdrawal of the cart, depositing them on the ground. That is very different from what is required upon a lighthouse work. Because of the dovetail joints it is necessary to lift the stone straight up, move it horizontally, and then drop it down straight into position between stones already placed.

So Stevenson devised what to-day we call a "jib crane." This consisted of a vertical mast held upright by means of guys. From a point near the base another timber springs upward on the slant. This latter is the "jib," and its upper end is connected by means of a rope to the top of the mast. The pulley blocks are fastened to the end of the jib.

Such an arrangement can easily be made so that the jib can swing round through half a circle, carrying its load with it. Thus it can lift up a load and place it upon any desired point upon that half circle. Moreover, by pulling in the rope which supports the head of the jib the radius of the half circle can be reduced so that the load can be deposited upon any point within the half circle described by the jib when working at its greatest radius.

Judging by the accounts of the work, Stevenson used two of these cranes, one of which was fixed at the foot of the tower, on the rock, for the purpose of lifting the stones out of the boats and landing them upon the rock. The second, which stood with its mast in the centre of the tower, then picked them up and placed them in the correct position.

There was no steam power or electric motors or such things in those days. The steam engine, in fact, was quite in its infancy and electrical machinery unknown, so all had to be done by hand. Simple tooth wheels fixed to the vertical mast and turned by the brawny arms of the workmen did it all.

As the tower rose higher and higher the guys became, of course, more and more vertical and ineffective, so Stevenson devised, for the upper portion of the work, a " balanced crane," which in an enlarged and more developed form is called a " Titan " and is used to-day for setting 50-ton blocks in breakwater construction.

In this, too, we have a vertical mast. In Stevenson's crane it consisted of a tube of cast iron. Upon the top of this was pivoted a horizontal beam upon which ran two little trolleys. One of these trolleys carried the pulleys for the lifting rope, so that the trolley could be run out to the end of the beam for picking up a stone. Then the trolley could be run back to drop the stone upon the wall of the tower. The beam could also swing round so as to deposit the stone upon any part of the wall. But that is only half the story, for such a crane would possess little or no advantage over the simple jib crane.

The other end of the beam had another trolley loaded with a cast-iron weight. This weight could be moved to and fro, so that whenever a stone was lifted this balance weight could be moved along the beam until the latter was nicely balanced. Thus the pull upon the guy ropes at any time was very light, and the vertical position of them was therefore of little moment.

CHAPTER VIII

THE "INVISIBLE" LIGHTHOUSE

IT is obvious that a means of communication between an island lighthouse or a lightship and the shore is a very important matter. At one time the only possible method was the use of visible signals. Then followed a cable laid on the bed of the sea, making telegraphy and telephony possible. In the case of the lightships, at all events, this was not very satisfactory owing to the movements of the ship causing the cable to chafe upon the sea-floor. Next came wireless telegraphy.

Indeed, one of the first uses contemplated for this new mode of communication was to keep a lightship in touch with the shore; and some of Marconi's earliest experiments were carried out between the South Foreland and the lightship on the Goodwin Sands.

Now that so much is being said and written about "wireless" it is quite unnecessary to deal here with the ordinary duties which it performs in the way of sending messages. It has, however, certain special services which it renders to shipping.

Of these the most important is its power to give accurate information as to position and direction.

THE "INVISIBLE" LIGHTHOUSE

Just as a ship can get its direction through seeing a well-known light, or its position by seeing two such lights, so in the densest fog a ship can get its direction through "picking up" signals from one wireless station or its position through "picking up" from two stations.

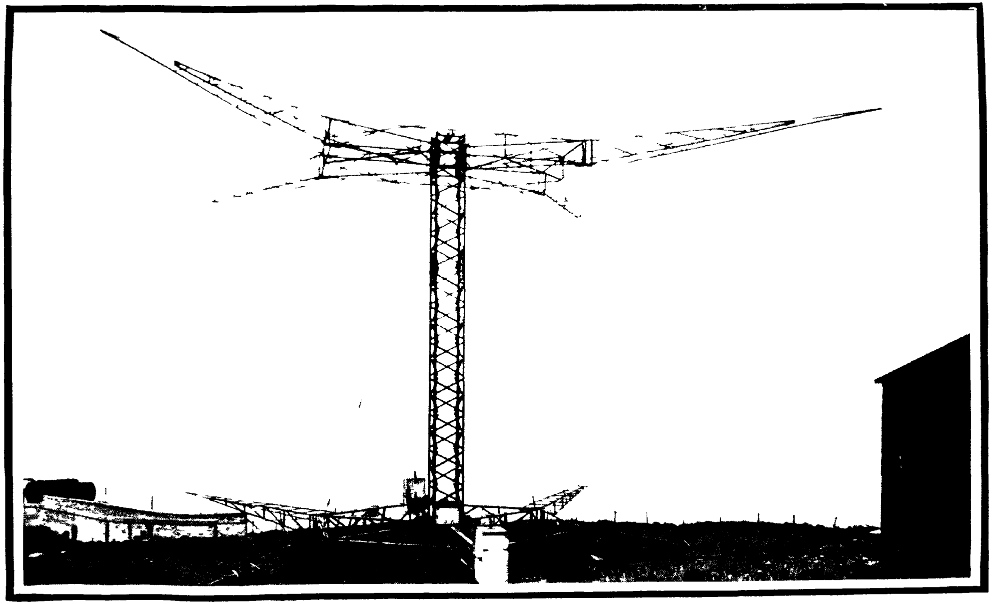
The æther waves which, when they fall upon our eyes, cause the sensation of light, and those which carry messages are in their nature precisely the same. They differ in wave-length—that is to say, the distance apart of the waves—and because of this difference they have certain different effects. The short waves of light cannot penetrate fog, for example, whereas the longer "wireless" waves can do so easily.

If you stand at the mouth of a small harbour and watch the waves you will generally notice that there are some long waves and some short waves all mixed up together, and you will observe that the long waves get into the harbour while the short ones are stopped at the mouth. In the same way, the short light waves are stopped by the tiny water globules which constitute fog, while the wireless waves pass around them almost unaffected.

When you look at a lighthouse you can tell by the eye the direction from which the light comes. In just the same way a suitably constructed wireless apparatus can tell from which direction the wireless waves come.

The essential feature of the "wireless direction finder" is the form of the "aerial."

As everyone knows nowadays, the ordinary aerial



WIRELESS LIGHTHOUSE AT INCHKEITH, FIRTH OF FORTH

The small transmitting aerial can just be seen on top of the wooden box in the centre. The reflector (a system of wires) is supported by the iron framework, the whole making one complete revolution every consists of a horizontal wire or wires connected to earth by a vertical wire, the whole forming roughly a T or an inverted L. These wires constitute an "oscillatory circuit." Now, we are all taught at school that an electric current can only flow when there is a complete circuit, and here we have a circuit which is obviously incomplete. How, then, can current flow in it?

The school dictum about the complete circuit, meaning a complete circuit of wire or other conductive material, applies to a steady continuous current such as that derived from a battery. When the current surges to and fro, flowing first one way and then the other, a strange thing happens. The "broken" circuit becomes complete, the space between the two ends being bridged across by an action which we can only attribute to the mysterious æther. The effect is not the same as would be that of a wire, but for all that a circuit like a wireless aerial when used for "alternating" currents behaves very much as if it were complete.

In wireless telegraphy the currents used are "alternating"—that is, they flow first one way and then the other. Instead of changing their direction, say, fifty times per second, as do those alternating currents which we often use for lighting and power, they change perhaps a million times per second. These very rapidly alternating currents are generally called oscillatory currents or electrical oscillations.

Now, the æther waves sent out by the transmitting station set up oscillations in the receiving aerial, which oscillations pass up and down the vertical wire.

Suppose, now, that instead of the usual form of aerial we use what is commonly called a frame aerial. This consists of one or more turns of wire wound upon a suitable frame. We will suppose for the sake of simplicity that the frame is square, but it may in practice be any convenient shape.

Set such a coil up upon its edge in such a position that a line through the two vertical sides of the square shall point at the transmitting station. As the waves come in they will act upon the two vertical sides *in succession*. They will first set up a current (we will suppose in an upward direction) in the nearer side and then do the same thing in the further side. The second of these currents will flow round the circuit in an opposite direction to the first, but since it will occur a little later it will not wholly stop the first, and the result will be an oscillation in the circuit. Moreover, the first side, being slightly nearer to the transmitting station than the other, will be acted upon slightly more strongly. Thus there is a difference in strength and a difference in time, both of which tend to cause oscillations in the circuit.

Now turn the apparatus round through a quarter of a circle so that the two vertical sides are the same distance from the transmitter. The incoming waves will then strike both the vertical sides with precisely the same strength and at precisely the same moment and will cause an equal force (upward or downward, as the case may be) in both. These two forces will oppose each other, and the result will be that nothing at all will happen.

Thus we see that a frame aerial is most sensitive to signals coming in from one direction and absolutely insensitive to those coming in at right angles.

If a frame aerial be mounted so that it can be conveniently turned round, it will be found that the sensitiveness gradually changes from maximum to zero and again to maximum as the apparatus turns. Consequently, if a ship be provided with a frame aerial and this be turned round until it picks up certain signals with the maximum power it will have a ready means of telling the direction from which those signals are arriving.

Or the opposite method can be used and the frame turned until the signals are inaudible. Whichever method be adopted, the frame aerial will, by the relative strength of the received signals, tell the direction from which they come.

But it is advantageous to have the frame aerial as large as possible, and a large frame is an awkward thing to manipulate upon a ship. Therefore it is usual to have a triangular aerial formed of a wire running from the top of a mast down to one side of the ship, across to the other side, and up to the mast again. To manipulate that, however, it would be necessary to steer the ship round a circle and compare the strength of the signals as it changed its angle with the distant station; so that will not do, in practice.

All difficulty is overcome by having two such aerials, exactly the same but placed at right angles, one with its base across the ship and one with its base upon the centre-line of the vessel. Then it is only necessary to compare the strength of the signals in the two aerials. For if the signals are coming from straight ahead, they will be strongest in the aerial upon the centre line and inaudible in the other. On the other hand, if they be coming broadside on, the centre-line aerial will be silent and the other at its maximum. In between these points will be directions from which both aerials will be acted upon to some extent. Indeed, the relative loudness of the signals in the two aerials will be an indication of the direction.

It only remains, then, to devise an apparatus by which the strength of the signals in the two aerials can be accurately and readily compared, and fortunately this is quite simple.

In some suitable spot upon the ship there is placed an instrument consisting of three coils of wire. Two of these are placed at right angles to each other, just as the aerials are, and are firmly fixed. The third is slightly smaller, is placed inside the other two, and is mounted so that it can be turned round into any position.

Each of the fixed coils is connected to one aerial. Aerial A, as we might call it, is connected to coil A, and aerial B to coil B. The movable or "search" coil is connected to the wireless detector and telephone.

The currents from the aerials pass through the two coils A and B, and each acts more or less strongly upon the search coil.

In using this instrument the operator turns the search coil round until he finds a position which gives *no sound* in his telephone. Then a pointer shows the direction from which the signals are coming.

This action is based upon the fact that whatever may be happening in the aerials there will be one position of the search coil when the effects of the aerials upon the search coil will balance and neutralize each other. The position of this neutral point will depend entirely upon the relative strength of the oscillations in aerial A as compared with those in aerial B, so that it forms a simple but accurate method of comparing them.

In practice, if the incoming signals be feeble, there will be no clearly defined neutral point, but as the search coil is turned the sound will be lost at one point and picked up again at another. Under those conditions the positions of the two points are noted and the real neutral point is exactly midway between them.

The apparatus might be worked by seeking for the position of maximum sound rather than that of no sound, but it is found to be easier for the ear to distinguish between a feeble sound and no sound than to choose between a sound and a slightly greater sound. Hence, the "no sound" method is more accurate.

The apparatus for tuning the circuits and for detecting the oscillations and translating them into audible sound are similar to those in use in ordinary wireless apparatus.

The arrangement just described is, as wireless things go, quite ancient, having been invented in the early stages of wireless communication by two Italians named Bellini and Tosi; hence the double aerial formed of two complete loops of wire at right angles to each other is called a "Bellini-Tosi" aerial.

The value of wireless direction-finding was appreciated greatly during the War. It was used by aircraft, notably by the Zeppelins which raided England, and it is generally understood that the fleet of Zeppelins which came to so inglorious an end in October, 1917, lost their way home through some failure in the wireless direction-finding arrangements. It must also have been particularly useful to shipping during those times when they had to sail with lights dimmed or out.

In times of peace there is still fog to be contended with, and so the direction finder will always have its place among the aids to navigation.

But there is another form of apparatus designed for the same end which is much more recent, and which in some ways is much more convenient. It is this more modern device which inspired the somewhat curious title of this chapter, for it is in many respects similar to the revolving light of the lighthouse, and the rays which it employs are in fact light-waves but for their longer wave-length. They can quite legitimately be called "invisible light."

The Bellini-Tosi system, as will be seen, is embodied entirely in apparatus upon the ship and uses for its guiding signals any which it may happen to pick up from the ordinary stations ashore. The newer system, which has been worked out by the Marconi Company, requires a special sending device as well as receiving, and it is in the sending device that its interest largely centres.

We have seen in an earlier chapter how the optical apparatus gathers up the light from a lamp, makes it into a solid beam, and with that beam sweeps the sea at regular intervals. The result is that when a mariner is so placed that the beam falls into his eyes he sees a bright flash.

In the "invisible" lighthouse we have a vertical rod which forms a short aerial, capable, when properly energized, of sending out wireless waves of a wave-length of about six metres.

Behind the aerial and partially enveloping it is a curtain of vertical wires placed along a parabolic curve. Now a curtain such as this, if properly arranged, acts as a reflector of wireless waves, and the result is that the effect of the aerial is concentrated into a beam very like the beam from a revolving light.

A second aerial, also with a parabolic reflector behind it, is placed behind the first one, the two reflectors being back to back, and the whole is mounted upon a turn-table which is revolved by an electric motor at the rate of, say, once every two minutes. A beam, therefore, sweeps over every point within the range of the apparatus once every minute.

And now we come to a point of difference between the beam from the lighthouse and the invisible beam. The former remains equally bright all the time; the latter while sweeping round is broken up so as to make Morse signals.

The purpose of this can be illustrated in quite a simple manner. It used to be the custom, and possibly is so still, for the bugler in a large military camp to give the important calls four times: once facing north, once east, and so on, the idea being to throw the sounds in the four directions so that all parts of the camp should hear them equally.

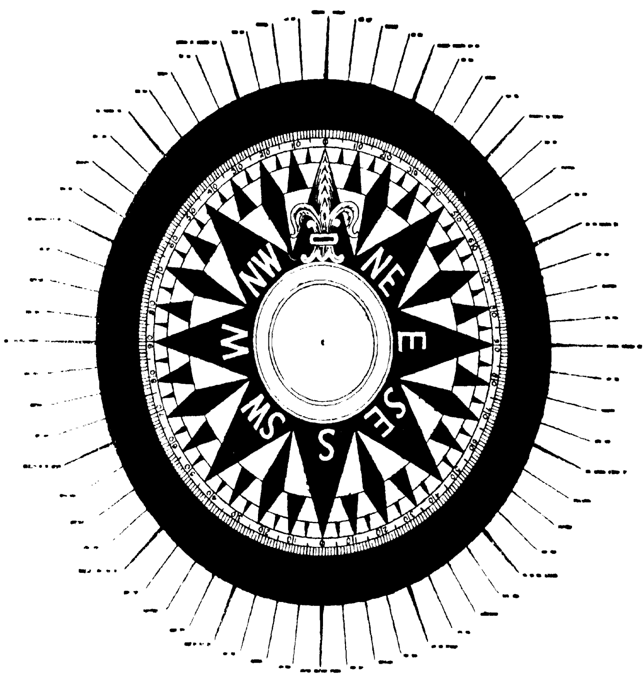
Assuming a very conscientious bugler who always faced exactly in the correct northward direction for his first call, to the east for his second, south for the third, and west for the last, it would be quite possible for a fog-bound soldier with a pocket compass to find his way home over country of which he was entirely ignorant.

It would work in this way: If, hearing a series of four calls, the first was distinctly the loudest, he would know that he was due north of the barracks and would make his way southward. If the second were loudest, he would know that he must walk towards the west. If the first and second were about equal, he would tramp in a south-westerly direction, and so on.

The wireless beam in its sweep makes a separate Morse signal at each of the sixteen important points of the compass. When it is pointing north, it says "M"; when south, it says "O": for each of the sixteen points it has a separate letter. The picture of a marked compass-card given by permission of the Marconi Company will make this quite clear.

So much for the sender. Let us now transfer our interest to the ship. Here upon the bridge we find a tiny aerial, and in one of the cabins an officer listening at a telephone.

He soon hears a series of letters: we will suppose them to be M.I.T.I.Z.I.T.I.K.I.T.I.F.I.T.I.G. After



"Wireless" Compass Card.

that he can hear no more, so he knows that the beam has swept past. What he wants to know is the letter which the sender sent out when the beam was pointing straight at him, which letter should be the one he heard the loudest. But out of that string of letters he cannot be quite sure. He may decide to take the middle one and assume that, of the series, that would be the loudest. Or he may proceed in another way.

By the movement of a knob he can make his apparatus less sensitive, so he uses this knob and then listens again. In about a minute the beam comes round once more and he gets this time the letters I.T.I.K.I.T.I. That is better, and the same letter is still in the middle of the series. But once again he uses the knob and listens a third time. Then he hears I.K.I.

By this time he is certain that when pointing straight at him the beam is pointing in the direction of north-east, so that if he draws a line upon his chart, from the position of the sending station in a north-easterly direction, the position of his ship must be somewhere upon that line.

If he can do this with two sending stations he will find that the lines will cut each other and his position will of necessity be at the point where they cut.

But if he heard signals from two stations, how would he know which they were? By those groups of intermediate signals between the sixteen points. It will be noticed that upon the card shown these are I.T.I., but any other group of short signals will do, and they will serve the double purpose of dividing up the spaces between the more important points and of giving "character" to the apparatus.

But our officer friend can manage, to some extent, to define his exact position, even from one station only. We have seen how he reduced the sensitivity of his apparatus until the signals were only just audible. If care be taken to keep the strength of the sending apparatus always the same, the amount by which he has to tone down his signals in order to make them only just audible will tell him fairly nearly how far he is from the sender. This distance he can scale off upon the line upon the chart, and he will then know fairly well where he is.

There is still another way in which wireless signals can help the mariner to find his position, but that is in conjunction with submarine sound signals and will be described in a later chapter.

CHAPTER IX

LIGHTSHIPS

OF the vessels themselves there is not much to say, except that they are strongly built and are specially shaped for riding at anchor. They are, as ships go nowadays, quite small, round about 100 tons or so. Some have no rudder or means of propulsion, since they are towed into position and are supposed to stop there. Some, however, have a rudder and a little propelling power for use in case they should by accident get adrift.

In one sense, of course, they are doubly liable to collision, since they can themselves do nothing to avoid it as a free ship can. They are therefore strengthened with a view to making them as capable as it is possible to be of avoiding damage under those conditions.

Their chief interest is in the lighting arrangements. It is quite evident, after a moment's thought, that the conditions here are widely different from those which obtain in a tower. For one thing, the tower is still, while these small ships roll heavily in bad weather. Until recently, therefore, the use of glass reflectors and lenses has been avoided as far as possible lest they should be broken by the movement. Metal parabolic reflectors are still largely used on lightships. As the size of these is necessarily small, it is usual to have a number of them, each with a burner at its focus, arranged in a framework forming a cylindrical lantern with a hollow axis through which the mast passes. It therefore slides up and down the mast as required, being lifted by a small winch.

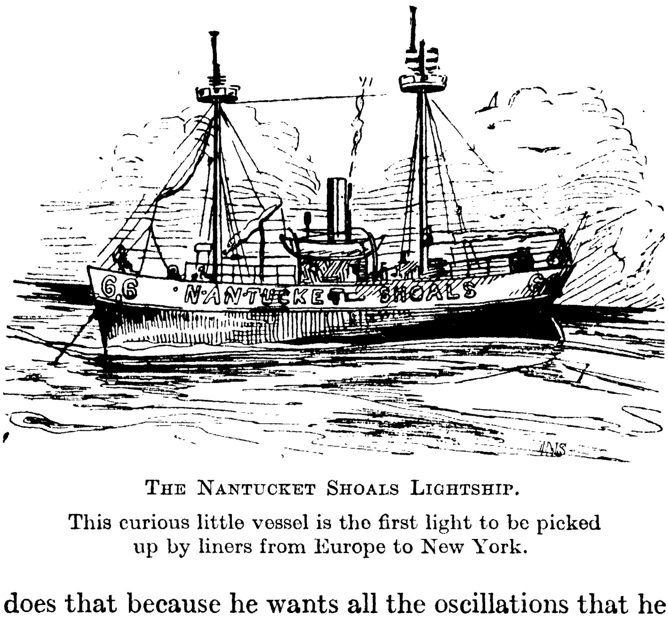
To get the greatest number of burners and reflectors into a small space, the burners are usually arranged in two rows one above another, those in the top row being spaced so that they come over the gaps in the lower one.

In the case of a fixed light these reflectors are set facing all round, with their backs, so to speak, to the mast. Where the light is revolving, they are arranged in groups, all those of each group facing in the same direction, thus producing separate beams just as the revolving apparatus does in the lighthouse.

Not only does the motion of the ship cause a risk of breakage of the apparatus ; there is a further and equally important point to be considered. The rolling, if the lamps were fixed, would throw the beams up and down, with the result that the distant observer would not see the true character of the light at all. To overcome this each reflector, with the burner at its focus, is hung upon knife edges, so that it can swing freely. The result is that while the ship may rock the individual lamps hang fairly steady.

Those who take an interest in " wireless " matters will be familiar with the operation called " tuning," and here we have an illustration of the same thing.

The wireless man knows that each of his circuits has a natural frequency of its own. That means a frequency at which the electricity in the circuit likes to oscillate. He adjusts his circuits until all have the same natural frequency, and then the oscillations in one quickly set up similar oscillations in others. He

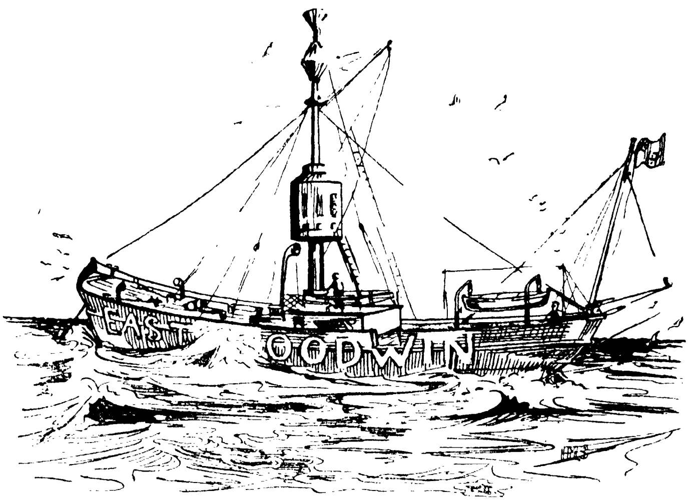


THE NANTUCKET SHOALS LIGHTSHIP.

This curious little vessel is the first light to be picked up by liners from Europe to New York.

does that because he wants all the oscillations that he can get.

The designer of a lightship, on the other hand, desires exactly the opposite. He knows that his ship will oscillate, but he does not want the swinging movement to be communicated to the lamps. Now, every ship has a natural frequency at which it likes to roll. And every suspended object, such as the lamps, also has its own natural frequency. The lightship engineer takes care that these shall bear the remotest possible relation to each other. If these two natural frequencies were the same or nearly so, the rolling of the ship would set the lamps swinging, and every subsequent roll would add to their motion until they would be almost turning somersaults.



THE EAST GOODWIN LIGHT-VESSEL, AT THE EAST SIDE OF THE GOODWIN SANDS.

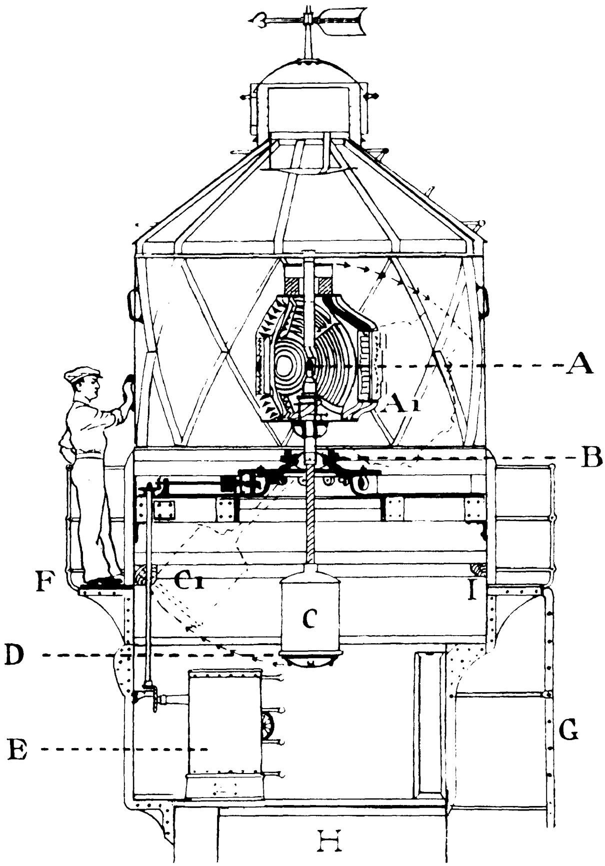
But if the lamps be so arranged that their frequency is longer than that of the ship, if in wireless language they are out of tune, each successive roll of the ship tends to check the swinging set up by the previous one. Thus the lamps remain comparatively steady.

A very simple but interesting experiment can be made illustrating this. Stretch a string across a room and near each end hang from it a weighted string, say, three feet long. Set one of these swinging and see how quickly the second one picks up its motion. Then reduce one of them to two feet long and again set it swinging. The longer one will now take scarcely any notice of the shorter. But to get back to our subject.

It will be easily realized that the labour of keeping all these burners and reflectors in perfect order is by no means small, a fact which has been amply sufficient to spur on the makers to produce a dioptric apparatus suitable for lightships in which a single burner will displace the many, and glass prisms which only require to be wiped shall take the place of the metal reflectors which so easily tarnish.

Judging by a cursory glance, one might almost imagine that in this latest kind of lightship the makers had just built a small lighthouse upon the deck of a ship. No longer is the lantern hauled up a mast or let down to be cleaned. A stout pillar rises from the deck supporting a chamber large enough for the cleaner to enter, and inside this lantern there is an apparatus corresponding in many details to a third or fourth order as made for lighthouses.

Even the mercury trough is sometimes present, although ball bearings are made great use of as well. The lantern, of course, being so substantial a structure, has to swing with the ship, but the burner and the whole apparatus of prisms are swung upon gimbals so that they are free to move in any direction, or, to put it another way, the ship may pitch or roll without imparting any movement to them.



MAST-HEAD OF A MODERN LIGHTSHIP

A is the lantern. B is the universal joint upon which the lantern swings. C is the heavy pendulum which keeps the lantern steady in rough weather. C1 and A1 show the lantern swung to the full extent. D shows the pendulum in its normal position. E—machinery which turns the light slowly round, causing the flashes. F—platform running round the lantern. G—ladder from the deck of the vessel. H is the mast. I, wooden rail which runs round the lantern housing to act as a buffer for the pendulum.

The apparatus is held steady by a weighted rod or tube which projects downwards through the pedestal. Here, again, care is taken that the natural frequency of this great pendulum shall bear such a relation to that of the ship that the whole shall hang quite steady.

In practically all cases revolving apparatus upon

THE ST. GOVEN LIGHTSHIP IN A STORM.
This vessel is stationed at the entrance to the Bristol Channel.

lightships is driven by clockwork. Where this is placed is just a matter of convenience. In some cases it is upon the deck just at the foot of the mast. With the dioptric apparatus it is sometimes in the same position ; in other examples it is in the lantern itself. It is all a matter of convenience.

In the same way, the method of lighting is adapted to the circumstances surrounding each particular case. In some it is simply oil lamps. In others it is gas brought up from below through tubes. In others, again, gas is stored in that long tubular pendulum which hangs below the lantern.

The favourite methods of lighting lightships are the vapourized oil with incandescent mantle, compressed oil gas with mantle and acetylene.

Intermediate between the lightships and the buoys (of which more later) there are a number of small untended lightships. Readers of the earlier chapters will understand already how these work, the burners being supplied with compressed gas or acetylene, controlled by a flasher and a clock or sun-valve.

The buoys, also, will be readily understood. Each is, in fact, a small untended light vessel, only its shape is usually a simple cylinder, upon the top of which there stands a light steel structure which carries a small lantern with a dioptric apparatus inside. The whole is made to float in an upright position by a heavy tubular pendulum hanging from the bottom of the buoy itself. Sometimes this is made to constitute a self-acting fog-horn. It is left open at the bottom, so that the water enters and rises to the same general level as that outside. When the surface is at all rough the body of the buoy rises and falls with every passing wave, while the water in the tube keeps to a fairly constant level. The water thus constitutes the piston of an automatic air-pump.

At the top of the tube is a valve which admits air as the " piston " falls, but prevents its escape when it rises. When the water rises, then, in the tube, it forces air out through a whistle arrangement, something on the lines of the railway-engine whistle. This arrangement is not very reliable, as so much depends upon the fickle action of the waters, but it has its uses.

CHAPTER X

THE LIFEBOAT

REFERENCE has been made already to the romantic attractiveness of the lighthouse. The lifeboat calls forth our admiration and interest even more strongly.

Just as, from prehistoric times, people have warned their friends at sea by beacon lights upon the shore, so have boats been used to go out in rough weather to the assistance of those who, by accident or misfortune, have suffered shipwreck. The first lifeboat, then, was just an ordinary boat used for the moment for this special purpose of trying to save life. It had no special features of its own.

The first hint of a special boat, designed and built for this particular service, appears in an old French book which tells us how a certain Monsieur Bernieres, in 1765, invented a boat capable of carrying nine persons, which would not sink even when filled with water and which might be turned over until the top of her mast was actually under water and yet would right herself when released. There seems to be no indication that such a boat was ever put to practical use.

The first definite information of a boat actually being made dates from 1784, when a citizen of London, a coachbuilder by trade, named Lionel Lukin, devised one which may fairly be called a lifeboat. True, it was not his idea to make such boats for the rescue of those in danger of drowning by shipwreck, but rather to make all boats safe. He probably had in mind a service such as that of the ship's lifeboat of to-day, rather than the purely rescue craft of the Lifeboat Institution.

It is interesting to note, in passing, that this ingenious coachbuilder lived in the street called Long Acre, where the coachbuilders, and their successors the motor-car builders, still congregate.

He took a boat of the type known as a Norway yawl and to her he fitted his own special features. First he placed a thick rib of cork all round the gunwale. Clearly this gives an increased stability, because when the boat heels over far enough to bring the gunwale to the surface of the water the cork rib comes into action, and by giving added buoyancy at that side checks the movement. Another thing he did was to add a heavy iron keel underneath the boat, the weight of which tended to keep her upright or to pull her back strongly if she should be canted over. Then at each end of the boat he fastened air cases, also under the seats, along the sides inside and below the flooring, so that even should the vessel be turned over on to its side or completely filled with water it would nevertheless continue to float.

In the year 1721 there died a certain Baron Crewe, who also was Bishop of Durham. He was a very wealthy man and also a man of great kindness of heart, who supported many schemes for the benefit of his fellows. Not only so, when he died, having no family to succeed him, he left his wealth for similar purposes, and about the time we are speaking of, these trust funds were under the control of Archdeacon Sharp, a man who was evidently animated by the same kindly feelings as the late Bishop. This gentleman had a boat sent to Lukin to be fitted up according to his methods in order that it might be stationed at Bamburgh, on the coast of Durham, for the purpose of saving life from shipwrecks. There we have the first rescue "lifeboat," but it should be noticed that it was only an ordinary boat fitted with certain special features.

That was about the year 1786. About the same time the mind of William Wouldhave, a house painter, of South Shields, was grappling with the same problem.

It is a curious fact that the first three names to be connected with the lifeboat all belonged to landsmen. A coachbuilder, a minister, and a house painter constitute the trio of pioneers to whom we owe in large measure the wonderful lifeboat service of to-day.

The particular feature which Wouldhave introduced was the self-righting principle. Lukin's boat was difficult to capsize and impossible to sink, but if by chance it had been capsized it would have remained so. Wouldhave's idea was to make a boat so that even if it were capsized it would quickly right itself. Lukin's idea was to add certain things to any kind of existing boat in order to make it stable and unsinkable; Wouldhave's, to fashion a special boat peculiarly adapted to this particular purpose.

It was a happy accident which led to his discovery of how to design a self-righting boat. Wouldhave was out for a walk when he saw a woman drawing water from a well. In lending a helping hand to raise the bucket to her head he noticed floating in the water a broken half of a wooden plate. Curiosity led him to notice that it always floated one way up, and do what he could to it, he could not make it float any other way. He quickly realized that he had found what he was seeking, namely a form of vessel which, whatever happened, would place itself right side up.

It will be interesting here just to see the laws which govern the way a vessel shall float in water.

In the first place it is essential that the weight of the vessel shall be less than an equal volume of water. When anything capable of floating is placed in water it pushes aside a volume of water exactly equal to itself in weight. No matter whether it is a small piece of wood or an Atlantic liner, when it enters the water it pushes the latter aside or "displaces" it, until it has "displaced" a quantity of water of exactly the same weight as itself. Then it sinks no further.

As every schoolboy knows, there is a certain point in every body known as its centre of gravity, and for many purposes it is convenient to regard the whole of the weight of the body as concentrated in that point.

In just the same way, when a body is floating in water, there is a point called the " centre of buoyancy " where we may regard all the upward force of the water as being concentrated. This point is really the centre of gravity of the displaced water.

When we throw carelessly a light object into a basin or pond it turns itself over more or less until it reaches a position of stability, after which it remains steady. Why does it thus turn over ? Because the buoyancy acting upwards and gravity acting downwards form what is termed in mechanics a " couple." It is a common amusement with boys to try to balance, say, a cricket bat upright upon the end of a finger. When you do that you know how persistently it tries to fall over and how, to prevent it doing so, you move your finger about.

What you are really trying to do is to keep your finger exactly beneath the centre of gravity. So long as you can keep your finger (the " centre of support ") exactly under the centre of gravity the bat stands upright, but as soon as the " C.G." gets the least bit to one side of the centre of support a " couple " comes into existence, which tends to make the bat turn a somersault.

You take advantage of a " couple " when you push a door open. You push the door in one direction ; the hinges react against your push in another direction, with the result that the door turns upon its hinges. There is one, and only one, way in which you can push a door without setting up a " couple " ; that is when you push it edgeways, so that its hinges react against your push along the same straight line.

So long, then, as gravity and buoyancy act against each other along the same straight line the floating body remains stable. As soon as you disturb it so that the two forces do not directly oppose each other, a "couple" is set up which tends to make the body turn.

A boat, therefore, is so shaped that (1) when it is in the desired position the centre of gravity and the centre of buoyancy are opposing each other directly in a straight line; (2) when we tip it over, more or less, to one side, the centre of buoyancy shifts *to that side* too, and tries to push the boat back. Thus, whatever we do to a boat, within certain limits, a "couple" comes into operation which tends to "right" it.

Boat builders have known for ages the best form to give their craft in order to make it stable. While ignorant, until quite recent years, of the underlying principles, they knew from experience how to make a stable boat.

The trouble with an ordinary boat is that it has two positions in which it is stable. If we turn it over far enough we reach a condition where the centre of gravity and of buoyancy change places and the "couple" commences to act in the opposite direction. Instead of restraining our turning-over action it then helps it, and the boat continues to turn over without our aid. That is why a boat capsizes. It goes on turning until it reaches another position of stability which occurs when it is upside down. To put it briefly, an ordinary boat is just as content to float upside down as to float right side up. Both positions are "stable."

Wouldhave, taking the broken wooden dish as his model, put an air case at each end of his boat rising well up, as high, in fact, as the gunwale. This has the effect of making the upside-down position unstable, so that a boat so designed will not be content to float in any position except the right one. You may turn it how you will; it will always right itself.

To these two men, Lukin and Wouldhave, may be given the credit of inventing the lifeboat, so far as Great Britain is concerned, at all events; the one devising the strong unsinkable, though not self-righting boat, and the other the self-righting one.

That brings us to a rather curious body of gentlemen, resident in the neighbourhood of South Shields, called "the Gentlemen of the Lawe House." They were in the habit of meeting as a kind of club in a building which had been a barrack on an eminence overlooking the mouth of the Tyne. They had some curious customs, such as calling their treasurer the "Chancellor of the Exchequer," and they also had a functionary called the "Sergeant at Arms" whose duties no doubt were to keep order among the members when they got "merry," and who was distinguished by an elaborate badge of office.

Now the mouth of the Tyne is a dangerous place for shipping, and these gentlemen, looking from the windows of their club house, must have seen many ships in difficulties. On the 15th of March, 1789, there occurred a particularly distressing calamity, the wreck of the *Adventure*, whose crew after taking to the rigging fell off and were drowned one at a time in view of thousands of spectators, including the Gentlemen of Lawe-House. This seems to have stirred their sympathies to such an extent that they decided to do something. They determined that a boat of some suitable kind should be kept at the mouth of the Tyne and equipped in the best possible manner for rendering aid under conditions such as they had just witnessed. They forthwith submitted proposals to this effect to the Newcastle Trinity House, a local organization which controlled the pilotage and certain other matters relating to shipping on the river Tyne, which body warmly welcomed the idea.

So the " Gentlemen " appointed a committee, and issued a public advertisement offering a reward of two guineas (not a very imposing sum, it is true) for the best suggestion as to the construction of a lifeboat.

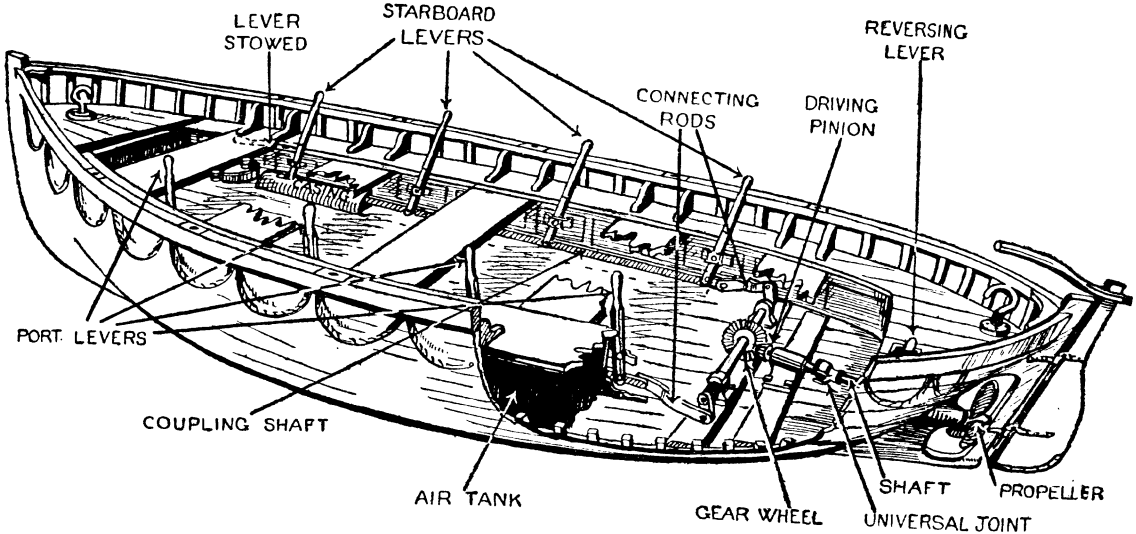
Among others Wouldhave sent in his model, and it took the fancy of the committee to the extent that they offered him half the award. He appears to have been somewhat annoyed at this, contending that he was entitled to all or none, but he showed his good spirit by leaving his model with them, although he refused the guinea. He did this because, so he said, he knew that its good points would be adopted, and his aim was not to secure the award, but to save lives.

The next thing that happened was that Mr. Fairles, the chairman of the committee, and a colleague named Rockwood, after studying all the models sent in, adjourned to a brickfield, where they made, in clay, a model which seemed to them to embody the best features of all. They then instructed a boat-builder named Greathead to build a boat to their design. It embodied some of Wouldhave's ideas, although not his great discovery of the self-righting principle. This, the first specially built lifeboat, was completed in 1789 and continued in service for forty-one years, that is until 1830, when she was dashed on the rocks and broken in two. She saved hundreds of lives and never lost a single member of her crew.

The service thus commenced has never ceased. Out of the activities of the two gentlemen just named there grew the Tyne Lifeboat Society, which is still carrying on the work. It maintains to-day four well-equipped lifeboats at the mouth of the Tyne. Its funds are derived from a voluntary tax paid by ships using the river, and it makes no claim for public support. Needless to say, the larger institution, the Royal National Lifeboat Institution, is only too glad to leave that little part of the coast to the care of this local society.

What, then, was this boat like? Her ends were alike, so that she could be rowed equally well in either direction. She had no rudder, but was steered by an oar at each end. Along each side of her was a thick belt of cork fastened on with copper bands, but she had no air cases and no means of getting rid of water except by baling. Her crew consisted of ten rowers, who sat two abreast, and a man at either end with an oar for steering.

At a later date certain improvements were introduced, including tubes for letting water out. A sister boat, built in 1800 and stationed at Redcar, actually



THE FLEMING LIFEBOAT.

Only one skilled seaman is required to work this boat; he has only to steer. All the "rowing" is done by means of levers, which cannot get lost or smashed, as oars would be on leaving a sinking ship in rough weather. A good crew can thus be formed from the passengers themselves, and a speed of over three miles per hour can be maintained.

went out to a wreck and rescued the crew as late as 1880, after eighty years of service.

These early boats had a curved keel, and for local reasons this is still a feature of boats of this society, although it is not in favour elsewhere. Even the latest boat of the society has only low air cases, so that it is not self-righting, but it has air cases along the sides "inboard" to give it greater buoyancy. Like its forerunner, it is steered by an oar and is fitted for rowing only.

A comparison of the series of boats used at the mouth of the Tyne shows remarkably little change, indicating, not that the society are lacking in enterprise, but that for those particular local conditions the pioneers did so well as to leave little room for improvement.

The success of the lifeboat on the Tyne resulted in her builder receiving orders for similar craft from many different sources, so that by the year 1803 he had built eighteen for various parts of England, five for Scotland, and eight for foreign countries. These boats appear to have been very similar.

A few years later, in 1807, our old acquaintance, Lukin, comes into the story once more. He was consulted by the Suffolk Humane Society about a type of boat suitable for use on their coast, and with them he evolved a craft a feature of which was to be that it should be capable of sailing, all lifeboats up till then having had oars only.

Even at the present day the Norfolk and Suffolk fishermen who form the lifeboat crews prefer a special type of boat, which is therefore known as the Norfolk and Suffolk type. No less than eighteen of these are in use and they are lineal descendants of the one designed by Lukin. She was 40 feet long, 10 feet wide, and 3 feet 6 inches deep. She cost £200, lasted 43 years, and saved 300 lives; not a bad record for the first boat of a type.

From 1802 onwards the Society of Arts interested themselves in the subject, and gave a number of awards to various people for suggestions for improving the lifeboat. Nothing very striking seems to have resulted.

In 1824 there occurred an event which has had the greatest possible effect upon the development of the lifeboat service. At that time there lived in the Isle of Man a gentleman named Sir William Hillary, Bart., a man possessed of a kind heart, public spirit, and determination. In the rough weather to which that island is subject he had seen many shipwrecks, and he determined to devote his time and energy to doing what was possible to mitigate its effects. Gathering together a number of like-minded men, he called a preliminary meeting at the City of London Tavern. This meeting was presided over by Mr. Thomas Wilson, one of the members for the City of London, and a number of other influential gentlemen were present. They determined that an Institution should be formed for the provision of life-saving apparatus at suitable points upon the coast, and decided to call a larger meeting in order to give the Institution a good start.

At this larger meeting Dr. Manners Sutton, the Archbishop of Canterbury, took the chair. The famous philanthropist Wilberforce, always to the front when some great movement for the benefit of mankind was proposed, was one of the speakers.

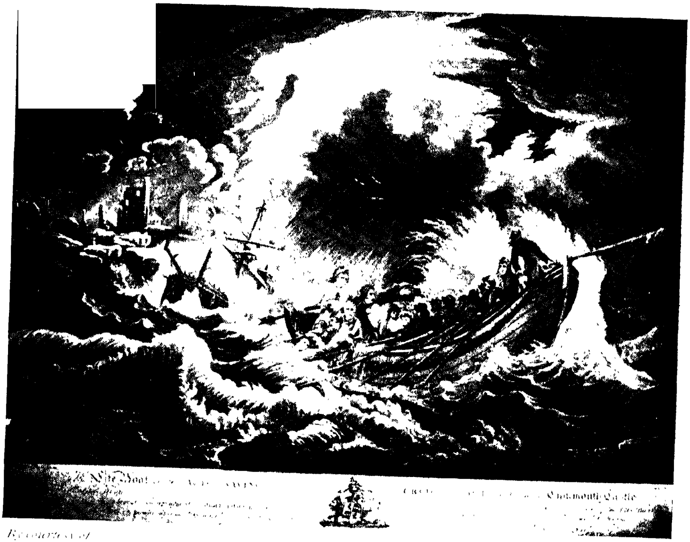
Thus was formed "The National Institution for the Preservation of Life from Shipwreck." The King himself became Patron, with the Prime Minister of the time (the Earl of Liverpool) as President; while eminent men such as Peel, Canning, and Lord John Russell were Vice-Presidents.

It is pleasant to note that Lukin, by then an old man of eighty-two, also took a great interest in the founding of this society which we now know as the Royal National Lifeboat Institution.

To commence with, the Institution cared not only for the lifeboat service, but also for the mariners themselves after their rescue, as well as the rocket apparatus. The care of the rescued men was taken over in 1854 by the Shipwrecked Fishermen and Mariners' Society; while in 1855 the rocket apparatus passed under the control of the Board of Trade.

Prior to the transfer just mentioned the Shipwrecked Fishermen and Mariners' Society possessed several lifeboats which, however, they handed over to the National Institution, so that, while they continue to work in close alliance, each society has its own clearly defined duties.

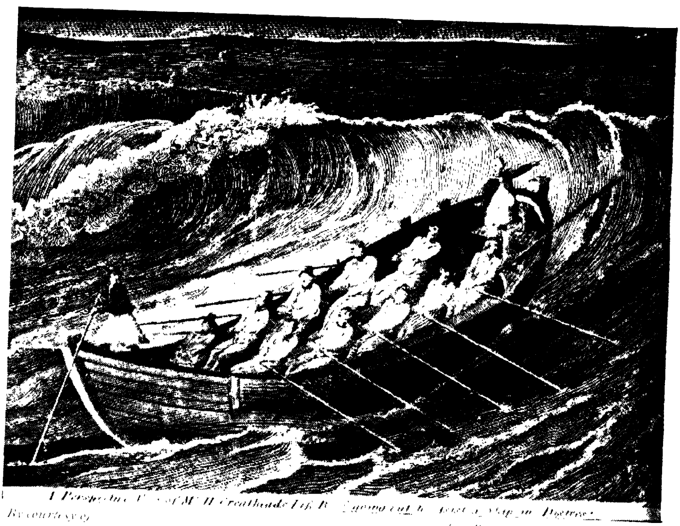
Although it was thus launched under very hopeful conditions, with many influential people to support it, the Institution did not for some years have a very



By courtesy of

The Royal National Lifeboat Inst.

A LIFEBOAT RESCUE NEAR TYNEMOUTH CASTLE AT THE END OF THE EIGHTEENTH CENTURY



By courtesy of

The Royal National Lifeboat Inst.

THE "ORIGINAL"

This early boat was built by Greathead in 1790 and was the first regular lifeboat to be stationed on the coast.

prosperous career. The explanation of this is that the country at that time was in a very unhappy state. From about 1825 to 1850 the condition of Great Britain was about as bad as it has ever been—wars, riots, famine, political unrest, strikes, and want of employment, all combined to make the time bad. During this period Mr. Fairles, the founder of the Tyne Lifeboat Society, was actually killed during a riot.

It is easy to see that an institution depending entirely upon voluntary support would find itself hard pressed for funds in such a period, and it is stated that in the year 1849 of all the lifeboats on the coast not more than twenty were in an efficient condition.

Yet even through this time good work was being done, and it is particularly interesting to hear of an incident of 1830. It has already been mentioned that Sir William Hillary was the founder of the Institution, and that he lived in the Isle of Man. In the year just named a mail steamer, the *St. George*, was wrecked in Douglas Bay. The lifeboat was a new one and, in fact, was unfinished, some of the air cases not having been fitted ; but Sir William himself, with two friends and a crew of fourteen, put off in this unfinished craft and succeeded in saving twenty-two lives. Sir William with two others was actually washed overboard, but managed to get back, and continued his work in spite of a crushed chest and broken rib. It is said that this was but a sample of the kind of thing which might be expected from the founder of the Lifeboat Institution.

The boats in use during this period were many of them built by Greathead, already mentioned, others by Pellew Plenty of Newbury, and others still by a boatbuilder named Skelton of Scarborough. None of them seems to have had surprisingly new features. They were all well-designed boats, with plenty of stability, reinforced by strips of cork to act as fenders, and masses of cork, and in some cases air cases to give increased buoyancy. None had up to this time the self-righting properties which Wouldhave had discovered how to obtain.

This lack was impressed upon the public mind by a sad event which happened in 1849. The brig *Betsy* of Littlehampton went ashore upon a sandbank near the mouth of the Tyne, and the lifeboat *Providence* went to her assistance. She reached the wreck and was made fast to her by a rope, when a wave recoiling from the wreck suddenly lifted the bow of the lifeboat right up, throwing the crew and a mass of water into the stern. Before things could be righted the rope which was holding her gave way and she drifted into a more exposed position where another wave completed the disaster by turning the unfortunate lifeboat right over—end over end—after which she drifted ashore bottom up. Of her crew of twenty-four, consisting of some of the finest pilots and seamen of the river Tyne, only two survived. Twenty-two men were drowned.

Fortunately, at this time the country was emerging from the period of trade depression and distress in which she had been for so long ; money became more plentiful, and the Institution was in a position to grapple with the problem thus tragically announced.

In the year 1851, the Duke of Northumberland became the President of the Institution, and he at once realized that the great need of the moment was an improved design of lifeboat. He therefore offered a reward of 100 guineas for the best model sent in to a competition. Models came from all over the world, not only British, but French, German, American, and men of other nationalities vieing with one another in this interesting contest. No less than 280 models and plans were submitted, fifty of which were exhibited at the Great Exhibition of London, thereby rousing great public interest in the matter.

To decide which was the best out of such a number was a very difficult task, but it was undertaken by a committee of men expert in seafaring matters, presided over by an experienced captain in the Royal Navy.

They awarded the prize to James Beeching of Great Yarmouth, who at once built a boat in accordance with the prize design. This was purchased by the Harbour Trustees of Ramsgate, where she did valuable service for many years.

It seems a pity that poor Wouldhave did not live to see this boat, for she embodied nearly all his ideas, besides of course newer ones. She was the first really self-righting lifeboat ever built. Wouldhave, indeed, like many other inventors, was in advance of his time. No less than sixty-two years intervened between the day when he handed his model to the committee at

South Shields and the day Beeching's boat was launched.

This historic craft was 36 feet long, 9½ feet wide, and 3½ feet deep. She could carry about seventy persons.

Great buoyancy was secured by a large amount of enclosed air space. There was a large air case at each end; other cases in the bottom, between the floor or deck and the skin of the boat and to some extent round the sides. Stability was ensured by the use of a closed tank under the deck in the centre of the boat which was filled with water, giving her no less than 2¼ tons of water ballast, besides a heavy iron keel.

Water ballast had been used before, as in the case of the lifeboat which was lost while trying to succour the *Betsy*, but it was then in an open tank, so that when the boat was thrown over it ran out, and the tank became an air space giving added buoyancy in the wrong place and helping to maintain her in the capsized position. Beeching closed his tank completely so that this could not happen.

Another important feature of the new boat was that the air cases round the inside were omitted in the middle of the boat. Air cases at each side at the widest part of a boat obviously tend to prevent her from righting herself. They tend to give considerable stability when she is upside down in the water. So Beeching cut them out, getting his buoyancy nearer the ends where the boat was narrower.

The end cases, too, following Wouldhave's suggestion, he raised high up, so that when capsized the boat should by them be lifted high in the water and given an irresistible tendency to " topple over " into her correct position.

Another feature of this boat was that it was self-emptying. Holes were provided in the bottom to let out any water which might find a way in. At first sight this seems ridiculous, and one is tempted to exclaim, " Surely such holes will let the water in and she will sink." The explanation is that the enclosed air cases give such buoyancy that under all conditions the deck is above the level of the water outside. Tubes, therefore, which communicate from the level of the deck downwards into the water below will drain the boat without endangering her in any way. At first these were just tubes, but it was found that the water used to splash up them in rather an annoying way, so that now non-return valves are fitted in them, which allow the water to run out but prevent any coming in.

It is interesting to notice in this boat, as in so many other structures, the spirit of compromise. To make a boat as stable as possible calls for as much enclosed air space as possible, not only at the ends but everywhere, and as much width as possible. To be self-righting the air chambers must be as near the centre-line as possible and the boat as narrow as may be. One could make a boat which, while perfectly self-righting, would be continually turning over ; or, on the other hand, one which it would be very hard to turn over, but which would not under any conditions right itself. Each of these alternatives would be comparatively easy, but to combine the two calls for great skill and judgment.

The lifeboat of the present day follows fairly closely along the lines thus laid down by Beeching, but it took time for his skill and wisdom to make itself fully felt. Although the committee gave him the award, they thought they could improve upon his design in certain respects, so they commissioned one of their own number, Mr. Peake, Assistant Master-shipwright at Woolwich Dockyard, to make still another design.

This boat was subjected to the most exhaustive tests, with the result that the excellence of Beeching's design was finally recognized. It had been feared that the air cases which he proposed would become punctured and would thereupon lose their buoyancy. This was overcome by subdividing them to a very considerable extent, so that in the event of damage to any one, the effect would be small. For a similar reason, the water-ballast tank was fitted with a number of water-tight partitions.

It may be interesting at this stage to enquire why water ballast is used at all in a boat of this description. The reason is that it enables the boat to be lightened for transport. The water can be emptied from the ballast tanks while the boat is being taken to the scene of operations, and when we remember that the ballast weighs over two tons, it is apparent how important a consideration this is. Those particular boats which never require to be moved on land are frequently fitted with a heavier iron keel and have no water ballast.

Roughly two-thirds of the boats belonging to the Institution are self-righting. About one hundred, however, are of various types in which the self-righting principle is not embodied. The policy of the management is, before installing a boat at any particular point, to consult the local fishermen and others who will form the crew, and to give them the kind of boat which they prefer. These experts, in some cases, consider that a non-self-righting boat is best. The high air cases at the ends, for one thing, must make a boat awkward to handle at times, and there are other considerations which lead them to prefer a good strong stiff " handy " boat, with plenty of buoyancy, but not self-righting. The root of the matter seems to be that they have such confidence in their own seamanship as to regard capsizing as out of the question. Instead of having a boat which will right itself after being capsized, they put their trust in their own skill to prevent it ever capsizing. Much, of course, depends upon the nature of the coast where they work, and so we find self-righting boats chosen at some places and non-self-righting at others. The existence of a special type, non-self-righting, already mentioned as being used on the coasts of Norfolk and Suffolk, is an example of this.

The most numerous of the non-self-righting boats is a type called the " Watson," since it was designed by the famous yacht designer, Mr. G. L. Watson, who it may be remembered designed several of the challengers for the America Cup. These boats have beautiful lines, air cases at each end very little higher than the gunwale, air cases all round inside above the deck and under the seats. They are wide compared with their length, and the ballast, in the form of a heavy iron keel and a water tank, is largely concentrated in the middle of the length of the boat. They are very good sailing vessels and very safe.

We see, then, that there are two main types of lifeboat, self-righting and non-self-righting, and that the latter is divided into a number of sub-types or classes. We will not dwell upon these latter distinctions, since it requires a skilled seaman to appreciate the differences.

We all know from our own experience parts of the coast with tall cliffs and with deep water almost to their feet, except, perhaps, for a barrier of rocks, themselves the remains of older cliffs. On such a coast, wrecks can hardly occur except close in, and a lifeboat stationed in a convenient crevice in the cliffs will not have far to go to reach any vessel in distress. There the oars will serve, with occasional help from sails, to propel the boat, and one of the self-righting type is the appropriate vessel.

On the other hand, most of us know parts of the coast where the beach is sandy and flat, with shallow water for a long way out, and probably strings of sandbanks farther away still. To succour a distressed vessel upon one of those far-off sandbanks the muscles of the crew can do but little. The strongest crew would be tired out completely long before they could accomplish such a journey, so that much sailing is necessary, and sails are a positive danger unless the boat can be easily manœuvred. Hence the objection to the tall air cases at the ends of the boat which are an essential feature of self-righting boats, for they offer a surface upon which wind and waves can beat.

Needless to say, in this mechanical age, motor power is coming into use in the lifeboat as in so many other spheres. The strong arms and the fine seamanship of the crews are just as necessary as ever, but the added power of an engine enables them to do more than could possibly be done by arms and sails alone.

In a later chapter we will deal with the motor lifeboat and its truly wonderful features.

CHAPTER XI

THE WORK OF THE LIFEBOATS

A GREAT deal might be written about the brave deeds of the lifeboatmen, but here we must be content with a few examples culled from the records of that admirable society the Royal National Lifeboat Institution.

First, one from the north of Scotland, concerning a sailing lifeboat.

At four o'clock one April afternoon in the year 1922 the coxswain at Thurso received a message which had been picked up by the Wick wireless station asking for aid for the steamer *Pretoria* which had broken adrift while being towed by tugs near Whiten Head, 35 miles to the west of Thurso. The position was grave because the ship was helpless and there was a strong northerly gale blowing. In half an hour the boat was launched, and in three and a half hours she was near the disabled ship. Signals brought no response, and it was discovered later that the crew had been taken off earlier by one of the tugs. The lifeboat stood by, however, for a considerable time, during which the weather got worse and worse, so that it was not until 6.30 the next morning that she got back to her station, having been afloat for fourteen hours, during which time she had covered no less than 70 miles.

Meanwhile the same call for help had reached the lifeboat station at Longhope in the Orkneys. This boat was afloat in so short a time as ten minutes after the receipt of the call, and in four and a half hours had covered the 45 miles which lay between her station and the place where the disabled vessel was reported to be. Search proved in vain, and after cruising about for an hour the lifeboat returned, having been out thirteen hours and having covered about 90 miles.

Rather tame stories, you may think. There was no triumphant return with a load of rescued people. No additions were made to the long list of lives saved by the lifeboats. Just two wasted journeys and nothing more.

All that is true, but they serve to show us the kind of work which the lifeboat men are frequently doing, work which scarcely gets mentioned in the papers, with no photographs of the crew or public recognition, work which just forms the normal routine, one might almost call it, of the lifeboat men.

Yet think for a moment of what it means. On a rough, cold night, with a gale blowing and heavy rain pouring down, the sort of night when we are thankful to stay indoors by the fire, these men were out upon the sea. For thirteen or fourteen hours did they endure cold and hardship such as few landsmen are ever called upon to endure in the whole course of their lives, and, correctly speaking, they were completely successful, for they accomplished their appointed task, which was to go to the spot where the disabled boat was said to be, and in the course of doing so they must surely have come near the record for distance travelled.

The journal of the Institution is full of accounts such as this. In some cases the errands are fruitless, in others a few men are brought back from what would probably have been certain death, but they "make no song about it."

Listen now to this story told at the Annual Meeting of the Institution for the year 1922.

"On Sunday evening, the 15th of January, the trawler *James B. Graham*, of Hartlepool, with nine men on board, went on the rocks of False Emanuel Head, on the north side of Holy Island, off the Northumberland coast, during a strong south-east gale, heavy sea, and snowstorms. She burnt signals of distress, and these were seen at the lifeboat station on the other side of the island. It was then eight o'clock. The crews of the lifeboat and the coastguard life-saving apparatus were summoned and the 'apparatus' was hurried across the island. The trawler was found lying in a very perilous position with a heavy list and the seas breaking along her decks. The apparatus was taken as near as possible, but it was too far away by 100 yards. No rocket could reach the vessel.

"Meanwhile the whole of the village, men and women, had turned out to launch the No. 1 lifeboat. The tide was low, and the wheels sank deep into the mud. It was only with extreme difficulty and by the gallant efforts of sixty helpers that the boat was launched. Undeterred by the bitter cold, the women waded out waist deep into the sea, and just forty minutes after the alarm had been given the boat was afloat. The distance around the island to False Emanuel Head was nearly four miles, and it was close upon ten o'clock when the lifeboat reached the stranded vessel. She lay surrounded by dangerous rocks and by the iron remnants of an old wreck. Among these the lifeboat would have to make her way in the pitch darkness and the blinding snow squalls if she were to rescue the crew. The coxswain made the attempt, but owing to the rocks he was compelled to pull out again. The lifeboat then lay off for two hours waiting while the tide rose. The coxswain then tried to approach the wreck from the other side. Again he had to pull out. The rocks were too dangerous. He waited another hour, and then, with his anchor dropped, he veered the boat slowly and cautiously down towards the vessel and in between two rocks, in the hope of reaching her.

"By skilful and daring seamanship this dangerous manœuvre succeeded, and all nine men on the trawler were safely taken aboard the lifeboat She was then hauled out from among the perilous rocks and reached her station again at two o'clock in the morning."

All lifeboat journeys do not have the happy ending of the two stories already told. Perhaps the saddest of all occurred in December, 1886, off the Lancashire coast.

A German barque, the *Mexico*, of Hamburg, having made signals of distress, the lifeboats from Southport and St. Anne's put out to the rescue. The wind was high and the tide, it so happened, at that particular time was causing currents in the opposite direction. This opposition of wind and tide caused very heavy seas which made the conditions particularly dangerous to any boat.

The signals of distress were observed at Southport about nine o'clock in the evening. The lifeboat crew were at once summoned, horses were procured, and the boat was transported on land about 3½ miles to a spot near to and suitable for approaching the wrecked vessel. There the boat was launched.

By about one o'clock she was near the wreck, and lowering her anchor the coxswain intended to let her veer down upon it.

Just at that moment a very heavy sea struck her and she capsized. At least six, and possibly nine, of her crew were entrapped underneath her, and she did not right herself.

Two hours later the unfortunate boat was found upon the shore with three men under her. Another man was found lying upon the beach with life almost gone; he did not survive many hours; while yet another was found in a dazed condition standing up to his knees in the sea close to the shore. Although taken to hospital, he too succumbed. Of the whole crew only two survived. These two appear to have been more fortunate than their fellows in that they escaped becoming entangled with the oars and gear, and, clinging to the upturned boat while she drifted ashore, they were saved. They were too dazed and weak themselves to render any assistance to the others.

Why the lifeboat did not right herself as she should have done was the subject of an official enquiry, but the question can never be answered. The fact that the anchor was just being let go when the accident occurred may have had something to do with it, and also the fact of men hanging on to the outside of the boat may have had an effect.

The same signals of distress were perceived at the neighbouring town of St. Anne's about 9.15, and by 10.15 the St. Anne's boat had been launched. What happened then no one knows. Towards noon the next day the boat was found bottom up upon the beach. She would necessarily capsize when she ran on to the sand, but whether she was capsized before or not can never be told, since all her crew were drowned.

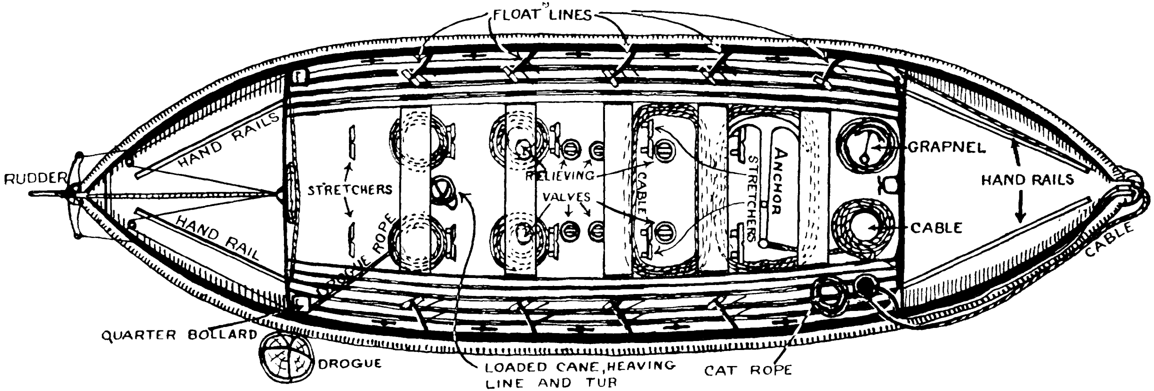
Two very pathetic features came out at the official enquiry into this sad occurrence. The coxswain who was in command was actually suffering from consumption, and had been told by the doctor that he could not live past the spring. Another man of the crew had fallen upon hard times and had, it turned out, been stinting himself of food in order that his children might be well fed. He had only had a basin of gruel the whole of the day previous to going out upon this heroic errand. Whether or not the lack of physical fitness on the part of these men had anything to do with the catastrophe is impossible to tell.

Meanwhile the lifeboat from Lytham, a little seaside town close to St. Anne's, was launched at 10.5, in the mouth of the river Ribble. After being rowed down for about a mile and a half the sails were set and she proceeded under canvas towards the wreck. About a quarter of a mile from the stranded ship sails were taken down and oars resorted to once more. Four or five times during this period was the gallant lifeboat completely smothered by the waves, so that momentarily she was under water. One heavy sea threw her over and broke three oars, but she managed to get alongside and succeeded in rescuing the crew of the wrecked vessel.

She neither saw nor heard anything whatever of the other two boats. As soon, however, as it was known that the others had not returned she put to sea again and, together with the lifeboat from Blackpool, engaged upon an unhappily fruitless search for her less fortunate sisters.

It is a significant fact that while the Southport and St. Anne's boats were in quite good condition and worthy of their place in the service, the Lytham boat, which succeeded where they failed, was much newer, in fact this was her first piece of active service. No doubt she had improvements which the others did not possess, and her superiority simply illustrates the constant development which the lifeboat was and is still experiencing at the hands of the Institution.

Here is a happier story. In September, 1896, the



DECK PLAN OF A SELF-RIGHTING LIFEBOAT

This plan shows the manner in which the gear is stowed on board a lifeboat. Note the relieving valves, which keep the craft ree from water.

Russian barque *Anna Precht,* carrying a crew of twelve and bound for Yarmouth, struck very rough weather and endeavoured to seek a safe anchorage. She failed in this, however, and ran aground upon a sandbank. Before she had time even to make a distress signal she went to pieces, but three men were able to get into a small boat, although they had not time to procure oars. Trusting themselves thus to the mercy of the waves, they drifted until by good fortune the coast-guard at Caister caught sight of them. Quickly though the lifeboat was launched after being called by the coast-guard, they were not in time, for the little boat was thrown upon the shore, where, fortunately, the three men were rescued and cared for. From them it was learned, however, that there were nine others somewhere, so out the lifeboat went, in the hope that they too might be saved.

First they found the captain of the barque and got him safely on board. Then, searching around among the wreckage, itself a source of no little danger to the lifeboat, they discovered a boy lashed to some timber ; him they untied and took on board. Further search revealed four more men who were also saved. By this time, of course, the lifeboat men were drenched to the skin and nearly fagged out, but still they kept on searching.

As an illustration of the personal danger and risk which the individual men have to take, it may be mentioned that most of the rescued were in a state of utter exhaustion, and members of the crew had actually to leave their boat and clamber about upon the wreckage in order to get hold of them.

Most cases calling for the aid of the lifeboats are small sailing craft, but sometimes even big liners need help. In March, 1907, in a dense fog, the White Star boat *Suevic* with 524 people on board went ashore on the Maenheere Reef off the Lizard. There was a strong wind at the time and a heavy sea.

Distress signals roused the lifeboats at the Lizard and at Cadgwith, while telephone messages called the boats at Coverack and Porthleven. A well-found vessel like the *Suevic* had, of course, her own boats, and by the time the first two lifeboats arrived two of these had been launched, full of women and children. The officers in charge of them, however, had no local knowledge and had they been unguided these two boats might well have met with disaster upon that rocky coast. As it was the Lizard lifeboat took one of them in tow, led her to Polpear, and then returned to the wreck. The Cadgwith boat got alongside the other, and one of her crew, a clergyman, jumped from the one to the other, so that he was able to act as pilot to the ship's boat, while the lifeboat resumed her work of rescue from the ship's side. Meanwhile the two other lifeboats had arrived, and all through the black, stormy night—for the weather got worse as time went on—these faithful little craft went to and fro until by noon of the next day every single person on that great ship had been safely landed, including no less than sixty small children.

It is interesting to note that three out of these four

Cornish lifeboats were self-righting, while one was of the other type.

And now for a change we will tell a tale of a steam lifeboat.

One night in February of 1908 there blew around the coasts of Great Britain a storm of exceptional severity. It was just one of those nights when a landsman likes to lie snugly in bed and gives silent thanks that he is not on the sea; the sort of night when the houses even far inland shake and quiver with the shocks, while occasional chimney pots fall with a startling crash, and when even seafaring men admit that it is "half a gale." (Did anyone ever hear a seaman admit a whole gale?)

On this particularly rough night the steam lifeboat at Holyhead, the *Duke of Northumberland,* had already done one errand of mercy, having been out to assist a disabled steamer, but on arriving home her coxswain received news of another steamer in difficulties. This vessel, the *Harold* by name, had tried to reach Holyhead but had failed, and was rapidly drifting upon the coast of Anglesey, and no one who knows the rocky nature of that coast can doubt what her fate would have been had she been thrown thereon.

So, having gained the comparative calm of Holyhead harbour, the lifeboat turned about and went forth once more to face the terrible seas outside.

In spite of the hurricane force of the gale, the sturdy little steamer found the object of her quest. It was almost against the cruel cliffs, and but a few yards more would have resulted in her being battered to pieces. There she hung on precariously to an anchor which just kept her off the rocks. The seas were so strong that the lifeboat dare not go near the disabled ship, but a rope was got across from one to the other and along this seven men clambered to safety, leaving two still on board. Then a fortunate thing happened: a huge wave caught the little lifeboat, lifted her up, and flung her towards the other. Had she crashed into the other both would have gone down, but fortunately she fell just short, and the receding wave and her own steam power enabled her to draw off again to a safe distance. But that brief moment when they were close together was just long enough to permit the two men left on the *Harold* to jump in safety on to the lifeboat. They must have been brave, resolute men thus to take advantage of what might so easily have been a terrible calamity, but which as it turned out was their salvation.

Having thus accomplished her mission, she battled her way back to Holyhead. The hardship of a trip such as this can scarcely be realized. The crew on deck, tossed about and drenched with water again and again as the huge seas break over the boat, and chilled by the biting wintry wind, have a time bad enough in all conscience, but they at all events have something to do, and have their attention taken up with what is going on. It was a steam lifeboat, however, and there were men down below stoking the fires and seeing to the machinery. When we remember the small size of the boat we realize what "down below" must mean. It means the closest of close quarters, stifling heat, and hard work, together with violent movements, and just the same danger as those working above. Just the same danger, yet knowing nothing of what is going on. The engine-room men have none of the excitement of striving, they have not the satisfaction of seeing success ; it is not theirs to witness the rescued come on board, a sight which must compensate for much hardship. True, they do not see the dangers either, but no doubt they can imagine them well enough, and we all know that a danger imagined is far more trying than one seen with the eyes. Altogether, it is probably true to say that of all the heroes of the lifeboat service none have a harder or more trying time than the engine-room staff of a steam lifeboat.

The motor lifeboat has a great advantage in that it does not need to be fed with fuel. Like mankind in its early stages it takes its fuel through a tube, so that it can be entirely boxed in and left largely to itself, being controlled by simple means from outside its water-tight chamber.

Let us turn, then, to the historic example of the services which only the motor boat can render—the rescue of men and women from the hospital ship *Rohilla* in the early part of the Great War.

At four o'clock in the morning of October 30th, 1914, this great vessel, of 7400 tons, with 229 people on board, "in a storm of terrific violence," went ashore near Whitby.

At daybreak the Whitby No. 2 lifeboat was taken by land to a suitable spot for launching, not far from the wreck, the journey involving lifting her over a wall eight feet high, in the course of which she was damaged. Nevertheless, she was launched and succeeded in reaching the *Rohilla*, or rather what was left of the unfortunate ship, for on going aground she broke in two and one part, with many of those on board, was lost immediately.

Surrounded though the wreck was by dangerous rocks, the plucky little boat got off twelve men and five women and brought them ashore. Not content with that she returned and brought in eighteen more, although so rough was the sea that time and again she was totally immersed in the masses of water which flung themselves upon her.

After these two trips the Whitby No. 2 was so damaged as to be out of action, and the lifeboat from Upgang essayed to carry on the work. This boat was lowered down the cliffs into the water. Needless to say, with the waves dashing against the foot of the cliffs, this was an operation attended with the greatest danger, but it was eventually accomplished and she was safely launched. Despite repeated efforts, however, she could not reach the wreck, and in the end, her crew utterly exhausted, she had to give up.

Meanwhile the Scarborough lifeboat and the Whitby No. 1 were towed out by steam trawlers, but they found it quite impossible to approach the wreck without being themselves dashed upon the encircling rocks. The Teesmouth boat also tried, but after sustaining serious damage herself was forced to put back. It had by then become evident that only a motor lifeboat could with any chance of safety thread its way among the rocks which surrounded the wrecked vessel.

So an urgent message was despatched to Tynemouth for the motor lifeboat from there. Within a quarter of an hour after receiving the call this boat was manned and on its way. After a trip of 44 miles, through the worst of weather and with all guiding lights out because of the War, she arrived at Whitby, and after replenishing her store of petrol there she sallied forth to attempt the task where already four "pulling and sailing" lifeboats had failed.

After spreading oil upon the water to mitigate the action of the waves, she made a dash at full speed past the stern of the vessel and so gained the comparative calm upon the lee side of the wreck. Here she managed to get alongside and took on board some fifty people, all, in fact, who then survived of the ship's company. With this load of human salvage she returned in triumph to Whitby. The significance of this story is that the power derived from a motor enables rescues to be carried out which are beyond the utmost power of the "pulling and sailing" boats.

In reading the stories of the lifeboat service one is struck with the number of times, when a boat has come home with her crew drenched and tired out, she has been summoned forth again in answer to a second call.

This same motor boat, the *Harry Vernon*, in 1917 went to the assistance of a steamer, the *Muristan*, which had gone ashore near Blyth (Northumberland) in a fierce gale. Though her crew were ready and anxious to help, the local boat, not being a motor boat, was absolutely unable to do anything, so terrible was the gale. The *Harry Vernon* was therefore sent for and actually approached the wreck without finding any signs of life on board.

The truth was that the conditions were so bad that the men on board could not possibly leave the shelter of the chart-house, and could not even signal their presence to their would-be rescuers. It is appalling to think what must have been the feelings of those men when they saw the lifeboat come so near and then turn and " steam " away.

What, also, must have been their delight when they saw her return. On her arrival at Blyth the coastguard reported that they had seen signs of life on board, and so, for the second time, the gallant boat faced the winds and the waves, this time with complete success, for they rescued every man who remained upon the wreck.

It would be possible to relate many more such stories, but that thrilling episode must end our tale of the motor lifeboat. May these words do some little thing to help to stir the feelings of the British public to a determination that the number of motor lifeboats around our beloved but dangerous coast shall be largely increased. We have the knowledge how to build the finest boats and the finest engines : we have plenty of hardy seamen to man them when built, we have an admirable Institution to manage them ; all that is needed is money to pay for them, and this the public alone can supply.

CHAPTER XII

THE MOTOR LIFEBOAT

IT is in the very nature of things that the motor should sooner or later be called upon to play its part in the lifeboat service.

Human muscles and sails are both of them good in their way, but both can at times be beaten by the energy derivable from a little box of mechanism fed with a few pints of oil, and in the case before us there is the important consideration that the human muscles and the sails can still be retained to a great extent while the motor power can be added.

The steam engine was naturally thought of first as the source of power for a lifeboat, and it has many virtues which fit it admirably for the work. It is so easy to control that a single cock will serve to regulate it from full speed to a crawl. A simple contrivance, which can be made so robust that it can never go out of order, serves to reverse it. It will start itself readily in either direction. It works at a speed which is just suitable for a propeller. But above all is its reliability.

A steam engine may, of course, have mishaps like everything else that is human, but while these may impair its efficiency they seldom stop it. It has been said that a steam engine may often work badly, but it will keep on doing its best until it almost falls to pieces.

Compare this with the fickleness, until quite recent years, of its rival the explosion engine. Men who are only middle-aged can remember the pathetic spectacle of the procession of motor vehicles from London to Brighton which heralded the advent of the motor car in 1896. The Brighton Road was that day strewn with broken-down machines. Still later it was a familiar sight in the City of London to see motor busses in distress every quarter of a mile.

All that has passed, however, by now. The petrol motor is almost as reliable as the steam engine and far more convenient in many ways. It was the boiler which spoilt the latter. Though a steam engine will work well under almost any conditions, it is not so with the boiler. Moreover, the boiler took up much space and gave much added weight.

Let us consider what is required of an engine for use in a lifeboat. The following are a few items from a list of conditions drawn up by the National Lifeboat Institution expressing their ideas to what a motor for use upon a lifeboat should be like :—

It must be simple, reliable, and strong in every part.

It must have not more than four cylinders, in order to avoid complications, or too many or too delicate parts.

Every part must be easily accessible.

No aluminium must be used.

The engine must work properly when tilted endwise upon a slipway to an angle of 1 in 4; it must also work well while inclined to one side at least 25 degrees permanently (when the boat is also using her sails), or momentarily to an angle of 45 degrees.

For self-righting boats the engine must have an automatic arrangement to stop the engine should she heel over to an angle of 60 or 70 degrees.

There must be an automatic governor to control the engine (quite independent of the engine-man), to prevent "racing" of the engine should the pitching of the boat lift the propeller out of the water.

Two systems of petrol feed and two separate arrangements for lubrication.

The engine to be fixed in a water-tight casing and to be capable of running for twelve hours without attention and without any need to open the casing.

The control gear to be in a standard upon the deck, but everything else to be securely stowed away under water-tight hatches.

To fulfil all the above conditions, as has been done, is indeed a triumph of engineering. The petrol motors of to-day are quite capable of doing all that is asked of them.

It must not be thought, however, that steam was not used at all for lifeboats, for the Institution had at least four in active service for a number of years. The difficulties already mentioned limited their use to places where they could remain permanently in the water since they were too heavy to launch, and they were not self-righting. They may be described as small steamers, specially built for the purpose, very strong, with many water-tight compartments.

Naturally, the first motor boats were sailing craft, with a motor added just by way of experiment. The propeller it was thought would be likely to become entangled with the wreckage which always abounds when a ship is breaking up, so it was placed in a kind of tunnel formed in the underside of the boat, an arrangement which is found to afford the necessary protection. The type of engine mostly used is of 60 horse-power, giving the boat a speed of about 8 knots. Motors are applied both to self-righting and non-self-righting boats, and so light is the machinery that (unlike the steamers) motor lifeboats can be carried upon the usual carriage and launched just like a "pulling and sailing" boat.

These motor boats are being placed all round the coast, the chief obstacle to their use being the expense, which is naturally very much greater than that of the older boats.

Anyone with a knowledge of petrol motors and their ways will be puzzled by two things. Such a motor must have access to the open air in two ways —one for the inlet of the fresh air necessary for the consumption of the petrol vapour, and the other the outlet or "exhaust" for the waste gases. How, then, can such an engine be arranged so that it will not be put out of action when it is smothered in water by waves breaking over it, or even turned right over?

The way out of this apparently insurmountable difficulty is quite simple. In the first place both the air inlet and the exhaust are duplicated in different parts of the boat, so that no matter how she may roll or even capsize, one of each will always be above water. Then an arrangement is made which prevents the entrance of water even to the one that is for a moment submerged.

In the case of the exhaust this is fairly simple, for nothing (neither air nor water) has to enter, so a simple back-pressure valve serves to keep the water out and at the same time lets the exhaust gases out. In this mechanical age most people have come across and understand the meaning of "back-pressure" valve, but it may be well just to explain that it signifies an opening covered by a door which can only open one way, so that it gives free passage in one direction, but is closed fast against anything which attempts to pass the other.

The problem is not nearly so simple in the case of the air inlet, since the air has to pass inwards, and if the air can pass in, what is to stop water doing the same? The arrangement made to meet this difficulty is beautifully simple.

Imagine a small chamber with an opening at the side and another at the top. The engine draws the air through this chamber, the air entering at the side and passing upwards. Lying in the chamber is a small hollow rubber ball which is unaffected by the air, but if water should enter it immediately floats up and stops the outlet at the top. Thus air can pass freely, but water is effectually stopped.

We see, then, that these apparently insuperable difficulties are completely overcome; the engine, whatever the position of the boat, has a free air inlet and an open exhaust pipe, and under no conditions can water enter either. Thus there is no fear of the motor becoming flooded with water.

In designing these engines everything has been done to make them reliable, for it is needless to point out that for a lifeboat motor to stop would be in most cases the prelude to a calamity. When we see, however, the way in which the airman entrusts his life to the care of a motor we realize that the motor must have reached a pitch of perfection sufficient to justify the lifeboat man putting his trust in it likewise.

It is no more difficult to drive a lifeboat engine than it is to drive a motor-car engine; in fact, the two are almost identical. There was a little difficulty at first about starting. We know how troublesome it is at times to start the engine of a car or lorry, and various arrangements were made for starting by compressed air stored in cylinders, and so on; but the 100 horse-power motors now made for the lifeboat service have a little subsidiary engine—a bicycle motor, in fact—whose one duty is to start the larger engine.

What may be termed the standard motor lifeboat is 46 feet 6 inches long and 12 feet 9 inches wide, with one 60 horse-power motor, capable of maintaining a speed of 8·3 knots, and having a radius of action of at least 50 miles.

What is known as the "Barnett" lifeboat is, however, far in advance of this. This is the largest and most powerful type of lifeboat in the world, and was designed for the Royal National Lifeboat Institution by Mr. J. R. Barnett, the Institution's Consulting Naval Architect.

The boats of the "Barnett" type are non-self-righting, but they are practically unsinkable. They are built of a double thickness of teak and are divided up into compartments by bulkheads of light steel plates. Nearly 100 buoyant air cases are fitted into the vessel at convenient places, so that this comparatively small boat has as many water-tight compartments as a modern battle-cruiser. Hence she is unsinkable.

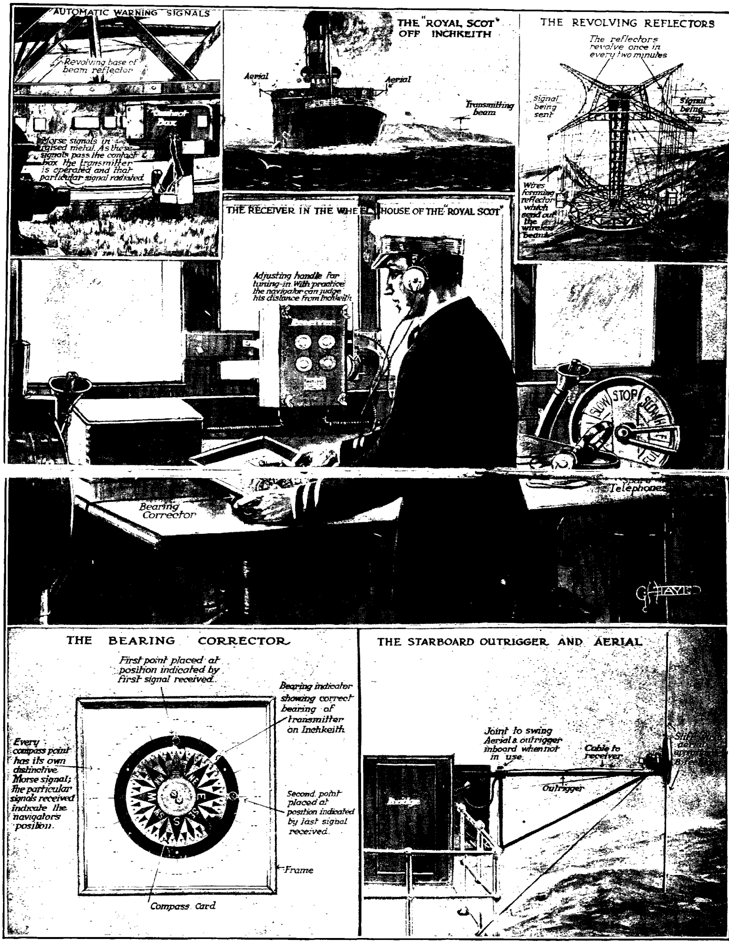
There are two motors, each of which is enclosed in a water-tight compartment, so that even if neighbouring compartments should be flooded, water would not reach the engines. Each engine is capable of giving 100 horse-power, although they will ordinarily work at 80.

Wonderful care has been expended upon the design of these machines, with the result that, although when at work they are as completely encased as it is possible for them to be, and effectively shielded against not only water, but even damp, they are nevertheless easily accessible in all parts, so that when they need overhauling it can be done with the utmost celerity, and the time during which they are out of action can be reduced to a minimum.

Another typical example of the care expended upon thinking out every detail is to be found in the cooling arrangements. As is well known, an explosion engine has to be kept cool by some external means. Very small ones are cooled by a draught of air, but all larger ones have to be cooled with water. For this purpose, jackets are formed round the cylinders and other parts which are apt to become too hot, and through these jackets water is kept in constant circulation. Now, every engine works best at a certain temperature. It is bad for it to become too hot, but it is also wasteful of the motive power—heat—if it be cooled too much, so an arrangement is introduced which has for its object to keep the cooling water at an even temperature. The heat itself opens and closes a valve through which the cooling water has to flow. If the temperature rises too high, this opens and the water circulates more quickly; if it falls too low, the valve closes, retards the flow of water, and restrains its cooling action. All this, of course, is quite automatic, so that the motorman while the boat is out upon its mission need never give it a thought.

The "Barnett" type are no less than 60 feet long, 15 feet wide, with a draught of 4 feet 6 inches. They displace 40 tons, so that they are quite large boats.

In addition to the main engines there is a smaller one of 8 horse-power which works a dynamo and an air-compressor. Just think of it—electric light on a lifeboat. Yet how easy it is for even landsmen to see the value of a powerful electric searchlight when looking for a wreck or for survivors who may perchance be clinging to wreckage or floating in the water.



DIRECTIONAL WIRELESS

The reflectors (top right-hand corner) revolve slowly, sending out "beams" of a short wave-length in the form of morse signals indicating the points of the compass. One of the signals is received by the apparatus on the ship, which then continues on her course until she runs across the path of a second signal beam. The bearing indicator between these two points on the compass card then show the exact direction of the wireless "lighthouse."

The people rescued by these boats have the shelter of cabins, of which there are two, lit by electric light and warmed by a stove. No less than 150 people can be thus accommodated. When we remember the pitiable condition in which the rescued must often be, after long hours of exposure to cold and wet, it is pleasant to think of these bright warm cabins where they can be tended and given warm food, without having to wait until the lifeboat can regain the land.

Another remarkable feature of these boats is a jumping net. A large net is spread out in a horizontal position, supported upon strong uprights in such a way that a person can jump from the side of a tall ship with a reasonable certainty of landing in the boat safe and uninjured.

The winches and pumps are worked by compressed air derived from the air-compressor already mentioned. This saves much manual labour, reduces the number of the necessary crew, and increases the space available for the succour of those who are rescued.

The speed of these vessels is 10 knots and the radius of action is given as 100 miles, but there is ample margin and both these figures could be considerably exceeded in an emergency.

There is still one interesting feature of the motor lifeboat which should be mentioned. Suppose the boat were to capsize and then right itself. The crew would be thrown into the water, but with the aid of their buoyant jackets they would probably be able to clamber on board again without difficulty, provided the boat remained there. Should the motor continue to work, however, the boat would run away and leave the men struggling in the water. To provide against this there is a pendulum arrangement so adjusted that if the boat heels over beyond a certain angle it cuts off the "ignition" and so stops the engine.

CHAPTER XIII

HOW A LIFEBOAT IS LAUNCHED

NOT only is each lifeboat specially designed for the particular coast where it will have to work; each one is housed in the most convenient way according to local conditions.

Naturally, where there is a nice sheltered river mouth or harbour accessible at all times, it is well to keep the boat always afloat, but conditions are seldom favourable to such an arrangement. Nearly always the boat rests normally upon dry land and is put into the water when required.

The simplest arrangement is where the boat-house is at the top of a steep shingly bank, for then the crew can just slide it down the shingle into the water, easing their task by placing iron plates in succession before it so that it always has a smooth surface upon which to slide.

The converse of this, getting the boat back into its house, is of course far more difficult, but it can be done at leisure, whereas the launching must be done "against time." Moreover, a winch can be called upon to help in hauling the boat home.

In some places this operation has been made easier by the provision of a well-designed and carefully constructed "slipway" of concrete or of timber, down which the boat can slide of its own weight. So well has this been schemed out that the crew can take their places in the boat while she is at the top of the incline, and when everything is ready the release of a catch will send her dashing into the water with a good start upon her journey.

As in the simpler cases, a winch comes to the aid of the crew when returning the boat to the house.

There are other instances where rails have been laid from the house right down into the water, and upon these rails the boat is conveyed by means of a trolley.

At Sunderland the arrangement is unique, since there the lifeboat descends many feet to the water by means of a lift or elevator, returning when her work is done by the same means.

When it was decided to place a boat here it was discovered that to make a slipway was almost impossible. In order to be able to place the boat in the water at low tide and yet raise it high enough to be safe at high tide a slipway of 200 feet in length would have been necessary, and no site for such a slipway was available. The first idea was to store the boat upon a floating pontoon which would, of course, rise and fall vertically with the tide, and from which a short incline would enable the boat to slide into the water. On going fully into the matter, however, obstacles were discovered which rendered this practically impossible, so the lift was devised.

The boat-house stands upon a number of tall timber piles driven into the foreshore. These are so arranged that they form two parallel jetties with a space between large enough to accommodate the width of the boat. At one end they are joined by a transverse deck, but at the other end there is nothing at all, so that the boat can be floated in between these two jetties quite safely and easily. Upon the top of the piles there is a floor or deck which forms the floor of the boat-house. Thus, on entering the house one sees a floor with a large oblong hole running from one end of the house nearly but not quite to the other end. Nearly filling this oblong is a platform, upon which the boat stands.

The platform is supported by a number of steel ropes the upper ends of which are wound round drums mounted upon the deck on either side.

A simple but strong and reliable mechanism enables eight men by turning four handles (two men to a handle) to raise the boat from the water level below to the shelter of the house. Turning the handles operates a train of tooth wheels; these in turn work what are termed "worm gears" which rotate the drums upon which the ropes are wound, thereby hauling in the ropes and lifting the platform with the boat upon it. All this gearing produces the necessary mechanical advantage which enables a small number of men to raise so heavy a weight.

The mechanism is so arranged that the boat can be lowered fairly quickly, although the raising is slow work.

At first man-power alone was relied upon for this work, but now a small petrol engine is employed.

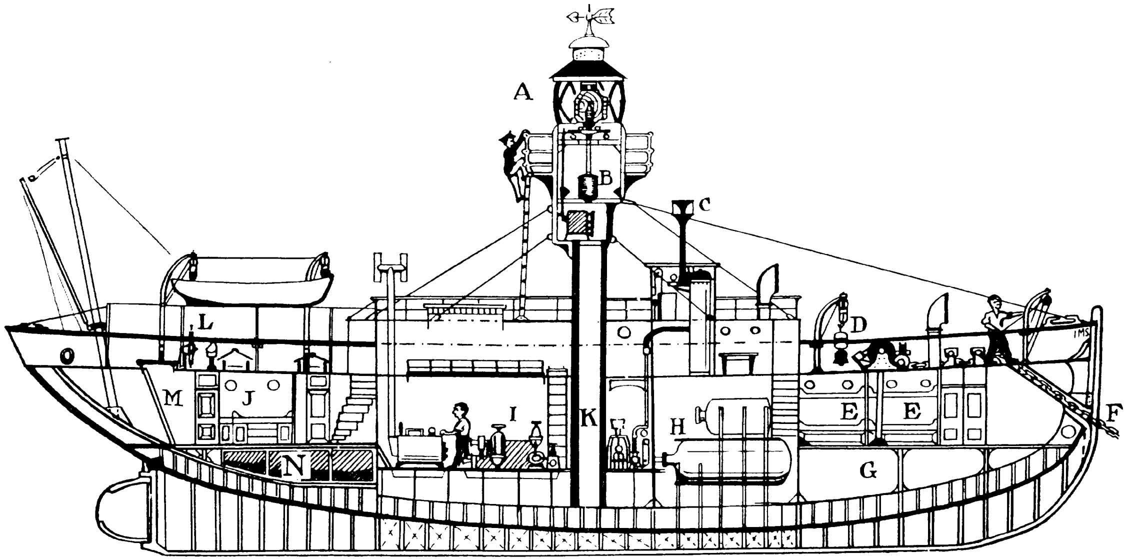
Let us in imagination watch the launching of the boat by this remarkable contrivance. The men take their seats and everything is made ready. Then the engine is started, and the platform, which till now has been level with the floor of the house, commences to descend. If the tide be fairly high the vessel is soon afloat and can pass out, but if the tide be very low the platform reaches the lowest point of its travel before the water is quite reached. Under these conditions the back part of the platform is arrested before the front part, so that it tilts in such a way as to shoot the boat off into the water. In order to prevent a premature shooting off the boat is tied, all the while, by means of a strong chain to a massive mooring bar of iron so arranged that it rises and falls along with the platform. Thus the platform tilts first, then when all is ready a catch in the chain is released and the boat slides off. Some iron rails laid on the slope of the bank assure that the boat, once started, shall slide safely right into the water.

On returning, the boat is floated in between the jetties and over the platform. The latter is then raised, lifting the boat up into the house as before.

There is a similar arrangement at Marseilles, but there the rise and fall of the tide is only about 3 feet against 14½ at Sunderland, so that the conditions are somewhat different.

There is at least one spot in Britain where the lifeboat is dropped into the water by means of a crane.

In most cases, however, launching is done by means of a carriage. Upon this the boat normally rests, so



A MODERN LIGHTSHIP

This section shows: A—the lantern. B—the pendulum which keeps the light upright when the ship is rolling. C—the siren. D—the submarine bell. EE—crew's quarters. F—the mooring. G—chain lockers. H—gas and air reservoirs. I—machinery room. J—officers' cabin. K—hollow steel mast. L—steering wheel. M—rope lockers. N—water-tanks.

that it is ready to be hauled to wherever it may be needed. It is clear that the best spot for the boat to be launched may vary from time to time. One place may be sheltered from one wind, and another place from a different wind. One launching place may be best if the wreck lies to the north, and another if it lies to the south. The state of the tide may also make a difference. Moreover, cases arise where it is worth while to take the lifeboat miles along the coast by road before launching her, so that she may be put into the water at the most suitable place for approaching the wreck.

The carriage has therefore to be suitable for moving along a road. It also has to be suitable for crossing the beach of sand or shingle, as the case may be. For this reason the wheels are sometimes fitted with a curious kind of tyre formed of a chain of iron plates so connected that each one in turn comes flat upon the soft sand, producing the same effect as would be produced by laying a track of plates for the wheels to run on. This reduces the sinking in the soft sand or shingle.

When we think of these long journeys by road and difficult movements across shingle or sand we realize the importance of the ballast being to some extent of water, as already mentioned. Were it of iron it would have to be carried about unnecessarily, but being water it can be put in at the last moment and emptied out while the boat is travelling.

The old way of pulling the carriage is by a team of strong horses, and in some coast towns a local horse owner makes that his contribution to the lifeboat service; he turns out, whenever needed, a team of powerful cart horses to haul it along. The more modern practice is to have a motor tractor with caterpillar wheels, the type of wheels made familiar to us all by the "Tanks" which did so much in the War.

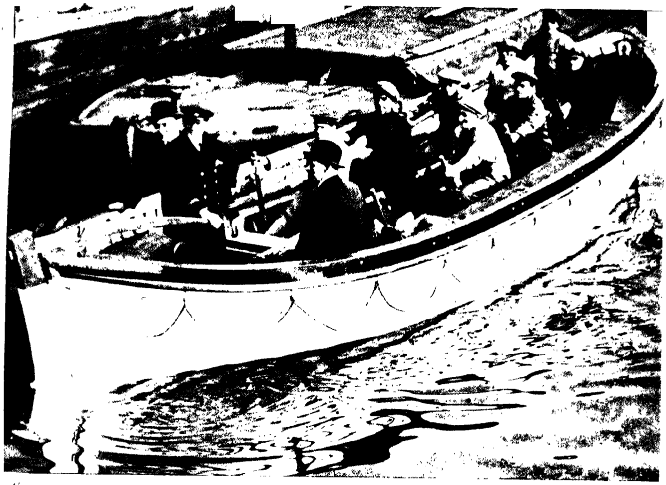
Not only has the tractor the advantage over horses that it is always ready, but it can push the carriage as well as pull it, which, as we shall see, is a matter of considerable importance.

The carriage is, of course, a very special type of vehicle; it is specially designed for its work, and forms almost a part of the lifeboat itself.

There are two large main wheels and a fore carriage with smaller wheels. Between these pairs of wheels is a little slipway upon which the boat may rest securely when properly fastened, but off which she can slide easily when desired to do so. The boat overhangs the carriage at the back, so that the greater part of the weight comes upon the two main wheels. The boat travels when on its carriage "rudder first."

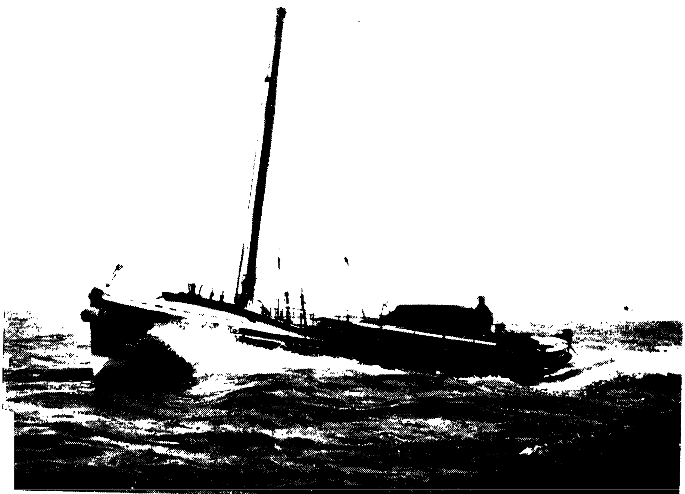
To launch the boat, the carriage is drawn by the horses down the beach as far as is practicable and then turned round so that the boat may take the water bow first. The act of turning brings the boat away from the water somewhat, so the horses are then hitched on to the carriage the other way, some on each side, and the carriage is thus moved backwards further towards the water, men and horses walking in the waves as far as they dare.

That is where the tractor shows to advantage, for



The Fleming Lifeboat

A scratch crew manning the levers, the working of which is explained by a diagram on page 149. She can be propelled by any people who may happen to be in her—stokers, passengers, cooks or seamen—without danger of breaking or losing oars.



By courtesy of *The Royal National Lifeboat Inst.*

The Watson Motor Lifeboat

his boat has cabin accommodation for the rescued and is driven by an 80-horse-power motor.

it can not only pull but push. It tows the carriage down, turns it round, and then proceeds to push it from behind, thus enabling it to place the boat further into the water than it is possible for horses to do.

When the carriage has thus been turned and moved as far seawards as possible, the fastenings are released and the boat launched off the carriage into the water. In some places a mooring ring and buoy are fixed permanently out to sea, and the men by pulling upon a rope attached to this buoy are able to pull themselves seawards. In other cases ropes and pulleys upon the carriage enable helpers ashore to launch the craft upon her journey.

CHAPTER XIV

THE "ROCKET" APPARATUS

WHEREAS in Great Britain the lifeboat service is maintained and controlled by a private "Institution" which derives its funds solely from voluntary contributions, the rocket apparatus falls to the care of a Government department, the Board of Trade.

Another example of the "makeshift" arrangements under which the British like to be governed, this is a "Board" in name only. Once upon a time it had some members, but nowadays it consists of a "President" who acts upon his own authority, subject only to that of the Prime Minister and Cabinet, of which body he is a member. Among his duties is the control of all matters relating to merchant shipping, and this includes the coast-guards. This admirable body of men are almost ideally fitted to have charge of the "Rocket Life-saving Apparatus."

Let us first see what the apparatus is. Its purpose is to pass a rope from the shore to a wrecked vessel and then to haul to and fro along that rope a little vehicle by means of which shipwrecked people can be carried to safety. Clearly, this is only possible when the wreck is within a certain limited distance of the shore, and mention has already been made of a case where the apparatus was tried, but the wreck was found to be beyond reach. On the other hand, wrecks close in upon a rocky shore are particularly difficult and dangerous for a lifeboat to approach, so that the apparatus and the lifeboat go together exceedingly well, each one making good to some extent the limitations of the other.

The chief problem, then, is to get one end of the rope on board the wreck, and for this purpose a large rocket is employed. The fifth of November has made most of us familiar with the form of a rocket. It consists of a tube closed at one end but open at the other, inside which is packed a quantity of some slow explosive. A fuse fixed to the open end enables us to set fire to this explosive, with the result that a powerful jet of hot gases issues from the open end of the case.

Now, when you go to the swimming bath and jump off the end of the spring board one effect of your effort to jump up is that the end of the board goes down. In just the same way the hot gases rushing out at the open end of the tube cause a pressure *in the opposite direction* upon the closed end, so that the rocket tends to move *closed end first.* In order to make the rocket move steadily a stick is fastened to the tube, so that as the rocket rushes along it trails behind and, as it were, steers it along a steady course.

Needless to say, the rocket used for carrying a line to a wrecked ship is very different in size from those we send up on "Guy Fawkes Day." The length of the stick—which is 9 feet 6 inches—is enough to indicate that fact. It differs in another way, also, in that it has two tubes instead of one. These do not, however, go off together, but in succession. A fuse is so arranged that as one is nearly burnt out it sets light to the other, which thereupon commences to burn. Thus the range of the rocket is considerably increased.

The most powerful rocket could not carry out to the ship a rope strong enough to bring the people to safety, so that has to be done by stages. The rocket first takes out a comparatively thin line, about a third of an inch in diameter, known as the "rocket line." This is about 500 yards long.

The rocket is fired from "the machine," a long trough-like object in which the rocket can lie. The rear end of the machine is pointed so that it can grip the ground firmly, while the front end is supported by two short, light legs. The trough itself and the two legs thus form a tripod somewhat like that of a camera, except that one "leg" is much longer than the others. Its excess of length over that of the legs causes the trough to stand at a slope just about right for launching the rocket upon its journey, and the precise slope can be adjusted by shifting the position of the legs. A graduated quadrant and a little hanging weight enable the operator to adjust the slope to a nicety.

Lest the hot gases from the rocket should set the line on fire, the first 20 feet or so are always wetted just before the rocket is fired.

It is of the utmost importance that as the rocket draws it from the box in which it is kept, the line should run out perfectly freely, without a suspicion of entanglement. This is secured by a beautifully simple but efficient arrangement. In the bottom of the box are a number of holes and through these wooden pegs project upwards, nearly as high as the box is deep. The line is not coiled, but is wound to and fro round and between these pegs, forming a very close zig-zag. Confusion between layers is avoided by winding each successive layer at right angles to the one beneath. When the lid is placed on the box the line is thus held perfectly securely without the slightest possibility of becoming entangled, but, of course, in pulling out it would be very liable to catch upon a peg, the result of which would be disastrous. This is overcome by fixing the pegs, not in holes in the box, but to a frame which can be clipped underneath the box. Just before the rocket is fired this frame is removed, all the pegs are withdrawn, and the rope while still lying in perfect order is perfectly free to run out with nothing upon which it can possibly catch.

When the rocket passes over the wreck, the rocket line of course falls upon the deck of the ship and is secured by the people on board. Naturally, they pull it in and by so doing carry out the "whip." This is a heavier rope, about half an inch in diameter. It is 500 yards long also, but its ends are joined together so that it forms a loop 250 yards long when stretched out. The "whip" is threaded through a pulley block having a single pulley, and it is to this block, called the "tail block," that the rocket line is attached, so that the first thing which comes on board when the rocket line is pulled is the block. To this is attached a wooden tally with an inscription upon it in English, French, German, and Norwegian. The English wording is as follows: "Fasten tail block to lower mast well up. If mast gone, then to best place handy. Cast off rocket line. See rope in block runs freely. Show signal to shore."

When the signal shows that these directions have been carried out, the crew ashore, having already lashed the hawser to one part of the "whip," commence to haul upon the other part, with the result that very shortly one end of the hawser arrives upon the wreck. This, again, has a tally attached, bearing an inscription in four languages, the English version being: "Make this hawser fast about 2 feet above the block. See all clear and that the rope in the block runs freely. Then make signal to the shore."

On receipt of this second signal the crew make fast their end of the hawser. This is done by passing it through a block supported upon a steel tripod standing upon the shore. This tripod holds it well up above the ground, but is not strong enough to take the pull, so the end is carried further back to a special anchor which is carried for the purpose.

The hawser is the stoutest rope of all, being about an inch in diameter and 240 yards long.

There is now a strong rope, the hawser, fixed by one end to the wreck and by the other end to the shore and the "whip," an endless loop, passing from the shore to the block upon the wreck and back again. Upon the hawser there runs a little single-wheel trolley called the "traveller block," to which is attached the "breeches buoy." This block being fastened to the "whip," the crew can haul it to and fro with ease. When they pull one part of the "whip," it goes out to the wreck; when they pull the other part, it returns to the shore.

The breeches buoy consists of one of those round lifebuoys such as we often see upon seaside piers, wharves, excursion steamers, and other places where there is any possibility of anyone falling into the water. It is slung from the traveller block by means of four short cords, and from it is suspended the "breeches" from which it takes its name. These together form the vehicle by which the people on the wreck are brought to safety. The passenger in the breeches buoy gets right inside it, his legs in the "breeches" and his arms over the buoy itself. The breeches are really a pair of rather large "knickers" made of canvas. In the event of the hawser sagging and dropping the buoy into the water, there is sufficient buoyancy to keep the passenger's head above water.

A part of the equipment of the rocket apparatus crew is a number of life-lines consisting each of twenty fathoms of rope and about a third of an inch thick, and a life-belt such as lifeboat men wear. As the breeches buoy comes ashore, one man, wearing the life-belt and with one end of a life-line tied round his waist, wades into the sea to help the passenger to land. Another man meanwhile holds the other end of the life-line.

Other pieces of apparatus carried by the rocket crew include a heaving cane, a piece of cane about *19 inches long with $1\frac{3}{4}$ lbs. of lead at one end, with a* light line attached. This is to enable a line to be got upon a boat fairly near with the least possible delay. There are periodical competitions among the members of a crew to see who can throw the farthest.

There is also a rope ladder, twenty fathoms long, to enable men to get down the face of a cliff if need be, and a cane helmet to protect them from falling stones as they descend.

Then there are red signalling flags, for signalling to the wreck, fuses, port-fires, and lights for illuminating the scene of the wreck; lights which will burn brightly for nearly half an hour, besides an excellent assortment of tools for any emergency.

The whole outfit is packed either in a four-wheel wagon or a two-wheel cart, whichever is most suitable for the country in which it will be called upon to work. Further, there is a "hand bearer" for carrying the apparatus by hand, should the cart or wagon be unable to reach the spot chosen for operations. This same thing can be used as a stretcher.

The whole outfit is kept packed in the wagon or cart, in a specially built house, ready for instant use. To ensure constant preparedness, whenever it has been used it is packed up and made ready again before the crew is dismissed.

Photo. [illegible]

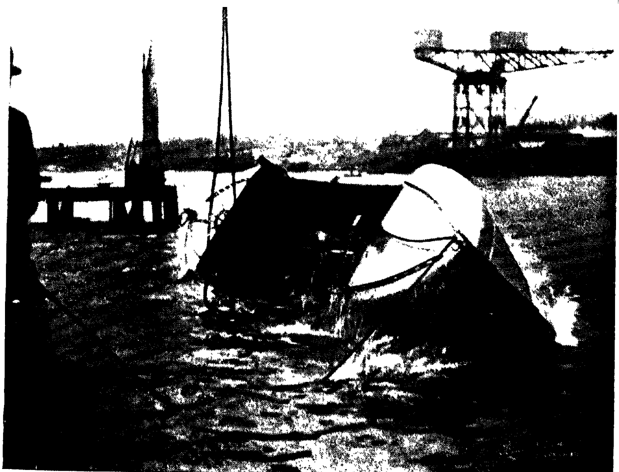
A LAUNCH THROUGH THE STREETS OF PORT ISAAC, CORNWALL

This method of launching is necessary where the shore is very precipitous.

[illegible] *Royal National Lifeboat Inst.*

LAUNCHING BY HAUL-OFF WARP

The crew is hauling the boat through the surf by means of a cable securely fixed some distance from the shore.



Photograph by *Beken & Sons, Cowes.*

TESTING THE SCARBOROUGH SELF-RIGHTING MOTOR LIFEBOAT

When the rocket station is near a coast-guard station, it is under the charge of the coast-guard; but where it is some distance from a coast-guard station, a civilian caretaker is specially appointed.

Arrangements are, of course, always made for the supply of horses for drawing the apparatus to wherever it can best be used.

The rocket company never exceeds twenty-five in number, and in some places it is impossible to have so many as that, since the men are not available. The regular members of the company then take the important posts, and others are impressed into the service when required to fill the less important duties. In cases of emergency the apparatus can be worked by a very few men.

The various duties have been carefully thought out, and each man can be told what to do in a very few minutes, so that if the company be short it is easy to make use of any help that may be available.

The regular company are called out periodically for practice. A rocket is fired at a post representing the mast of a ship and the whole series of operations is gone through, even to bringing a few make-believe shipwrecked mariners along in the breeches buoy.

CHAPTER XV

SHIP'S LIFEBOATS

PRACTICALLY every ship carries a number of small boats to which those on board can resort in the event of catastrophe to the main vessel. Originally these were simply ordinary rowing boats, but special types have been devised specially adapted for this particular purpose, with special devices for getting them into the water.

At first sight, the arrangement of these boats seems a very simple matter. The owners know just how many people there will be in the crew and how many passengers, if any, there will be on board. They also know how many people each boat will safely carry, so that it is a simple matter of arithmetic how many boats there ought to be.

As is often the case with apparently simple matters, however, the people who have to deal with these arrangements find themselves confronted with enormous difficulties. Let us try to picture to ourselves the conditions likely to exist when the ship's lifeboats are required. Probably the ship has collided with another or with a rock, so that some of her water-tight compartments are filled with water. She has therefore heeled over to some extent, and the deck, which is normally so level and easy to walk upon, is now like the side of a steep hill.

Along each side of the deck there is a row of "davits," those slender curved posts which form such a prominent feature of every large ship, and to each pair of davits there is a boat.

Along that side of the ship which is lower, at the bottom of the hill, so to speak, there is not much difficulty. The crew, by manipulating the ropes attached to the davits, can lift the boats off the deck, swing them out over the water, and lower them on to its surface. Providing the sea is calm, that is a simple, easy, and safe operation.

But what about the row on the other side ? They are tilted high up in the air. If the higher row of boats be hoisted up in the same way, it is quite probable that the davits will not reach far enough out to place them in the water, for the bulge of the ship's side will come in the way. As these boats are lowered they will surely bump against the ship, quite possibly be overturned and their occupants thrown into the water. If the sea be rough, and it often is, this difficulty will be magnified many times over.

We see, therefore, that even taking the simplest case, where there is a row of boats along each side of the vessel each with its davits ready to lower it, there is a very strong probability that one-half of these boats will, just when they are needed, be useless.

Again, that is only one of the difficulties. On a passenger ship, one row of boats along each side of the ship is not nearly enough to accommodate all the people on board. It becomes necessary, therefore, to increase this number by some means or other.

One obvious way is to make the boats to nest, that is to say fit one inside another, so that a single pair of davits can serve several boats in succession, lifting first the top one, then the next one, and so on. This is done, but it is not so simple as it looks. Were the boats just empty shells all would be easy, but to serve the purpose of lifeboats which may have to carry a number of people safely in a rough sea for many hours, something more than an empty shell is required. There must be air cases to ensure buoyancy, seats to sit upon, oars and gear, stowage for water and food. All these things must be in the boat always, ready for immediate use, not left to be put in at the last moment when hurry and excitement would surely lead to something being forgotten.

Thus, when we think of all the things which, from the very nature of things, must be continually stored in each boat, it is quite easy to see that to make them nest easily one in another is very difficult.

Another obvious arrangement is to have several parallel rows of boats along each side, so that when one of the outermost row has been lifted out another may be slid under the same davits and lifted out likewise. This, too, presents great difficulties when we come to think it over. First of all, the boats need to be very securely fixed or else, when the ship heels over, they will come sliding down upon each other, resulting in hopeless damage and confusion. For, of course, the boats used for this purpose need to be strong and sturdy, so that even the smallest of them are no light weight. So they must be securely fastened, yet must be quickly freed for use when needed, and when thus freed they must not go sliding down-hill along the sloping deck.

Given ideal conditions—namely, a steady, level deck, with no obstructions whatever—it would be quite possible to store boats in rows, slide each one in turn under a pair of davits, and lower it on to the water; moreover, every boat could thus be launched from either side of the ship, whichever was most convenient, or boats could be lowered from both sides simultaneously according to circumstances. Unfortunately, these ideal conditions do not prevail at those times when ships' lifeboats are needed.

Moreover, there is the question of the actual weight of the boats overloading the ship. Clearly, they must be kept upon a very elevated deck, so that they may be as free as possible from battering by the rough seas even when the ship is tilted over. Usually they are on the very highest deck of all, from which they are lowered down, pausing at one of the lower decks for the people to get in.

To carry too many boats, therefore, would tend to make the ship top heavy, and might even bring about a disaster instead of providing against one. When, after the *Titanic* was lost, there was a public demand for more lifeboats upon passenger ships, the owners were faced by a very difficult problem. Either they must provide more boats, with the possibility of making their ships top-heavy, or they must reduce the number of passengers carried, thereby putting up the cost per passenger and entailing an increase in fares. As is usual in such cases, when this choice of evils had to be faced, a way out was found which has proved fairly satisfactory.

In Great Britain, merchant shipping comes under the control of the Board of Trade, a Government department presided over by a Cabinet Minister. Large powers have been given to this department by numerous Acts of Parliament, and among many other things they have power to make and enforce rules for the provision of life-saving appliances on ships.

To commence with, they group all ships into no less than sixteen classes—four classes of foreign-going ships and twelve of home-trade ships—and then lay down a set of rules appropriate to each. It would be wearisome to describe all the sixteen classes, but it may be said that the first is ocean-going steamers carrying passengers, the second ocean-going steamers not carrying passengers, the third and fourth being sailing ships with twelve or more passengers and with under twelve passengers respectively.

Naturally, home-trade ships present greater variety, since some go right out to sea and undergo perils similar to foreign-going vessels; while others trade mostly or partly in smooth or protected waters, some even rarely leaving an estuary, and others, such as excursion steamers, only ply in fine summer weather. All the different classes of vessel have their suitable "class" for which suitable regulations are made.

Generally speaking, a ship's lifeboat is similar to an ordinary rowing boat except that it is more strongly built and has either "external" or "internal" buoyancy added. Internal buoyancy means that air-tight chambers, made of copper or some other in-corrodible metal, are fixed inside the boat so that she will not sink under any conditions. External buoyancy is usually produced by masses of cork fastened outside the boat. It must be solid cork, not merely pieces enclosed in a casing, lest the latter should be ripped open and the pieces leak out.

Unless the ship be small, so that its deck is not very high above the water, a lifeboat must be strong enough to withstand suspension by its ends while its full complement of crew, passengers, and gear is on board.

Every lifeboat has to be clearly marked to show how many people it is intended to hold, and there must be seats for the whole of that number. It also has to be provided with the following equipment, which must be placed in it before the ship starts and remain throughout the whole voyage :—

A full complement of oars, two spare oars, and a further one for steering ; a sea-anchor—a contrivance which tends to drag in the sea, so that when attached to the bow of the boat and thrown into the water it keeps the bow pointed towards the wind ; an iron bucket and a bailer for bailing out any water that may get into the boat ; two hatchets and a lamp.

A cord must be fitted all round the boat, attached at intervals, so that a person in the water may have something to catch hold of easily. Enough water has to be carried, in a suitable container, to provide one quart for every person on board, and a drinking mug.

Showing the minute care with which everything has been thought out, it is laid down that the lamp must be ready-trimmed and filled with oil for eight hours' burning; while all the small articles must be secured by cords so that nothing be mislaid, forgotten, or lost.

In addition to the above, every lifeboat on a foreign-going ship has to have a mast or masts, with at least one good sail (unless, of course, it be a motor boat), a good compass, an air-tight tin containing a pound of biscuits for each person, a gallon of oil to spread upon the water to calm it, a dozen self-igniting red lights in a water-tight tin, a box of matches in a water-tight tin, and one pound of condensed milk for each person.

In addition to the open type of boat, there is a type of lifeboat known as the "pontoon" type, which are decked over, with a well in the middle in which people sit. In other words, they somewhat resemble the shore lifeboats and, for the same reason as they, have to be made self-emptying. These are not so easily kept in order as the open boats and are more liable to deteriorate.

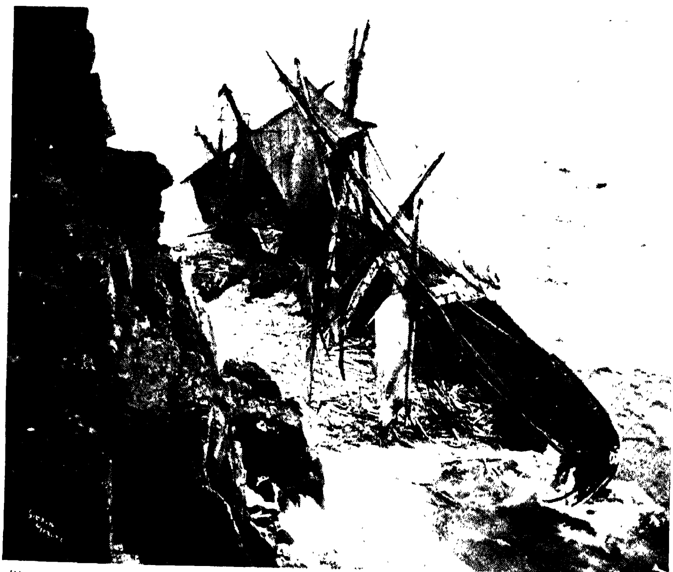
Lifeboats of both types are sometimes made with their bulwarks to fold down, so that they may take up less space and be the more easily stowed one above another.

In addition to lifeboats, there is what is known as "buoyant apparatus." It has even been suggested

By courtesy of *The Royal National Lifeboat Inst.*

THE GOODWIN SANDS

These treacherous sands, which lie off the Downs, have been the scene of almost innumerable shipwrecks. Every year they witness many fine rescues by the neighbouring lifeboats and their dauntless crews.



Photograph by *Gibson & Sons, Penzance*

A WRECK OFF THE CORNISH COAST

A sailing ship, the *Hansy*, on the rocks at the Lizard.

many times that the whole upper part of a ship should be made buoyant and detachable from the lower part, so that in the event of the hull proper sinking, the upper part might remain afloat. It is an excellent idea, but quite impossible to put into practice. For one thing, it would be difficult to connect the two parts loosely enough to permit the upper to float off if the lower sank, yet firmly enough to withstand the buffetings of a heavy storm. For another, to make the upper part strong enough to float by itself in rough weather would entail much additional weight, making the ship not only cumbersome but top-heavy. Certain parts of the ship's furniture, such as seats and even larger objects, can, and are often, made buoyant, so as to form, in effect, rafts upon which people can ride or to which they can cling. All these things above a certain size have to have always attached to them a pair of paddles, a boat-hook, and a tin of red lights.

On a foreign-going passenger ship there have to be a certain number of sets of davits, according to its length. The largest vessels have no less than thirty. To each of these there must be one lifeboat of the best class—twenty out of the thirty being open boats. If these are not sufficient to take all the persons on board, then an additional boat may be provided for each set of davits, and if that be not sufficient, then further boats must be placed upon an upper deck in such manner that they can be moved to the davits or launched in some other way on either side of the ship. Finally, all these boats must be so attached that in the event of the ship sinking before they can be launched they will float off automatically.

In addition to the lifeboats, foreign-going passenger ships must carry enough " buoyant apparatus " for 25 per cent of those on board.

Where there are more than ten lifeboats on a ship, one of them must be fitted with a wireless telegraph installation. Where there are more than fifteen lifeboats, one has to be a motor boat, fitted with " wireless " and also with a searchlight. Where the number is more than twenty, there are two motor boats with " wireless " and searchlight.

Every ship must carry lifebuoys, according to its size, the largest having no less than thirty, and a lifejacket for every person on board.

The methods of loading and launching the lifeboats from a ship will form the next chapter.

CHAPTER XVI

HOW A SHIP'S LIFEBOATS ARE LAUNCHED

HOWEVER well a ship may be provided with lifeboats, there is not much advantage unless they can be safely launched upon the water with the people in them, or so that the people can reach them.

At the commencement of a voyage each passenger is given a printed slip telling him or her what to do in the event of danger. Moreover, all are assembled at the various " boat stations " as an experiment just to familiarize them with the proceedings, and to give them that confidence which arises from knowing just what to do.

It is a matter of discussion among shipping authorities which of two ways of mustering the passengers is the best. One way is to tell each person to assemble near a certain boat. Another is to gather them all at certain places upon the ship and from thence draft them to boats as may be most convenient at the moment.

The following are the printed instructions handed to all passengers on the ships of a certain well-known line :—

LAUNCHING OF SHIP'S LIFEBOATS

"Please understand that the place in which you
" are now mustered is where you are to assemble in
" time of accident, and await instructions.

"In case of disaster the procedure will be as
" follows:—

"1. On hearing the alarm signal, you are at once
" to assemble as at present, warmly clad.

"2. The boats will be lowered level with the rail
" of the deck on which you are assembled.

"3. You will then get into the boats and be
" lowered to the water.

"In the event of it being impossible to lower the
" boats on your side of the ship you will go to the
" corresponding boat on the other side.

"If any circumstances arise which prevent the
" above procedure being carried out, you will receive
" special instructions when mustered here."

All of the above seems simple and easy to understand, but behind this simple procedure lies the enormous practical difficulty of getting the boats on to the surface of a probably rough sea from a ship which as likely as not has heeled over considerably, rolling from side to side and in imminent danger of sinking. Many clever brains have been employed on this problem, and the results of their labours we will now consider.

To start from the very beginning, there is no doubt that the first way of getting a boat into the water from a ship was by two men. A rope would be attached to each end of the boat, which of course would be small and light, and the men, each holding one rope and steadying himself by clinging on to something, would lean out over the water and let the boat down as steadily as they were able.

From a man thus leaning from the ship's side over the water it would be a natural step to fix a post upon the edge of the ship's deck the upper end of which curved outwards over the water. A pair of such posts would hold a boat nicely, a rope passing from each to one end of the boat.

To facilitate hoisting and lowering, a " block," quite an early feature in ships' rigging, would be attached to each of the posts and the ropes from the boat would pass over the pulleys inside the blocks to men upon the deck. As boats grew larger, blocks with more than one pulley would be substituted for single blocks, thereby enabling the boat to be lifted more easily or lowered more steadily because of the " purchase " which blocks so arranged give.

Meanwhile another development would take place. It would be very convenient to keep a boat suspended from these posts, yet it would hardly be safe to allow a boat to hang over the side, as it would thereby be exposed to all the buffetings of a rough sea. The posts, or davits as they came to be called, were therefore made to rotate in a socket upon deck, so that the curved end could be swung round when desired, and the hanging boat brought " inboard " into a much safer position.

This is the arrangement which is commonly seen on small steamers and on large ones, too, so long as they do not carry many passengers.

The davits, each pair with a boat swung between, are a very familiar feature of a present-day ship. Just simple steel posts, suitably curved and mounted in suitable sockets, with suitable blocks, they are remarkably efficient and serve their purpose well within certain limits. For motive power they depend upon the muscles of the crew, and for all-round reliability there is no machine to beat the human frame, especially in an emergency. The man can adapt himself to circumstances as nothing else can. If one part of a machine is damaged, the whole stops; but if a man damages one hand, he pulls with the other; if he hurts one leg, he stands upon the other; if he hurts both, he may even pull sitting down. Because, therefore, of its simplicity and the fact that it is worked by hand, the ordinary davit is still used on a great many ships.

In some cases a simple form of winch is employed to add to the lifting power of the men, but such mechanism can be made very simple and strong, and it is so closely under the control of the man working it that it really takes away little of the reliability.

In the simplest cases the boat is swung out over the side of the ship by pushing it in such a way as to cause first one davit and then the other to swing round in its socket until its end juts out over the side.

To keep the boat from swinging about and knocking against things it is sometimes merely lashed with cords, but in other cases it is lowered on to supports fixed upon the ship beneath the davits, these supports consisting of suitably shaped blocks of wood, placed in pairs so that the keel of the boat fits comfortably between them. They are called " chocks."

In a more elaborate type of davit what is called a " worm gear " is fitted to the socket in which the davit stands. This consists of a toothed wheel with a short coarse-threaded screw engaging in its teeth. By turning the screw the wheel can be forced round, great power being gained thereby, for a very little force applied to the screw, or " worm," to give it its technical name, causes the wheel to be moved with great power. In the case of a davit, the wheel is attached to the davit, while the screw is fixed to the socket. A man turns the screw by means of a handle and the davit thereupon turns, one man thus being able to do what it might require several men to do otherwise. At the same time, this form of gear is the most simple imaginable : it can be entirely enclosed in a strong metal case, so that external damage is impossible and it can hardly get out of order, so that this second addition to the simple davit does nothing to impair its reliability.

But what has already been described, while excellent upon some ships, is hopelessly inadequate where a vessel carries a large number of passengers in proportion to its size, and where, therefore, the number of boats necessary exceeds those carried in a few pairs of davits on either side. In such cases, far more highly developed machinery is necessary.

Foremost among these new appliances is the davit associated with the name of Mr. Axel Welin, an engineer who has devoted a lifetime to this important subject. Instead of the usual vertical rod curving over at the top, we have, in the "Welin" davit, a steel column only slightly curved at the top. This is not mounted to swivel round, like the ordinary davit, but to swing inwards or outwards at right angles to the side of the ship. To put it more precisely, while the ordinary davit swings round a vertical axis, this swings upon a horizontal axis, the axis being parallel with the side of the ship.

A pair of these davits have a boat suspended between them by means of ropes attached to their upper ends, and when it is desired to launch the boat they swing downwards and outwards, reaching well away from the side of the ship and placing the boat safely upon the water.

Some of these are "single-acting," which means that they can pick up the boat which normally lies between them and pass it outwards, away from the ship. Others, called "double-acting," can also swing the other way as well, so that they can not only lift the boat which is between them, but can reach back towards the centre of the ship and so pick up a second boat, which normally lies alongside the first one. Thus, with these davits two rows of boats can be handled just as easily as a single row.

The to-and-fro swing is caused by a very simple and strong but effective mechanism.

In some cases, where there are many boats to be handled, there are not only davits along the sides of the ship, but also in the middle, the latter being called "feeding davits," because it is their duty to pick up those boats which lie beyond the reach of the others and pass them outwards—in other words, to "feed" the davits along the side.

In other cases there are trolleys which can run to and fro across the ship right from one side to the other. These trolleys are fitted with lifting arms so arranged that they can run underneath a boat and then lift it off its chocks. The latter, being made to fold down flat on the deck, can then be put out of the way, and the trolley can run with the boat to the davits on either side.

Another interesting arrangement is sometimes used where two boats are stowed one inside the other. Each davit can be supplied with two pairs of blocks; the ropes, "falls" the sailors call them, belonging to one pair are attached to one boat, and those of the other pair to the other boat. Thus both boats are lifted simultaneously and passed out over the ship's side. Then the underneath one is lowered first, the passengers getting on board from a lower deck. As soon as that is loaded and lowered upon the water the second boat comes down level with the deck where the people are and is filled in like manner.

On large ships electric motors are fitted for operating the boat-launching gear. There is, of course, always this objection to such an arrangement, that should the supply of current fail, as it might do in time of accident, the motors are useless. As a matter of fact, however, in the very great majority of cases, a ship is not damaged so severely that the machinery stops at once. It can generally be kept going long enough for this purpose. One of the grandest and most heroic pictures which the mind is capable of conjuring up is that of the engine-room staff on a damaged ship working away down below, in the utmost danger themselves, in order to keep going the machinery necessary to save their less unfortunate fellows above. There is a grand tradition of the sea that the engine-room people will die at their posts if thereby they can save the others.

But of course the accident to the ship may actually put the machinery out of action, in which case the most heroic exertions of the men cannot keep it going. For such occasions auxiliary gear can be provided so that the lowering apparatus can be worked if need be by hand.

Even if the electric motors were no good at all in time of emergency, they would still play a very useful part. Lifeboats, like everything else, will get out of order if they are not carefully looked after. There is little time for such things to be seen to during a voyage, but every lifeboat is supposed to be thoroughly examined at the end of each voyage and all the repairing, repainting, and refitting which may be needed carried out. The term "supposed to be" is not meant as any reflection upon the men concerned, but simply means that they are often very pressed for time and cannot always be as thorough as they themselves would wish to be. It is easy to see how, under such conditions, electric motors for handling the boats will help matters very materially. Every boat can be easily and quickly lifted out of its chocks for examination or repair. Where the boats are stacked one above another, this is particularly important. Indeed, the presence of the motors may often make all the difference between the important work of caring for the lifeboats being done thoroughly or partially, and this may mean the saving of many lives should an accident occur on the next voyage.

CHAPTER XVII

SHIPS THAT WILL NOT SINK

IF only we could make a ship that would not sink under any conditions there would be little use for lifeboats—indeed, all ships would be lifeboats—and even the lighthouse would lose some of its importance.

In the old days when ships were made of wood they would not of themselves sink, even if filled with water, because of the lightness of the wood. A wooden ship loaded with a cargo of some heavy material might, of course, founder if the water got in, but frequently after a collision a wooden ship would merely float low in the water without actually going down. In this state the crew were to some extent safe. They might be washed off, but so long as they could hold on they stood a good chance of being safe until rescued. On the other hand, of course, such derelict ships, floating so low in the water that they could not be seen from a distance, caused great danger to other ships.

When it was first proposed to build ships of iron many people thought the idea ridiculous. Knowing how quickly a piece of iron sinks in water, they exclaimed, "How can an iron ship possibly keep afloat ? " Yet the ship of to-day is almost invariably made of iron or steel.

The explanation, of course, is in the shape of the vessel. A solid iron ship would not float for a moment, but since it is hollow and contains a lot of air, the whole thing—ship, cargo, and air together—weigh less than an equal volume of water, and so they float.

A simple illustration of this is a saucer which will float safely if placed flat upon the water with its hollow side uppermost. That is because in that position it can hold air. The porcelain is heavier than water, but the porcelain and air together weigh less than water : therefore they float.

Tilt it over, however, so that water can run over the edge and push the air out ; it will then sink. Or make a hole in it, or even a tiny crack ; the water will then find a way in, will push the air out from inside the saucer, until finally the saucer and its contents will be as heavy or heavier than water, and down it will go.

It is just the same with a steel ship. If a certain amount of water should find its way in, the finest ship will founder. Nor need the quantity of water always be very great, for suppose water should get into one side it may cause the vessel to tilt over until more water can run in through the port-holes.

The designer of a ship therefore takes great pains to make his vessel " hole-proof," as we might call it. For one thing the bottom is made double. There is an outer skin of steel plates, and some distance inside that a second skin, so that a ship might possibly scrape over a rock, tearing the outer skin, without damaging the inner one. Sometimes, too, the sides are also made double, so that there is practically a ship inside a ship.

These spaces are used to hold water, to form water-ballast. By means of certain valves water can be let into the double-bottom, or by means of steam pumps it can be quickly removed. If a ship is lightly loaded more water-ballast is used; if heavily loaded, some of it is pumped out. Moreover, the space being subdivided, water-ballast can be removed from one part and increased in another, so that the "trim" of the vessel, or the position which she assumes upon the water, can be adjusted to a nicety.

But a double bottom, even with double sides as well, does not save a ship from sinking after a serious collision. The inner skin cannot be far away from the outer, or the interior of the ship would be so reduced that she would not be serviceable. In a collision, therefore, there is a great probability that both skins will be perforated. Something more than two skins is necessary for safety.

A ship is therefore subdivided into a number of compartments by means of water-tight partitions—"bulkheads," shipping people call them—so that if water should find a way in it cannot fill the whole ship. Things are usually so arranged that any two compartments can be flooded without endangering the ship.

For perfect safety, we can easily see, these bulkheads should be solid, that is to say, have no openings at all in them, and should reach right from the bottom of the ship up to well above the level of the water even when the ship has partly sunk through two compartments being flooded.

Such an arrangement would be safe, but think how extremely inconvenient it would be. Every time a man needed to go from one part of the ship to another any considerable distance away, he would have to come right up to one of the higher decks in order to get over the top of a bulkhead.

It would make specially arduous the work of the engineers and firemen. The engines are usually in one compartment, or possibly the main engines in one and subsidiary machinery in others. The boilers are in another, or rather several more; while the bunkers where the coal is stored are themselves water-tight compartments. Fancy the labour involved if the coal from the bunkers had to be hoisted up to the deck and then lowered down to the boiler room. Further, there is the tunnel, through which the propeller shaft runs from the engine-room amidships to the propeller at the stern. This has, for safety's sake, to be divided up by water-tight partitions, yet the engineers must be able to get along it when necessary.

So, in spite of the amount of safety which they would afford, it is generally agreed to be impracticable to have water-tight bulkheads without any openings in them. The alternative, of course, is to have openings which can be closed by water-tight doors. Unfortunately that introduces the human element, with its tendency to make mistakes. For what good are the doors unless people can be relied upon to shut them? Many a ship has been lost because someone had omitted to close a water-tight door, or else, in the excitement of the moment and in the short time available, had been unable to shut it.

The bulkheads, of course, are made of steel plates upon a steel framing, just like the rest of the hull, and the doors are of the sliding variety so arranged that when closed they wedge close up against the door frame and make a practically water-tight joint.

So that their own weight may make the closing easier, they are frequently made to slide up and down vertically, but sometimes that is impossible, in which case they have to slide horizontally.

Reference was made just now to the necessity for openings between the coal bunkers and the boiler rooms, and there a further difficulty arises in that the doorways are very apt to be choked with coal. The veriest landsman knows from experience how hard it is to latch the door of the coal cellar when a piece of coal has got in the hinge. Let him consider for a moment the case of a heavy steel door which needs to be so well closed as to be water-tight, the working parts clogged with coal and not a moment to lose if the ship is to be saved, and he will realize the extremely uncomfortable position of the man whose duty it is to close such a door by hand in an emergency.

So it is pleasant to be able to describe a system by which all these difficulties have been overcome, and by which a ship with many doors can yet be as safe as if she had solid bulkheads. The system referred

By courtesy of *Messrs. J. S. [illegible] & Co.*

SAVED BY HER WATER-TIGHT DOORS

The tremendous damage done to this vessel in a collision off Lisbon would have caused her to sink, had the water-tight bulkheads not been closed.

to is known as " Stone's," and while not the only one, has been chosen in order to illustrate how mechanical ingenuity has attacked and solved so difficult a problem.

Briefly the working of the system is this. Within easy reach of the officer upon the bridge, probably the captain or chief officer, is a small wheel which can easily be turned by hand. Looking round, the officer sees signs of a fog settling down upon the sea, or the thought occurs to him that he is about to enter waters which are dangerous because of the rocks and currents, or it may be that he sees another ship coming unpleasantly near whose movements he cannot quite understand. In other words, he may scent danger of some sort. However slight the risk may be, he may, particularly if he be a careful man, think it wise to take precautions, so he just reaches out and gives that wheel a turn.

The wheel belongs to the bridge control valve of the door-closing system, and as soon as it has been operated electric bells begin to ring all over the ship, indicating to everyone that the water-tight doors are about to close. A moment later they begin to move. As each commences, the electric bell above it stops and another one commences, telling anyone near that the door is actually closing. Then each door as it settles down against its frame into the water-tight position makes an electric contact which sends a message back to the bridge to tell the officer there that his orders have been carried out, and that the door is safely shut.

This message is recorded upon an indicator wherein there is a little electric light for each door. As the door closes the corresponding light glows brightly. It is only a matter of seconds between the movement of the hand-wheel and the appearance of the lights.

After the operation just described the ship is for the moment practically fitted with solid bulkheads, and so it remains until the officer considers that danger has passed, when another movement of the hand-wheel reverses the operations and the doors open.

A very important point about all this is that only one man is concerned in it, and he probably the man or one of the two or three men on the ship best fitted to act in an emergency.

But during the period in which the doors are closed the compartments are not entirely isolated. It is not necessary to lift the coals from the bunker and to drop them into the boiler room, or for an engineer to mount deck-high in order to pass from one part of his domain to another. At one side of each door there is a small lever, the movement of which causes a closed door immediately to open. Having opened it, the man slips quickly through, for the moment he lets go the handle the door commences to close again. Thus, short of a man deliberately holding a door open, there is no chance of one not being closed, and as his own safety would be imperilled by such an action we may safely assume that no man would do it.

But what about the coal in the doorways, as referred to just now? How is that difficulty overcome? Under these conditions it hardly arises, for the door has a comparatively sharp edge, and the power behind its movement is such that it can cut its way through the interfering coal, or crush it out of its way.

A most important point to notice is that all this can be done with little inconvenience to anyone at the approach of the slightest danger. To close all doors by hand is such an undertaking, and so upsets the normal working of a ship, that it can only be done when absolutely necessary and may easily be left till too late. When a ship has been struck by another, or has run upon a rock, the shock usually distorts the whole framework, making it very difficult to close the doors at all, and sometimes quite impossible. Hence, when the accident has actually occurred it may be "too late."

And now let us examine more in detail the wonderful mechanism by which this amazing operation is carried out. The first thing that will strike us is its simplicity, a most important virtue, since simplicity and reliability are inseparable, and without reliability such a system as this would be worse than useless, for it would simply produce a false sense of security.

The bridge control valve, which has already been referred to, is a strong and simply constructed valve which is able to close the end of either of two pipes which are connected to it. It has combined with it an electric switch, so arranged that as soon as the officer turns the wheel to close the doors, the same action switches on the current to the warning bells.

The two pipes lead away to the engine-room, where they connect to a pair of steam-driven pumps whose special duty it is to work the water-tight doors.

The reason there are two of these pumps is to ensure that at least one will always be available to provide the necessary pressure to work the doors. If only one were installed, a moment might arrive when the doors should be closed when the pump was under repair or for some special reason not usable, but with two of them one can always be relied upon. To make assurance doubly sure, one or both of these pumps is always at work. When closing the doors they work at twenty-five strokes per minute, but even when not actually doing any useful work they still keep on, although at a much slower speed, namely, three strokes per minute, slowly circulating the water through the system of pipes and thereby making quite certain that there is nothing the matter with any part of the apparatus, but that everything is ready for immediate action if required.

But to return to those two pipes which lead from the bridge control valve to the engine-room. The pumps send water through these, but so long as that water can escape at the bridge end no considerable pressure is caused in them. The moment the end of either of them is stopped the action of the pump in trying to force water in causes a rise in pressure, and that rise in pressure is employed to operate a very important appliance in the engine-room called the master control valve.

It is easy to see, then, that the bridge control valve, by closing the end of one pipe, can operate the master control valve in one way, and by closing the other pipe can operate it in the opposite way. Thus the action of the officer on the bridge is repeated in a very simple but powerful way in the engine-room, and the result is just as it would be were he to go down to the engine-room and work the master valve himself. Let us see, next, what the master control valve does.

From it there run two pipes which pass near to every water-tight door in the ship. These are called the main pipes, and their duty is to supply the hydraulic cylinders with water at a pressure of 700 lbs. per square inch.

At a convenient point near each door two other pipes branch off, one from each main pipe, to the hydraulic cylinder which is placed close to the door.

The hydraulic cylinder is a beautiful piece of mechanism, made regardless of expense almost, the sole consideration being that it shall do its duty faithfully when called upon. Instead of being made of iron, as such things often are, it is made of bronze, a metal which is much more expensive, but which is not so liable to rust or other form of corrosion when in contact with water. This massive bronze cylinder is closed at both ends, and no moving mechanism is visible except a spindle which emerges through a hole near the centre, so that the working part of this important device is entirely enclosed and nothing can get " mixed up with it " to impede its working.

Of course, there is a piston-like arrangement inside the cylinder, capable of sliding to and fro, and if the water under pressure be admitted at one end this is forced to the other end, the action being entirely reversed if the water be admitted at the other end. By forcing water in at either end, then, and releasing the water at the opposite end, the piston in the cylinder can be made to move either way at will.

Embodied in the piston is a rod or bar with teeth upon it, forming what engineers call a " rack," which engages with a small wheel, also with teeth upon it, housed in a small cavity formed near the centre of the cylinder. When the piston moves, therefore, the teeth in the rack, catching in those of the small wheel, or " pinion," to give it its technical name, cause the latter to turn, thereby turning the spindle already referred to, the end of which emerges through the side of the cylinder. So, whenever the piston moves the spindle turns, and thus the power generated by the water inside the cylinder is transmitted to the outside.

Although it takes some time to describe all this, it is very simple, yet it is a type of mechanism which lends itself to a very strong form of construction, and it would be hard to imagine any device made by human hands less likely to fail in time of need.

The branch from one main enters the cylinder at one end, and that from the other main at the other end. It is easy to see, therefore, that if we force water into one main and release that in the other one we can make the piston move. Further, by forcing water into one main we make the pistons move one way, and by forcing it into the other we make them move the opposite way.

It is the work of the master control valve to direct the water into one or other of the mains according to the instructions of the bridge control valve, which again is controlled by the hand of the officer in command of the ship.

But we have not yet seen how the cylinders open and close the doors. This is done by mechanism of the simplest and most robust kind. Upon the back of each door is a "rack"—that is to say, a bar with teeth upon it—which engages with a toothed pinion, supported upon a strong steel spindle. This spindle is either continuous with, or is in some way connected to, that which emerges from the cylinder, so that when the piston in the cylinder moves it turns this spindle with its pinion and so forces the door along, either to one side, up or down, as the case may be.

So we can now sum up the whole series of operations. The officer turns the hand-wheel which operates the bridge control valve, that works the master control valve which directs water into one or other of the main pipes, through which it passes via the branches to one end of each cylinder, forcing the pistons along, and so closing or opening the doors, as the case may be.

As each door closes, the rotation of the spindle which closes it rings a bell. This is in addition, it must be remembered, to the electric bell which starts to ring as soon as the bridge control valve is worked, so that there is practically no risk of anyone getting caught in a closing door. When the doors move there is great power behind them: necessarily so, in order to ensure that they shall really be closed and watertight and, in the case of the doors of the coal bunkers, to cut through any coal which may be lying about in the doorway, so that to be caught by a closing door would be a very serious matter to anyone. The risk, however, of such an occurrence can only be very small when a loud electric bell rings as a warning for some seconds before the door moves, only to be succeeded by a totally different bell while they are actually on the move.

Furthermore, there is no reason why anyone should make a rush to get through a closing door. We need not picture to ourselves the tragic situation of some unfortunate man cut off by one of these doors and imprisoned in a compartment into which water is flowing, there to meet a slow but certain death. Such a happening is amply provided against, in the following way.

The branch pipes, on their way from the main pipes to the cylinder, pass through a door-control valve. This is an arrangement on the lines of the slide valve of a steam engine, that simple but efficient device by which steam is admitted first to one end and then to the other of a steam-engine cylinder. Normally, this valve connects one main pipe to one end of the cylinder and one to the other, so that when the master valve says "close," so to speak, the doors immediately close; but the door-control valve can reverse this arrangement, so that the same pressure which has just closed a door can be made to open it again. The valve is so made, however, that if left to itself it always goes to the normal position, so that as soon as the person who has opened a door releases the handle it commences to close again. There is a handle for working the door valve on each side of the bulkhead, so that the door can be opened from either side.

The system may be further elaborated in the direction of making the doors not only obedient to the wishes of the officer in charge, but actually able to anticipate his instructions.

Below a cylinder there may be suspended a weight, so connected that its pull keeps the door open. Should water enter the compartment, however, it will tend to raise the weight, thereby setting the mechanism into motion and closing the door. The whole operation is still hydraulic, as described above, but it is placed to some extent under the control of the float. In the same way, fire can be guarded against by the use of plugs of fusible alloy, so arranged that if the temperature of a compartment rises above a certain point a plug will melt and set the door-closing mechanism in motion.

Finally, there is the indicator, to which reference has already been made. At one side of each door there is an electric contact device which is closed by the action of the door itself, when it closes. This contact permits current to flow to the indicator on the bridge and lights a small lamp which is marked so as to show to which door it relates. By arranging things so that the contact is only closed when the door is right " home " in its water-tight position the indicator is made to be a very true and reliable messenger, faithfully recording the state of the doors in all parts of the ship. The indicator usually takes the form of a rough diagram of the ship with the lights placed in positions which correspond with the positions of the doors, so that the officer can tell at a glance if all is right.

With this simple but effective arrangement it is evident that when a door is opened for a moment by someone using the door control the fact is duly shown upon the indicator, the light going out while the door is open, but shining again as soon as it is closed.

A simple but efficient system of doors, such as this, goes far to make a ship unsinkable and forms a striking example of how much is done in the modern steamship to ensure the safety of its passengers.

CHAPTER XVIII

FOG SIGNALS

IT comes as a great surprise to learn that the use of audible signals to warn ships in foggy weather is no older than the middle of last century. At no time does a mariner need help more than in a fog, and since to warn a friend by shouting to him is man's natural instinct, one would have expected a mechanical shouting apparatus to have appeared very early.

That such things did exist is testified by the well-known " Bell Rock," but they were very few and far between.

During the last half-century or so, however, much ingenuity has been expended upon devices for making sounds, some of them very unpleasant sounds, for warning ships. All the lightships or lighthouses at places subject to fogs are provided with fog-signalling apparatus of some sort.

The best known of these is the syren. Whether this name is an ironical reference to the hideous " row " which it makes or means that, in the ears of a mariner, the sound is a sweet one, since it leads him to safety, is not known. The apparatus consists of a cylinder or disc in which are cut a number of slits. These slits being made to pass in front of powerful jets of air produce a powerful series of pulsations which cause a loud howl or roar. The tone can be varied by varying the speed of the cylinder or disc, and in some cases high and low sounds are made to alternate in order to give character to the signal.

The most modern kind of syren is called the diaphone, the invention of Mr. Hope-Jones, a well-known organ builder. In this there is a cylinder with certain slits cut in its walls, and a hollow piston with similar slits which slides in it. The compressed air forces this piston up and down rapidly, at each movement releasing a puff of air through the slits. This results in a very distinctive, arresting, and penetrating sound. A diaphone at Cape Race (Newfoundland) has been heard at a distance of 40 miles.

All compressed-air apparatus of the syren variety is placed at the small end of a trumpet in order that the sound may be concentrated in the desired direction.

Other audible signals, again, are produced by a reed, as in certain pipes of church organs. The compressed air enters at one end of a pipe through a slit which is almost closed by a flexible tongue or "reed" which it causes to vibrate. The movement of the reed is communicated to the passing air, and sound results. One might almost describe these reed signals as huge clarinets, or oboes.

Whistles are not much used, owing doubtless to their being too much like the whistles on ships. They are still employed in buoys, where the rise and fall of the waves is made to operate them.

A fog signal needs to have its distinctive character just as a light does, and this is generally provided for in the case of syrens by a clockwork mechanism which controls the admission of the air. Generally the distinguishing feature is the frequency and the duration of the blasts, since changes in tone are not altogether desirable. The reason for this is much the same as in the case of lights of different colours: it is impossible to be sure that both sounds will penetrate to an equal distance, and if one should fall short of the other the result is a false "character."

In order to ensure that the apparatus shall be ready to act at short notice in a sudden fog, there is usually a large reservoir in which air is stored at a comparatively high pressure, from which it can pass, through a reducing valve, to the smaller reservoir which forms a usual part of the outfit. This affords time to get the compressor to work.

It may be interesting to note that the pressure of the air as it enters the syren is usually round about 20 lbs. per square inch.

The air-pump or compressor is usually worked by an engine, generally an oil engine. There are small installations which can be worked by hand and others where the usual working is by a small engine, but hand-working is possible in case of emergency, such as a breakdown of the engine.

The larger plants are almost always in duplicate, so that should one fail for any reason the other can be started up immediately.

It is evident that so extensive a plant as this would be an impossibility in the cramped quarters of a rock lighthouse, so that in such cases an explosive signal is more often used. This consists, in its simplest form, of a cartridge filled with gun-cotton or other suitable explosive, which is for safety's sake thrust out from the tower upon a mast or jib and there fired by means of a mechanical trigger arrangement.

An improvement upon this is the acetylene-gas gun of Messrs. D. and C. Stevenson, the famous lighthouse engineers, of Edinburgh.

This does not give quite so penetrating a sound as does a cartridge of "tonite," the favourite explosive for this purpose, but it has the great advantage that it can give reports at intervals of a few seconds, against the five-minute intervals of the other method and can be made quite automatic, whereas the other has to be operated by hand. The gun will go on working without attention as long as the supply of gas lasts out. There are cases where one works for six months on end without stopping. There are others which are started and stopped from a distance by means of a simple adaptation of wireless telegraphy. Thus the gun can be placed in all manner of inaccessible places where attention is impossible except at very rare intervals. Moreover, its form is such as to make it very convenient for fixing upon the apex of the roof of a lighthouse.

Let us now examine this remarkable apparatus more in detail. The "gun" itself is a vertical metal tube. At the top or "muzzle" end there is a small circular chamber formed of two horizontal discs of metal, one forming the floor of the chamber and the other the roof, their edges being joined by a " wall " of wire gauze. This gauze prevents the entrance of spray even in the roughest weather, but allows the sound to pass out quite freely.

The " muzzle " of the gun terminates in a hole in the centre of the " floor " of the chamber, so that sound waves generated in the lower part of the gun rush upwards, strike the roof, and by it are deflected horizontally in all directions. By adjusting the height of the chamber a tuning effect can be obtained, and it is arranged that the upper disc can be raised or lowered until the apparatus works at its highest efficiency.

Passing next to the lower part of the gun, we find there a small metal chamber with a flexible diaphragm similar to that described in connection with the flasher on page 48. This is the gas " regulator," but it is really more than that, for it is the engine whereby the gas itself generates the power required to work the whole machine.

The gas itself may come from a generator of any ordinary form or from storage cylinders. It enters the " regulator " through an adjustable inlet valve and upon entering lifts the diaphragm.

Near the " regulator " is an air-chamber formed of a bell-shaped vessel in a reservoir of water precisely similar to the " holder " at the gasworks, but on an exceedingly small scale. The bell is connected by a lever to the diaphragm in such a manner that as the diaphragm rises the bell is lifted too. The sizes of regulator and bell are such that whatever quantity of gas may enter the regulator the bell in rising will draw into itself precisely the correct quantity of air to form with the gas a good explosive mixture.

When the diaphragm has risen to a certain point it " trips " or throws over a little weighted lever which opens the outlet from both regulator and air-bell and permits gas and air together to rush into the bottom of the gun. As the gas rushes out of the regulator the diaphragm falls and lowers the air-bell, finally closing the outlet valve and leaving everything in readiness for a fresh start. Thus we see how the gun is " loaded " automatically, over and over again, and it is at once apparent that it is only necessary to adjust the inlet valve in order to produce this result at any desired intervals.

So much for the " loading " ; let us now see how the gun is " fired." Everyone to-day is familiar with the so-called " flint and steel " pipe lighter in which a little serrated wheel of hard steel is made to rub against a " flint " of soft steel, thereby producing a shower of sparks. That method of lighting is applied to this gun. The serrated wheel is acted upon by a spring, and the diaphragm when rising, in addition to the action already described, also turns the wheel against the force of the spring, thereby winding it up. Just at the correct moment this is liberated and the wheel springs back, sending a shower of sparks into the gun. The " flint," consisting of a rod the end of which is pressed by a simple but effective device against the edge of the wheel, is sufficient to last for a very long time.

The rising of the diaphragm, therefore, does everything. It measures the gas, it draws into the bell a suitable quantity of air, it winds up the firing wheel, and finally it lets the mixture into the gun and fires it by a shower of sparks.

For starting and stopping the gun it is only necessary to have a valve to turn on or cut off at will the supply of gas to the regulator. At attended stations this valve can be operated by hand. In other places it can be operated quite easily by an electro-magnet energized by current through a cable. By this means a man ashore can easily and in safety start and stop the fog-signal gun upon a buoy or beacon which it would be difficult, if not impossible, for him to reach.

Indeed, we can go one better than that and dispense with even the cable. Right in the centre of the Firth of Clyde is a lonely beacon known as Roseneath Beacon. Upon it is installed one of these guns. A mile and a quarter away is Gourock Pier. When a fog comes on, a man on Gourock Pier presses a key, and in a few seconds he hears the gun booming away at its characteristic speed of three sounds per minute. When the fog lifts he presses the same key again and the sound stops.

Yet there is no cable stretching between the two. The only link between them is a series of æther waves operating through a clever device specially designed for the purpose by the Marconi Company.

From the wireless telegraph point of view we are here back at the very beginning of things. The sender is the spark coil, the receiver the coherer, two of the very earliest features of the art of telegraphy without wires, but very suitable for their purpose here and cleverly combined with a mechanical tuning device.

In the instrument at Gourock there is a balance wheel with a spring, like the balance wheel and "hair spring" of a watch, only larger and heavier. Now, as we all know from experience, the balance wheel and spring enable our watches to keep correct time. If they are too fast or too slow, we alter slightly the tension upon the hair spring until we arrive at just the correct setting. In other words, a balance wheel controlled by a spring has a natural period of its own which we can change to some extent by varying the tension upon the spring. Once set, however, such a wheel will oscillate with a regularity which is astounding.

When the man presses the key he sets this balance wheel moving to and fro, and once set going an electro-magnet keeps it moving on the same principle as the familiar electric bell. Thus, when it has once been set going the wheel continues to move at the rate for which the spring has been adjusted, namely, 180 per minute.

We might picture this to ourselves, therefore, as the balance wheel of an electrically driven clock giving 180 ticks per minute. Attached to this wheel is a projecting arm which once in each movement comes into contact with a fixed point, thereby completing an electric circuit. Therefore, as soon as the apparatus is set going electrical impulses are produced at the rate of 180 per minute.

These impulses work a relay. Now, a relay is an automatic electric switch whereby a feeble current can open and close a circuit in which a stronger current flows. Each of the 180 impulses causes the relay to close and to send a stronger impulse through an induction or spark coil, thereby producing an electric spark. Each spark sets up oscillations in an aerial and sends forth into space a little series or train of ætherial waves.

Thus, upon the man pressing the key 180 wave-trains per minute are sent out until he presses it again and so stops the wheel.

We can now take our stand, so to speak, upon the beacon and see what happens there. The wave-trains striking the aerial there cause "high-frequency" currents to flow in it which are led to a coherer.

This was the first appliance used for the detection of wireless signals. It consists of a small glass tube with a metal plug in each end. The plugs do not quite touch, and in the space between them there lies a pinch of metal filings. Current from a battery close by is always trying to pass through these filings, but because they are only lying loosely together they offer great resistance and very little is able to get through. When, however, the high-frequency currents from the aerial arrive they cause the little pieces of metal to "cohere" together, make the whole of them more conductive, and thereby allow battery current to pass. In effect, therefore, it is a relay, by which the feeble high-frequency currents from the aerial start and stop the stronger current from the battery, so that for each incoming wave-train a short splash of current from the battery flows through the local circuit.

These splashes pass through the winding of an electro-magnet which therefore gives 180 pulls per minute. Those pulls act upon another balance wheel the spring of which is so adjusted that the wheel will swing naturally at the rate of 180 per minute.

Now here is the important feature. The first tug by the magnet does not move the wheel very far ; it just moves it, and that is all. The second tug adds to the movement ; the third makes it greater still, and so on. It is just like " working up " a friend upon a swing. So long as you push the swing at the right intervals a series of little pushes will soon have the swing swinging as high as you dare send it, and likewise, in a few seconds, these regular impulses acting upon a wheel *tuned to the same rate of movement* cause it to swing vigorously to and fro.

When the wheel swings far enough it causes a contact upon itself to touch a fixed contact and sends current to another magnet which turns on the gas to the gun.

As soon as he hears the gun in operation, the man stops his balance wheel ; that stops the wave-trains ; that cuts off the impulses from the other balance wheel, which thereupon " dies down " until it is still once more. To shut off the gun after the fog has lifted, he does precisely the same thing again, and the same series of operations follows. The only difference is in the effect which the last action of the series has upon the gas supply. One turns it on; the next, although exactly the same, turns it off. This is quite easy to arrange.

Any device of the "ratchet" order will enable a series of pushes or pulls to turn a wheel round. At each impulse the wheel moves one "step." Now arrange a series of projections upon the wheel so that in certain positions a lever will be lifted and in certain other positions it will be dropped. Make those positions to occur alternately and to correspond with succeeding steps. Then, when the wheel is turned one step it will lift the lever, when it moves the second it will drop it, the third will lift it, and so on. All the impulses will be the same, but they will alternately produce exactly opposite results.

There you have the principle applied in the case of the wireless-controlled gun. The first impulse from the balance wheel sets it going; the second, although by nature precisely the same as the first, stops it, and so on.

But the reader may ask, what is the reason for all this elaboration? Why not make the wireless signal act upon the gas valve more directly?

The answer is, "For safety's sake." Of course, the two aerials, the one at Gourock and the one on the beacon, are tuned in the ordinary way; but there is no reason why a ship might not use, either accidentally or on purpose, the same wave-length and so affect the instruments upon the beacon. It cannot do any harm, however, because, as we have seen, there is a mechanical tuning device as well. If the balance wheels were not both set so as to work at the same rate little would happen, and a series of impulses coming in at any other rate than 180 per minute would have little or no effect. To interfere with the fog gun a ship would not only have to signal upon the particular wave-length employed, but would have to send a series of signals at precisely the correct rate.

But for this arrangement, of course, an accidental signal from a ship might set the gun going on a lovely summer's day, or, what would be worse, stop it in the midst of a dense fog.

Another type of fog signal based upon the ease with which sound can be sent through water will merit a chapter to itself.

CHAPTER XIX

SUBMARINE SIGNALLING

OF all the dangers to which a seaman is subject, those which arise from fog are undoubtedly the worst. It has been reckoned that in the ten years from 1893 to 1902 between 900 and 1000 ships were lost through fog, resulting in the loss of 500 lives and £10,000,000 in money.

The forms of fog-signal apparatus already described no doubt go far to mitigate these risks, but they are not by any means sufficient. All of them, whether bells, whistles, sirens, or explosions, depend upon the efficacy of the air as a means of carrying the sounds which they create, and the air cannot be relied upon to do the duty with any sort of regularity. Owing to variations of density and other causes, it may be possible to hear 10 miles away a sound which is inaudible 2 or 3 miles away. In fact, there have been cases where a fog signal could not be heard at close quarters, but was quite loud at a distance. Moreover, when cliffs are near curious echo effects are produced which make the signals at times actually misleading.

Air being the natural medium by which sound reaches our ears, it is somewhat of a shock to learn that it is really a very bad substance for the purpose.

The reader may like to verify this statement for himself, and he can do so by the following simple experiments.

Take your walking-stick, place one end over your ear and the other upon the watch pocket of a friend. You will find that you can hear his watch ticking plainly, whereas if you depend upon the air to bring the sound to you, you will hear nothing. In other words, sound can pass more easily along a wooden stick than it can through an equal thickness of air.

The next time you take a bath you can try an even more striking experiment. Let the tap drip slightly so that a series of drops of water fall from it on to the surface below. Then immerse your head at the other end of the bath so that the sound will be carried right into your ear by water instead of by air. You will at once perceive the superiority of water over air as a carrier of sound.

Sound travels through water at the rate of 4700 feet per second, as against only 1100 feet per second through air, but not only does it travel faster, it travels farther and in a perfectly uniform manner. There are none of those "areas of silence" which occur in air. A sound coming through water varies in strength with the distance from which it has come. Although echoes occur in water as in air, they are not so confusing. In fact, however it be regarded, water is immensely superior to air for the transmission of sound signals.

What, then, could be better than water for carrying fog signals at sea? Just as we naturally hear by means of the air it seems quite appropriate that a ship should hear by means of the water, and in the latest apparatus the device for receiving the signals upon the ship bears a very remarkable resemblance to the human ear. It is just as if the vessel had been fitted with an ear of its own, or rather a pair of ears.

To carry the analogy further, there passes from each of these " ears " an electric wire which carries the sounds to the officer in the cabin, just as the nerves carry the sounds from the human ears to the brain.

The two ears upon the ship function very much as the two ears of the man. We judge the direction from which a sound comes by instinctively comparing the effect upon our two ears ; we compare the sound as heard in one ear with the same sound as heard in the other ear, and precisely the same principle is applied to the " ears " of the ship.

But it seems as if we are getting on with the story a little too fast, so let us go back to the beginning and see how this remarkable invention has been developed.

As long ago as 1767 a Scotch man of science tried the experiment of listening to a bell rung under water while he himself was immersed—the bath experiment described above on a larger scale. He found that he could hear it at a distance of 1200 feet.

In 1826 a further experiment was tried upon the Lake of Geneva. Again a bell was struck under water, and some distance away a man leaning from a boat put the bell-mouth of an ear-trumpet in the lake. Placing his ear to the small end of the trumpet he was able to hear the bell. Both this experiment and the preceding one were made for purely scientific purposes, and with no idea of signalling through water.

Probably the first actual use of water in this way was made by the pearl divers who, it is said, have for many years made it a practice to signal to each other when beneath the surface by simply tapping two shells together. Another example of accidental submarine signalling is found in the story, of which the writer does not know the date, of the diver who went down to search for a valuable watch which had been dropped into the sea. The case proving to be water-tight the watch continued to tick; the diver's helmet acted like a diaphragm and picked up the sound from the water so that the man heard it clearly and was thereby guided to the watch.

So far as we know, the first definite attempt to send sound signals through water was due to a Mr. Henry Edmonds, an Englishman, who took out a patent upon the subject in 1878. His sending apparatus appears to have been a bell rung under water, and he had ideas for arranging an electric gong for this purpose, also of using an ordinary telephone. For receiving he apparently used an oar with the blade immersed and with the handle pressed to his ear, a somewhat crude idea, it is true, but one which contained the central idea of submarine signalling. He also suggested, but probably never tried, an ordinary telephone transmitter immersed in the water so as to pick up the sounds and transmit them to the ear of a listener.

Quite a number of other ingenious men attacked this problem both in England and in the United States, but up to the year 1898 they did not succeed in doing more than prove that some system of underwater signalling was possible and would probably be valuable.

In that year Mr. Arthur J. Mundy took up the matter and induced a number of other people to join him in forming a syndicate with funds sufficient to carry out the necessary experiments and make the thing a success. One of his associates was Professor Elisha Gray, a man well known for his ingenuity in applying the discoveries of science to practical purposes. These two men, together with several others, carried the development of the apparatus much farther until the death of Professor Gray in 1899. They had by that time got to the point of hearing a bell sound at a considerable distance by means of an apparatus lowered over the side of a ship. The ship, however, had to be stationary and the water calm, otherwise the noise of the water drowned the sound of the bell and rendered the effective range very short. That, evidently, would not do in actual practice.

At this stage all the trouble seems to have been at the receiving end. A bell struck by a simple mechanism under water was up to a point quite satisfactory for making the sounds. It has been improved upon since, but at the time we are speaking of it was far better for its purpose than any known receiving device was for the other end. All thoughts were therefore concentrated upon a good receiver, and, as so often happens, the best thing when found turned out to be remarkably simple. It is so with nearly all inventions. A man's first ideas are always needlessly complicated, and when after much thought he has discarded, one after another, a host of unnecessary complications, he finds himself with a perfected invention of so simple a form that when he looks at it he cannot help but exclaim, "Why ever did I not think of that to commence with ?"

Thus Mr. Mundy arrived at the best form of receiving apparatus. It consists of a microphone immersed in water in a small tank fixed to the skin of the ship, not, as one would expect, outside it, but *inside.*

For the sake of those readers who are not familiar with the structure and working of a microphone, a few words on the subject will be opportune. It is the transmitting part of a telephone apparatus, and it depends for its action upon the fact that a mass of loose particles form a bad conductor of electricity, even though the particles individually are good conductors. If therefore we were to take a little box with metal ends, but otherwise made of wood or cardboard, we could easily make of it a microphone.

We should have to fill it loosely with granules of some conductive substance—carbon is the usual thing—and then try to pass an electric current from one end to the other. At first little or no current would pass, but if we tapped the box so as to make the granules pack more tightly together we should thereby improve the conductivity and so permit more current to flow. Every time we tap the box, then, a little rush of current takes place.

Suppose, next, that we make one of these box-ends into a diaphragm and instead of tapping it talk at it so that the sound waves give it a series of taps ; the little spurts of current will then correspond exactly both in time and in strength with the sound waves. By passing this changing current through a telephone receiver the variations are changed back into sound waves, and the sound which caused them is thus reproduced.

Of course, the microphone used in this apparatus is specially designed for the purpose, but the principle of it is exactly what has just been described.

Let us now follow out in our minds what happens. The sound waves reach the ship through the surrounding water, pass through the steel plates which form the skin of the ship into the water in the small tank, and from this water to the microphone. Here they impart to the granules a slight shaking—far too slight to be perceived by any of our senses, but violent enough to act upon the current of electricity passing through the microphone, and to produce thereby a strong sound in a telephone.

Fortunately, this action is most effective when the waves strike directly against the side of the ship. When we come to think of it that is just what we might expect, although things do not always happen so. If, therefore, we regard the side of the tank which is fixed to the skin of the ship as the face of the "receiver," we can say that it is most effective when it faces the direction from which the sounds come. That is a most fortunate and important thing, because it furnishes a means whereby the direction of the sending apparatus can be discovered with remarkable accuracy.

If the tank were fixed in the middle of the ship so that it faced at right angles to the course of the vessel, signals would be heard clearly when the ship was abreast of a signalling station, but scarcely, if at all, when pointing towards it or away from it. By adding a second tank on the opposite side to the first it would be possible for a ship to pick up sounds from either side, but not ahead or astern. The latter is of no moment, because a ship need not trouble about dangers which are behind it. On the other hand, it is of the utmost importance that it should hear warnings from the direction in which it is moving. So the tanks are placed towards the bow, where the inward curve of the sides gives them a position such that they face to some extent in the direction in which she is moving. The exact position is fixed in each particular case after a careful study of the shape of the vessel.

Thus, to revert to our human analogy, each ship so fitted has a pair of ears so placed that they can hear sounds from either side or (more faintly) from directly ahead. The two "ears" are carefully "paired," that is to say, they are made as nearly as possible of exactly equal sensitiveness, and the officer on the ship listens first to one and then to the other, and by comparing them can judge very accurately whence the signals come. By altering the course of his ship until they are both exactly equal he can be sure that he is steering directly towards the signal.

Now let us turn our attention to the sending devices. The chief of these is still the bell struck by a hammer, but there have been much thought and ingenuity expended upon the mechanism for working it.

Of this mechanism there are at least five different types producing separate types of apparatus suitable for different purposes. First there is the kind specially appropriate for a lightship, operated by compressed air. This is just hung over the side of the ship, the air passing down to it through two flexible tubes. This type would obviously be useless at a shore lighthouse many feet from deep water, so there we have the second type in which the bell is suspended from a tripod placed on the sea-floor, and the striking is done by electricity supplied and controlled from the lighthouse.

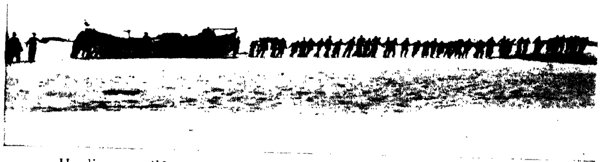
Again, there are many places where a warning is very desirable, yet it is impossible or too costly to have either electric or pneumatic machinery. In such cases a bell can be suspended below a buoy which rising and falling with the waves will itself actuate the mechanism. It has been found that with suitably designed machinery there is enough movement even in calm weather to make this work quite satisfactorily.

The fourth type is intended for use in emergencies, to enable ships to communicate with one another. A historic example of the need of this type is the wreck of the White Star liner *Republic* by collision with the *Florida* in the year 1909.

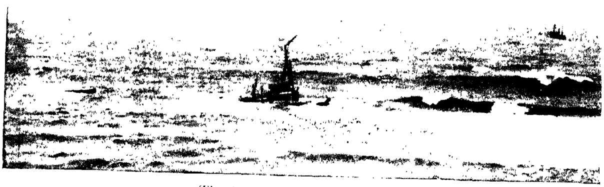
The *Baltic* picked up a wireless message from the *Republic* appealing for help and at once rushed to her assistance, but could not find her for many hours. For twelve long hours was the *Baltic* zig-zagging and circling around her disabled sister before she found her, and that despite frequent wireless signals. Over 200 miles did she steam in her search, until at last, when within 100 feet, a glow was seen in the fog. It was the crippled ship.

Now all this time the *Baltic* was getting submarine sound signals from the Nantucket Lightship. If the *Republic* had possessed an emergency bell it would have been heard too, and the *Baltic* could have made straight for her instead of having to search about for twelve hours. It was fortunate that the *Republic* kept afloat. She might easily have sunk before aid arrived.

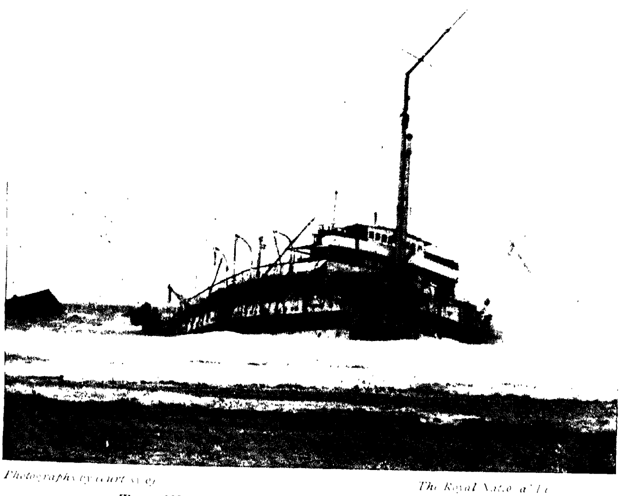
The fifth type is similar, in being specially for use in emergencies, but it is made small and light so that it can be carried by small boats. This type is of peculiar interest because of its personal appeal. There is no more tragic picture in the whole of human experience than a small boat containing castaways from the wreck of a ship, drifting about upon the open sea



Hauling up a lifeboat after an unsuccessful attempt to reach the *Rohilla*.



The *Rohilla* nearly submerged.



Photographs by courtesy of *The Royal Nat[illegible]*

THE WRECK OF THE HOSPITAL SHIP *Rohilla*

The *Rohilla* breaking up, with wav[illegible] with nothing but water in sight, hoping hour after hour, sometimes day after day, for help to come; with no means of calling for help, and with the possibility that by night or in hazy weather a friendly steamer may possibly pass close by them in entire ignorance. A small submarine bell would in almost all such cases bring aid surely and quickly. Even if it did not, the moral effect upon the people in the boat would probably be very great. They would feel that they were doing something and that they were in communication with those who were coming to their assistance.

We can now proceed to examine how these various appliances work, starting with the lightship type.

The standard bell is made of bronze, weighs 220 lbs., and when struck, under water, vibrates at the rate of 1215 per second. The hammer, also of bronze, hangs inside the bell in the usual position. The operating mechanism is in a cylindrical chamber to the lower end of which the bell is fixed. The whole thing is suspended by a rope or chain.

Upon the lightship there is an air-compressor and an engine—either steam or oil—to drive it. Another important device upon the ship is the "code-regulating valve." This little machine, itself driven by compressed air, lets out little puffs of compressed air in groups, so timed as to give the signal bell its own peculiar "character" by which it can be distinguished from its fellows.

The impulses from the valve pass down a pipe to the operating chamber above the bell. They do not actually ring the bell themselves, but they cause the bell to be rung by the air which passes down the other pipe—it will be remembered that there are two.

One is inclined to wonder why the matter should be thus complicated by the use of two pipes when one would apparently be sufficient. To use one pipe would be rather like trying to work an ordinary "pull" bell with a piece of elastic. As we know, the result in that case would be that most of our energy would be expended in stretching the elastic, and very little would reach the bell, which would respond but feebly.

The bottom of the operating chamber forms a reservoir where a certain amount of compressed air can be stored, and the function of one pipe is to keep this full. The short puffs or impulses coming down the other pipe simply open a valve and liberate some of this, permitting it to give the hammer a vigorous impulse every time. Thus, whenever the code-regulating valve sends an impulse down, a stroke of the bell follows.

The bell is suspended from a davit usually at a depth of about 18 to 20 feet. The whole apparatus is generally in duplicate, in order to provide against the possibility of a temporary failure.

The strokes on the bell may be made at the rate of 30 to 35 per minute.

The second type of apparatus entails the use of some structure to stand upon the ground and uphold the bell which hangs from it, just as the other kind hangs from a davit. Generally this is a strongly constructed tripod of steel with heavy cast-iron feet to give it stability. It has to be carefully laid in order to ensure that it shall be reasonably upright and the bell free to operate. A cable connects the bell with the lighthouse or wherever the controlling devices may be. This cable carries four wires, two for the operating current and two for a telephone.

Externally the electrically driven bell looks much like the other, but inside there is an electro-magnet which is energized periodically by the current from ashore. When energized this magnet attracts an armature the movement of which by a simple mechanism moves the hammer and causes it to strike the bell.

The reason for the telephone wires is to enable the attendant ashore to listen to the bell himself and assure himself from time to time that it is working properly. There is also a device by means of which he can tell that the bell is hanging vertically, in order to guard against any possible displacement of the tripod.

That brings us to the type where the bell is rung by the movement of the water itself, an exceedingly interesting type for several reasons. Of course, such a signal can have no distinguishing character, since so much depends upon the action of the waves; its absence of "character" suffices, however, to distinguish it as being merely a buoy. The mechanism is so devised, too, that whatever the sea may be like, whether rough or smooth, the strokes of the bell are all equally loud, so that its distance can be judged roughly.

Externally this is a most imposing affair. First, there is the buoy itself. This may be of any shape or form so long as it has buoyancy enough to sustain the $2\frac{1}{2}$ tons or so which hangs beneath it. Generally it is drum-shaped, with a framework beacon of some sort above it to make it more clearly visible.

The mechanism and, to a large extent, the bell itself is enclosed in an iron box 4 feet square and 5 feet long, open top and bottom, which box is attached to the underside of the buoy by a strong framework or large tube. The length of the framework, including the box, is somewhere about 18 feet. Since that is in addition to the buoy we see that we are dealing with a structure of no small dimensions. To the many readers whose idea of a buoy is a small barrel or even a biggish piece of wood, these figures will come somewhat as a surprise.

The buoy, of course, rises and falls more or less with every wave that comes along, but the water from 13 to 15 feet below the surface remains still. It follows, then, that the iron box already referred to, with its open ends, is continually rising and falling in still water, which is precisely the same as the water rising and falling inside the box. A large "vane," hinged and balanced, is fixed across the inside of the box so that this movement causes it to be lifted and depressed alternately. The movement of the vane is communicated by simple mechanism to the internal machinery which is enclosed in a water-tight case fixed to the side of the box.

This case is filled with oil, which ensures perfect lubrication and also prevents any possible leakage of sea-water into the machinery. Ball bearings are used wherever possible, so that friction is kept down to the minimum.

The essential feature of the internal machinery is a crank which is pulled in one direction by a spring. You can get a good idea of its method of working if you picture to yourself the domestic mangle with a heavy weight tied to its handle. This handle, being fixed to the rim of a wheel, forms with the wheel a crank. Now, if you were to turn that crank while the weight was attached you would have to lift the weight during one half of the revolution, but the weight would itself turn the wheel during the other half. You would be storing up energy while lifting the weight, and the moment the handle passed over the "centre" the energy would come back and would turn the wheel itself.

That is just how the crank works in the automatic submarine signal. The up-and-down motion of the vane turns a "rocking shaft" first one way and then the other. By an ingenious arrangement of wheels and catches ("pawls" is the technical term) every movement of this rocking shaft turns the crank more or less against the force of the spring, until at last it passes over the centre. Then the spring pulls it round the rest of the turn with a rush, and in doing so works the hammer.

The force of the blow therefore depends only upon the strength of the spring and not upon the force of the waves, so that every blow is of equal strength.

But surely, the reader may ask, the state of the sea must make some difference. What is it? In the number of signals per minute. If the waves are large and the buoy is moving up and down through a considerable distance, the vane will turn the rocking shaft far more at each movement than if the waves are small. Consequently the crank will be turned more quickly and the bell will be struck more frequently. In average weather the bell is struck about fifteen times per minute, and even in an apparent calm there will be several strokes per minute.

The hand-operated bells, to which we now come, are naturally much simpler than those already described. The actual bell used by ships for communicating with other ships in an emergency is about the same size as those already referred to. It is lowered over the side of the ship from a davit, and the hammer is actuated by pulling a rope.

In the smaller contrivance, intended to be carried by a ship's lifeboats, the bell takes a different form, being a simple disc of bell metal. This is lowered into the water over the side of a boat by means of a cord, and the hammer is operated by pulling another cord. The total weight of this is only 25 lbs.

To complete the story we must now return to the receiving apparatus. In each of the two tanks fixed to the skin of the ship there are two microphones, one of which is called A and the other B. The reason for the use of two is that one pair, that is to say the two A's, may be checked against the two B's, thereby avoiding the possibility of a defect in a microphone giving a wrong indication.

Wires from all these microphones pass to the chart room or other convenient place, where they terminate in an instrument called the "direction indicator." This is a small square box which is fixed to a wall. On the front, near the top, there is a little window at which can be seen the word "port" or "starboard." Lower down are a small lever handle and a knob, while on either side there hangs a telephone receiver.

When using this the officer places the telephones to his ears and listens. Suppose he hears the sound of a bell; he looks at the little window and there sees the word "port," from which he knows that the sounds are coming in on the "port" side. Then he moves the lever handle, and the word "port" is displaced by the word "starboard." Listening again, he hears bell sounds once more. By mentally comparing the intensity of the two sounds he is able to judge the direction in which his ship is pointing. He will probably change over several times in order to confirm his own judgment of the two sounds.

Then he will probably turn the knob, by which he will cut out one pair of microphones and bring the other pair into operation, repeating his observations with them.

If he wishes to get the direction very accurately he will have the ship turned slowly towards the side where he hears the loudest sound, listening the while until he gets equal sounds on both sides. Then he will know that his ship is pointing directly at the signal station.

Thus far we have seen the submarine signalling system in its simplest form as it is installed at a number of stations and on over 1000 ships. Further developments will be described in the next chapter.

CHAPTER XX

THE UNDER-WATER TELEPHONE

THE whole history of submarine signalling is a very short one, and the bell signals just described are very few years old, yet already a newer device has come into use.

The essential feature of the new system is an instrument called an " oscillator " which was invented by Professor Fessenden for the Submarine Signal Company, the company which has already been referred to as the agent responsible for the development of this extremely valuable method of safeguarding ships by sounds through the water.

It must not be supposed that the bell signals have failed. They have done remarkably well and are still in use in many places, but they have their limitations, and it was felt that an apparatus for sending signals which could be operated by an ordinary telegraph " key " would have great advantages over a bell. For one thing, it would be possible, with such an apparatus, to send verbal messages, just as telegrams are sent over the wires. With a bell, making just one sound, it is only possible to send a few signals. By grouping the strokes one can make one signal differ from another, but it would be quite impossible to have a separate group to represent each letter of the alphabet and to send those groups with any speed. With an instrument controlled by a key it is possible to make long signals and short signals, thereby using the familiar Morse code and sending letters and words with great rapidity.

A moderate speed for telegraphy is twenty words per minute; the average word, using the Morse code, is equal to thirty-five "dots," as the short signals are called. This shows us that to send twenty words per minute we need something which is able to produce these short signals or dots at the rate of seven hundred per minute or about twelve per second.

In order to distinguish between different stations, under this arrangement, it is necessary to give each station its own peculiar "note," and in order to achieve this it is necessary that each dot or dash (by which is meant the long signals) should consist of a number of impulses or waves arriving at the rate of hundreds, if not thousands, per second.

Thus we see that the people who started to devise this oscillator had a task before them of no easy kind.

It is hardly necessary to state that electricity furnishes the key to the solution of this, as of so many other problems. The electro-magnet is the essential feature, as it is in most forms of signalling apparatus. Let us picture the device to ourselves first of all in its general principles, and then see just how those principles are applied.

First we have a coil of insulated wire almost surrounded by a casing of iron so arranged that when current is passed through the coil a very powerful magnet is the result. The general form of this is circular, with a hole in the centre in which is the magnetic field, that is to say, the area in which the magnetic effects can be perceived. Things are so proportioned that in this small space the "field" is very intense—in other words, the magnetic effect is very strong indeed. This magnet, since its purpose is to produce this intense magnetic field, is called the "field magnet."

Inside this ring-shaped magnet is a cylindrical object of iron called the armature, and upon this is wound a single layer of insulated wire termed the "armature winding." The presence of the iron armature intensifies the magnetic field still more.

Now, if a current of electricity be sent through a wire or any other kind of conductor when it is in a magnetic field, the conductor will try to move. The force which it will exert will vary according to the strength of the current, and the direction will depend upon the direction of the current. If the current be made to flow first one way and then the other, the conductor will try to move first one way and then the other. Whether it actually moves or not will depend upon whether it is firmly fixed or not.

Suppose, then, that the field magnet be firmly fixed and the armature winding be free to move; when an alternating current is sent through the armature winding it will move to and fro, and if it be attached in some way to a diaphragm it will make the diaphragm move to and fro in the manner necessary to produce a musical sound.

There is a practical difficulty, however, in attaching the armature winding to the diaphragm with sufficient firmness, for great rigidity is necessary since otherwise much of the movement would be lost on its way to the diaphragm. In other words, the winding would expend a good deal of its energy in bending or stretching the means of attachment rather than in shaking the diaphragm. The difficulty could, of course, be overcome, but only by making the moving part very heavy, so a very original but effective substitute is adopted.

The armature and its winding nearly fill the hole in the centre of the field magnet, but not quite. There is a little space all round the armature, and in this is placed a thin copper tube. The tube is rigidly attached to the diaphragm, but otherwise it is free to move. The armature with its winding is, however, firmly fixed so that it cannot move at all.

Now, when a changing current flows in a winding near any sort of conductor it induces currents similar to itself in that conductor. The consequence of this is that when the alternating, or to-and-fro, current flows in the armature winding, currents are induced in the copper tube. These currents flow round and round the tube just as if it were a single turn of very thick wire. Because of the high conductivity of copper the induced current is very strong, and being immersed, so to speak, in a very strong magnetic field, it is thereby urged to and fro with a very strong force. Yet it is quite light, so that it moves easily and it is easy to connect it in a very rigid manner to the centre of the diaphragm.

The diaphragm is a thick plate of iron; it may even be a part of the skin of a ship. The field magnet is a thick heavy ring of iron which is securely fixed to the edge of the diaphragm, forming, with a small cover over the back end of the tube, a very strong, heavy contrivance, robust enough to withstand the roughest usage and almost impossible to put out of order.

When, therefore, an oscillator is lowered into the water or fixed to the side of a ship and an alternating current is sent through the armature winding, a sound wave is produced in the water for every alternation in the current. If the current alternates 100 times per second, it will produce waves at the rate of 100 per second; if the alternations be 1000 per second, there will be 1000 waves per second. It is quite easy to design a little dynamo to give alternating current of almost any frequency up to thousands per second, so that it is only necessary to couple the oscillator to a suitable dynamo, and to drive that dynamo at a steady speed, in order to make the oscillator emit almost any sound that we may want. Then, by inserting a telegraph key in the circuit between the dynamo and the oscillator, we can split this sound up at will into "shorts" and "longs" with any desired intervals between, and so send telegrams through the water just as easily as we send them over the telegraph wires.

In practically all apparatus whereby an electric current serves to make something move there resides the virtue of reversibility. That is to say, if we make it move an electric current will be the result. An ordinary electric motor if turned round by external force becomes a dynamo or generator of electric current, and in just the same way if the diaphragm of an oscillator be moved a current will flow in the armature winding. Thus, the same oscillator can be used both for sending signals and for listening. It is claimed that this is the most efficient form of telephone transmitter in existence.

It should be explained that in addition to the alternating current a supply of steady direct current is necessary in order to energize the " field magnet." This is required for both sending and receiving.

In actual practice there is a switch with two positions. In one it connects the oscillator up so that the manipulation of the key sends out signals ; in the other, the key is cut out and a telephone receiver is brought into the circuit so that the incoming signals after being changed into electric current by the oscillator are reconverted into sound at the operator's ear.

So far we have considered only those cases where Morse signals require to be sent. Suppose we send a steady current from a battery through the oscillator and then vary the strength of that current by means of a microphone, the diaphragm will respond to every change of strength. By speaking into the microphone we can make the variations correspond to the sounds of our voice, and these sounds will then be repeated by the oscillator and carried away by the water. In like manner articulate sounds coming in through the water will be changed by the oscillator and telephone into human speech in our ears. Naturally, the changes produced by speaking into a microphone are less violent than the alternations of a powerful alternating current, so that the range of audibility with speech is much less than with Morse signals. This is analogous to the experience of all wireless enthusiasts, who know that Morse signals can be picked up at much greater distances than telephony.

The first oscillator that was made was tested at the Boston lightship, U.S.A. It was suspended in 12 feet of water and was heard by a microphone lowered into the water from a boat 31 miles away. For practical purposes a range of 20 miles is probably quite sufficient, and this first test alone shows us that that is well within the limits of possibility. More recent tests show that a range of 50 miles is possible.

Clearly, an oscillator is an easier thing to handle and to work than a bell, and in course of time it will probably displace the bell at all places where a supply of electric current is available, or can be produced. Its enormous range will enable us to reach the conditions when every coast will, as it has been put, " be surrounded by a wall of sound," so that a ship approaching land anywhere will have a certain warning, a warning which, unlike fog signals in air, can be relied upon absolutely. Let us take a further illustration.

THE UNDER-WATER TELEPHONE

The one tragic word *Titanic* suffices to remind us of the terrors of icebergs. Icebergs cannot be charted, icebergs show no lights, so that they are a danger during the hours of darkness even in clear weather. It is unnecessary to dwell upon their awful possibilities during fog. It really seems as if submarine sound signals may rid them of their terrors.

It comes about in this way. If a short signal be sent with an oscillator from a ship the sound is reflected off the bottom of the sea. If an iceberg be near it is reflected again by the iceberg. We have, therefore, a twofold safeguard, for we can take soundings with great ease, and we can also " sound " for possible icebergs. Of course, the time interval between the despatch of the sound and the receipt of the echo is very small, but a simple contrivance enables this to be measured quite easily.

Imagine a drum-shaped object, mounted upon a spindle so that it can be rotated easily, driven round at a steady speed by an electric motor or other convenient means. One small segment of this drum is conductive, but the rest is non-conductive. As it turns, a little block of metal or carbon rides steadily but firmly upon it, forming what is known to electricians as a " brush," presumably because it sweeps the surface of the drum as it rotates. Every time the conductive segment comes under the brush a circuit is thereby completed and current passes to the oscillator. The contact between the conductive segment and the brush is equivalent to the contact of the two parts of the key when a key is being used to send signals.

Alongside the first brush is a second one which can be moved round and set in any desired position round the drum. This second brush communicates with the telephone ear-piece.

When both brushes are side by side no sound can be heard in the telephone, because by the time the echo has come in, the " live " segment has moved away and both brushes are out of action.

If, next, the second brush is slowly moved round, in the same direction as that in which the drum moves, it soon reaches a position in which the echo is picked up, but if it be moved farther the sound is lost again. That is because, when it is in that particular position, the signal which is sent as the live segment passes under the first brush arrives back just as the segment is passing under the second brush. The time taken by the sound to go and return is equal to that taken by the live segment to pass from one brush to the next.

Knowing the speed of the drum and the number of degrees through which the brush is moved, it is easy to calculate the distance which the sound has travelled. Half that will be the distance of the object which causes the echo.

When no iceberg is about only one echo is heard, that from the earth ; but when there is an iceberg near, a second echo reveals the fact, also the distance.

Speaking of sounding, there is another method which can be used and which has advantages over that just described. Assuming that the sea-floor is flat, as it usually is, a sound wave striking it at an angle is reflected at an equal angle. That is simply the well-known law of reflection with which we are familiar in the case of light. If, therefore, a sound be sent from the front of the ship, some part of the waves set up will strike the ground directly under the centre of the ship, and these will be reflected up again to the rear of the ship. Then, if an instrument be installed at the rear of the ship capable of telling the direction from which these sounds are received, the depth can be told quite easily. The length of the ship, or to be more precise the distance between the sound-making and sound-receiving apparatus, will always be the same, but the angle at which the sound arrives will vary with the depth. The angle, therefore, will give us a measure of the depth.

The difficulty here is to tell accurately the direction from which the sounds arrive. It can be done by placing the receiving instrument at the end of a tube lined with felt or some other material which does not reflect the sound waves. This tube is then moved about until the loudness of the sound shows that its open end points directly in the direction from which the sounds are coming.

Another development is a handier method of determining the direction of a station or another ship. The way already described of turning the ship until the sounds are equally loud on both sides is clumsy, to say the least of it. Suppose that a ship were proceeding up the English Channel with submarine signal stations at intervals of 50 miles along the English coast. To get the best results the vessel would have to steam round a loop once every 50 miles in order to get the direction of two stations. As we have seen in an earlier chapter, short range wireless signals are much better in this respect, since the direction can be found with considerable accuracy without interfering with the motion of the ship at all. Moreover, all the methods which we have discussed so far depend upon the comparison of the loudness of sounds, and anyone who has tried it will bear witness that to distinguish between a fairly loud sound and one slightly more loud or less loud is extremely difficult. Where possible it is best to arrange things so that you seek for the faintest, not the loudest, sound because you can then dim the whole thing down until you get a point where a faint sound changes to no sound, a change which the ear can detect with remarkable accuracy. In the apparatus about to be described, however, another principle is employed, in which difference in time is substituted for difference in loudness.

It is found by careful experiment that human beings can distinguish the direction from which a sound arrives much better with two ears than with one, and further, that this is not owing to the increase of hearing capacity due to using two instead of one. It is due to the fact that if one ear be farther from the source of sound than the other the sounds reach it slightly later. The difference in time must often be exceedingly small, but it is not too small for our ears to detect. We do not notice it consciously, but we have been practising listening to and judging sounds ever since we came into the world, and without knowing it we have all acquired a wonderful sense of this difference.

This is rather surprising, but a simple experiment will support the statement. Place yourself near a window looking upon a busy street. Turn your back to the light so that you cannot see what is happening outside and listen to the passing vehicles, first with one ear closed and then with both uncovered. You will find that with only one ear in use you cannot tell which way the vehicles are going. With two you can.

Let us therefore suspend from the ship a vertical bar with a horizontal bar fixed to its lower end, like an inverted T. At each end of the horizontal bar we place a microphone.

By rotating the vertical bar we can change the positions of the two microphones relative to the source of sound. When both are equidistant from the source the waves strike them simultaneously. Each microphone is connected to one of a pair of identically similar telephones, and the sound from each therefore enters an ear at precisely the same moment as that from the other. It seems, then, to a man listening at the telephones that he hears a sound from his front. *His* front, be it noted, whichever way he may be facing actually. The way he is sitting does not matter; when it seems to him that the sounds come from his front he knows that, as a matter of fact, they are coming along a line at right angles to the horizontal bar.

In all probability, however, when he first listens the sounds will be coming more or less from one side and the listener will think he hears sound from one side. He will then turn his vertical rod until it seems to him they are coming from the front. The mode of procedure, therefore, is to turn the vertical rod until the sounds seem to be in front of the operator; then a pointer fixed to the vertical rod shows the direction.

There are, however, two difficulties in the way of this plan. One is that if the ship be moving, the dragging of the inverted T through the water causes sounds, known generally as "water noises," which tend to mask the sounds which are being listened for, and make the comparisons difficult.

This trouble is apt to occur with all the different forms of listening apparatus. It is to avoid water noises that the internal tank with its microphones immersed in water is used, and even then the trouble is not entirely removed. It is easy to see, therefore, that an object such as has just been described when dragged through the water would create considerable noise.

It is overcome to some extent by having a series of floats of "stream-line" form, so that when dragged through the water they will cause the minimum of disturbance. These are connected with the ship by the necessary wires, but are towed a considerable distance astern. By fitting them with suitable fins they can be made to float under the surface at a level suitable for their purpose. Each float, of course, contains a microphone.

Another drawback to the two-microphone arrangement is that it gives precisely the same indication whether the sound be coming from the front or the rear. This can be obviated by the use of three microphones set at the points of an equilateral triangle. The three are then brought into operation in pairs, and the results compared in a very ingenious manner.

The three telephone receivers connected to the three microphones are not placed close to the ear, but are connected to the ears of the operator by tubes the length of which can be varied. Of course, the sound takes an appreciable time to travel along these tubes, which time will vary according to their length, so that the length of the tubes can be made to measure the difference in the times of the receipt of the sounds by the microphones.

In action, the operator first takes telephones A and B, which are connected to microphones A and B respectively. He then varies the lengths of the "speaking tubes," as we might call them, until it seems to him that he hears sound from the direction in which he is facing. The lengths of the tubes at that moment enable him to tell the direction. He can then repeat the operation with telephones B and C and then with C and A, and by combining the results of the three he can be absolutely sure whence the sound comes.

THE UNDER-WATER TELEPHONE

It must be understood, however, that many of these ideas are still in their infancy and are likely to undergo rapid development in the near future. What has just been said will enable us to see the vast possibilities of this wonderful system of signalling.

CHAPTER XXI

SUBMARINE AND WIRELESS SIGNALS COMBINED

THE question of submarine signalling is naturally of keen interest to the Trinity House and the other lighthouse authorities, and has been to a greater or less extent adopted by them all. Among the members of one of these bodies, the Irish Lights Commissioners, Professor John Joly made the subject peculiarly his own. This gentleman developed a remarkable scheme based upon submarine signals for the avoidance of collisions at sea.

The principle involved is very old. Even the most unscientific person knows how to estimate the distance of a thunderstorm, by noting the interval between the flash and the sound. The light of the flash travels at the rate of 186,000 miles per second, which means that it covers ordinary terrestrial distances practically instantaneously. The time taken is so small that we can only measure it with great difficulty, and so we can assume for most purposes that it does not exist. We can go on the assumption that we see the lightning flash, therefore, at the very same moment that it takes place.

Compared with this speed, sound is a veritable sluggard. While light is travelling 186,000 miles, sound in air covers only 1100 feet. Every second, therefore, between the time we see the lightning flash and hear the roar of the thunder represents a distance of 1100 feet. Take the interval in seconds, multiply it by 1100, and we have the distance away of the storm in feet.

In water, as we have seen, sound travels much faster—namely, 4700 feet per second; but even then it is exceedingly slow compared with light, so that we can estimate a distance on just the same principle when the sound passes through water as we can when, in a thunderstorm, it passes through air. Suppose, for example, we arrange matters at a submarine signal station so that, precisely as the oscillator sounds, a tray of photographer's flash powder shall be ignited. The sound and the light will then start precisely together; but whereas the latter will reach our eyes instantaneously, the former will take an appreciable time before it reaches our ears. That interval in seconds multiplied by 4700 will give us the distance of the station in feet.

That arrangement would hardly be suitable for foggy weather, however, since we could not then see the light signal. Fortunately, there is a kind of light which travels at exactly the same speed as ordinary light and takes no notice whatever of fog. This "kind of light" is the long-wave radiation which carries our wireless messages. We can therefore substitute a short wireless signal for the flash of light and get the same result, and such an arrangement will be equally effective whether the air be clear or opaque with fog.

There is a further advantage, also, in the fact that it is particularly easy to time these two kinds of signal so that they are sent off at the same moment or at a certain desired interval. By combining, therefore, a submarine sound signal with a small wireless transmitter and the submarine receiving outfit with a wireless receiver, we have a very convenient and accurate device for measuring the distance between a ship and a signal station or between two ships.

Both the wireless and the submarine signal will be received upon a ship by means of a telephone, and it is quite practicable to make them both audible in the same ear-piece. Moreover, it is also easy to arrange that they shall have quite different sounds, so that to confuse them would be impossible.

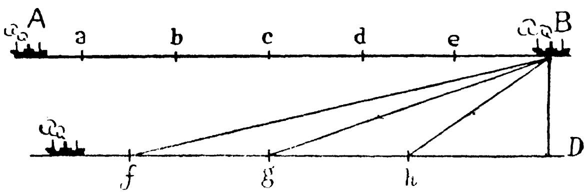
The essence of the whole operation is, of course, to measure the interval of time between the receipt of the wireless signal and of the submarine signal, but that again is not difficult. The speed of sound in water being 4700 feet per second, a distance of a nautical mile is represented by an interval of well over a second. To be precise, an interval of ·62 of a second corresponds with half a mile. The timekeeper at athletic sports reckons to give us the performances correct to ·2 of a second, so that, using an ordinary stop-watch such as is used at sports, it would be possible to measure distances correct to well within a quarter of a mile. As a matter of fact, a much more convenient arrangement is possible.

It can be arranged that a clockwork mechanism shall control the despatch of both sorts of signals. This apparatus can then send off a sound signal and a wireless signal at precisely the same time. If then it continue to send wireless dots at intervals of ·6 of a second, the man who is listening in the receiving telephones has only to count the number of wireless dots which he hears before he gets the sound dot. That number will enable him to calculate the distance. He will really be using a chronometer, just like the sports timekeeper, but the chronometer will be at the sending end instead of the receiving end. The same result could be obtained by the receiver having a loudly ticking stop-watch, but then he would have the difficulty of starting it at the correct moment and the possibility of making a mistake.

As a matter of fact, the operation is immensely simplified if the sound signal be sent off exactly ·6 of a second *before* the first wireless signal. Then the number of the wireless dot with which the sound dot coincides is the number of half-miles. It reduces the necessary calculations to one which a man can do in his head quite easily.

By this means a distance can be measured much more accurately than at first seems possible. For suppose the sound dot arrives just midway between two wireless dots, say between six and seven. The distance is then obviously $3\frac{1}{4}$ miles. Or suppose it be between six and seven, but distinctly nearer six than seven ; it can then be written down as $3\frac{1}{8}$ miles. Again, should it be close to one of the wireless dots but not quite coincident, it would be safe to write down the distance of $3\frac{1}{16}$ or whatever it may be. In other words, it is quite possible to take a reading which will be accurate to within a sixteenth of a mile, or little over 100 yards.

Now let us turn to the diagram below, where we see the courses of three ships. Ship A is moving



Two ships A and C are moving towards ship B but along different routes. B is stationary ; a, b, c, d, and e, represent positions of A *at equal intervals* of time, while f, g, and h, similarly represent positions of C. The distances a–B, b–B, etc., diminish with perfect regularity. Therefore ship A will collide with B. On the other hand, the distances f–B, g–B, and h–B do *not* diminish regularly. Therefore C will clear B.

along the line A–B, ship C is moving along the line C–D, while ship B is stationary at the point B. The principle about to be described is just the same if ship B be in motion, but for the moment it makes the explanation simpler if we regard it as still while the others move.

We must suppose that each of these ships is fitted with the signalling apparatus just described, and that at frequent intervals each sends out a series of, say, twenty wireless dots and one sound dot. In between the series each ship can send out, either by sound or by wireless, a special signal of its own, so that it will be easy for any one of the ships to recognize the two others.

The speeds at which the ships A and C are travelling will not matter in the least. The only thing essential for this system is that they shall be moving steadily; that each one shall maintain a fairly uniform speed.

Let us suppose that we are stationed upon ship B and that once every ten minutes we pick up a signal from A and also from C. Thus we know the distance of these two ships at intervals of ten minutes. We note these distances down as they are ascertained, and by subtracting the last distance found from the last-but-one we discover how far ship A or ship C has moved in ten minutes.

This distance, it will be evident, is not necessarily the distance which the ship has moved along her course; it is the distance by which she has approached *us*. We notice particularly whether the distance thus ascertained is the same every ten minutes or if it gets less and less.

If, now, we turn again to the diagram we shall see the significance of this variation. Suppose the graduations on A–B indicate the positions of ship A at successive intervals of ten minutes, and that the marks on C–D show the similar positions of ship C. Each successive mark on A–B is nearer to B by precisely the same amount, but the lines from the marks on C–D to B while getting shorter are diminished to a less extent every time. In other words, to an observer on ship B, ship A will appear to be approaching at a uniform speed, while ship C will appear to be approaching more and more slowly.

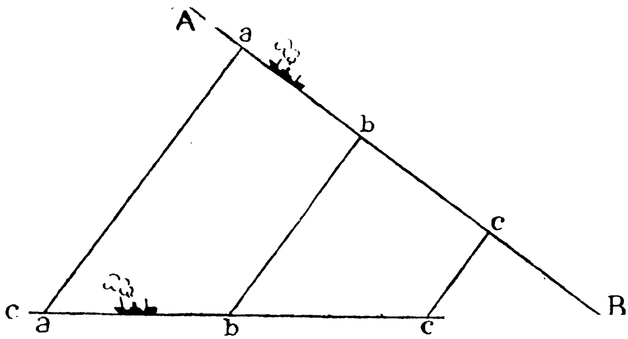
Now, it is evident from the diagram that ship A and ship B will collide, while ship C will pass safely to one side.

So by taking the distances at regular intervals of time and comparing the rate of approach we can tell whether another vessel is likely to run us down or not. If the rate of approach is regular, something must be done; if the rate gradually diminishes, we know the other ship will clear us and that there is nothing to worry about.

As a matter of fact, there will usually be only one ship within range at a time, so that it will only be a question of timing the approach of one single ship and not of two; and Professor Joly has devised an instrument by which the operator can easily record the distance given by each signal and which will tell him at once whether the rate of approach is steady or diminishing.

At first sight it seems as if this method only holds good when one ship is moving towards another which is at rest or both are moving on a straight line towards each other, but that is not the case. The essential condition for a collision is that two ships shall arrive at a certain point at the same moment. In other words, we can represent upon a diagram the courses of two colliding ships by two lines which meet or cross. It does not matter at what angle the lines meet or cross. If they meet, they represent a possible collision.

Let us now glance at the diagram, in which A–B and C–B represent the courses of two ships meeting at B. Let a, b, and c represent the positions of the two ships at successive equal intervals of time. Their successive distances apart will therefore be a–a, b–b



Both ships are moving towards B, but at different rates, each taking the same time from a to b, as from b to c. The distance between the two ships, i.e. a–a, b–b, c–c, diminishes with perfect regularity. Therefore they will collide.

and c–c, the lengths of which *diminish with perfect regularity.*

It will be noticed that in this diagram the speeds of the two vessels are shown to be quite different, and it is a fact that, whatever their speeds may be, whatever their directions may be, if two ships approach each other at a perfectly regular rate they are certain to collide. That is, of course, assuming that their courses are straight and their own speeds regular.

If, then, this signalling system were universally employed, as well it may be in the not distant future, it will only be necessary in foggy weather for each ship to be careful to move at a uniform speed in a straight line and the combined submarine and wireless signals will give unerring warning of danger.

Moreover, the danger will become apparent to both vessels when they are still far enough apart to take the necessary steps to avoid each other. They will be in communication with each other by Morse signals, at all events, if not by actual speech, and will be able to act on a perfect understanding of each other. Under such conditions, collisions should be almost impossible.

CHAPTER XXII

THE AUTOMATIC PILOT

IT has already been remarked that in course of time the visible lighthouse may be superseded by the wireless apparatus in some form or other. In like manner the personal pilot, that bronzed individual who turns up in a small boat, comes on board and generally takes charge of things when a ship approaches the end of its voyage, may give place to a simple electrical device. In some ways it will be a pity, for the pilot is to many passengers such a welcome indication that the voyage is nearly over, and usually he possesses such an air of confidence and competence that he is a very admirable figure whom we would be sorry to lose.

One advantage of the electric pilot is that he is always on the spot. No ship need ever wait for him or stop while his frail boat comes alongside and he clambers up the steep hull of the vessel. " Waiting for the pilot " will then be a thing of the past.

For another thing, it is difficult to see how the electric pilot can ever make a mistake. Even the best of human pilots may do this, particularly when the weather is bad. Such mistakes are exceedingly few even under the worse conditions, but they do occur occasionally. On the other hand, the automatic pilot has its limitations. The fixedness and definiteness of it, so advantageous in some ways, are a serious defect in others. It cannot adapt itself to unexpected changes in the conditions, as the human pilot can.

In this it illustrates a general principle. Mechanical devices excel human efforts in many ways, as, for example, the bicycle excels the human limbs, for progress upon a nice smooth road. On a bad road, however, a cyclist gets off and walks, for his own limbs can adapt themselves to varying conditions in a manner impossible to the best bicycle. So our automatic pilot will no doubt as he grows older reveal weaknesses unexpected at first, but quite real enough and bad enough to save the human pilot from extinction. What is more than likely is that the automatic pilot will simply serve as a helper to its human namesake.

What, then, is this automatic pilot? The name, it should be said, is simply one invented for the purpose of this book, as explaining clearly and distinctly its purpose. The technical name is the "leader cable," since it is a cable laid upon the bed of the sea or river which leads a ship along a certain channel.

To understand its working, let us in imagination try a simple little electrical experiment. Suppose that a length of insulated wire, say 100 yards long, be laid out upon the ground in the form of a large loop. Between the ends of it insert an electric bell, a battery, and a switch.

When the switch is closed the bell will ring, and since the action of an electric bell consists in its alternately making and breaking an electric circuit, it follows that so long as the bell is at work an intermittent current of electricity will be *flowing round* this loop.

An electric current is always surrounded by what the electrician calls a " magnetic field," which means a region in which certain magnetic effects can be perceived. For example, a pocket compass if taken into the neighbourhood of an electric current will behave in a somewhat unusual manner. This " field " remains steady and unchanging so long as the current flows steadily, but it changes with every change in the current. It springs into existence when the current starts ; it collapses and disappears when the current stops ; it grows stronger or weaker as the current becomes stronger or weaker ; it changes its character altogether if the current changes its direction. This last change is most important of all, because if two fields are formed by two currents close together but flowing in opposite directions, the two fields neutralize each other and it is as if they did not exist.

The " field " is strongest close to the current and gradually becomes weaker as the distance from the current increases. If two " fields " due to currents of opposite directions overlap, there is a spot somewhere where the strengths of the two are equal and where therefore they neutralize.

Thus, when the intermittent current is flowing in our loop of wire that wire is surrounded by a magnetic field which is continually changing. First it grows, and then, after reaching a maximum, it dies away again, doing this at each stroke of the bell.

The next piece of apparatus that we shall need is a telephone receiver, or " ear-piece," as we are getting into the habit of calling it. In case any reader, not being satisfied by doing it in imagination, should be tempted to try this experiment, it should be stated that a low-resistance telephone is required, such as is used for ordinary telephonic purposes. The high-resistance " wireless " telephone will not do.

Then we want a wooden frame, like a small wooden hoop, such as children play with, and some more insulated wire. Coil this wire round into a circle the same size as the hoop and tie it thereto at intervals with string. The hoop serves no purpose other than to keep the coil in shape. Finally, connect the telephone between the ends of this coiled wire and the apparatus is complete.

Having switched on the bell, take the coil in your hand, holding it vertically, and place the telephone to your ear. On coming near the loop of wire upon the ground you will find that you hear a sound in the telephone—a somewhat curious rattling sound. That is because you have entered the magnetic field due to the intermittent current in the loop.

If a circuit of any sort capable of conducting electricity comes within a magnetic field, a current of electricity is " induced " in it by every *change* in the field. Therefore, every time the current in the loop starts or stops, induction takes place in the coil and the resulting currents flow through the telephone, thereby producing the sound which you hear.

If, then, you move the coil about in the neighbourhood of the loop, you find that there is one position in which the sound is loudest. That is when the coil is right over the wire and the plane of the coil in line with the wire.

Now try holding the coil horizontally, and you will find the effect quite different. You will then hear a sound when on either side of the wire, but perfect silence when the centre of the coil is exactly over the wire. This is due to the fact that when the coil is in that particular position the magnetic field induces forces in each half of the coil, equal in strength but opposite in direction, so that they oppose each other exactly and no current results.

The effect, then, is that we can by two distinct methods trace the wire upon the ground. We could follow it with our eyes closed. We could also follow it if it were buried either underground or in the water.

In the actual apparatus, of course, something more than a common bell and battery would be used for making the intermittent current, but that is not difficult. In many places the current supplied for lighting purposes is of the kind called " alternating." It does not flow continually in one direction, but moves first one way and then the other. It commences, grows gradually to a maximum, dies away again, grows in the opposite direction, reaches a second maximum, and then dies away once more.

That series of changes is termed a " cycle," and in most places where alternating current is supplied from the public mains, fifty cycles occur each second. It seems rather a lot to happen in a fiftieth of a second, but things do happen quickly in electrical matters. Now the magnetic field surrounding a current of that sort would induce currents in a coil such as has been described, and make a pleasant humming sound in a telephone attached to it.

If you have been keen enough to make the circular coil described above, and happen to live in a district where alternating current is supplied, you might like to take your coil out into the street and see if you can trace the electric light main. Probably you would be disappointed, because the electric light people do not want to make a humming sound in the telephone wires and other things, so they often use concentric cable. That means that one of the conductors in the cable is made of wires so arranged as to form a kind of tube, through the centre of which the other conductor runs. Thus the current as it flows forms one field, and the current as it returns forms another field, of exactly the same strength and in exactly the same place, but in the opposite direction. However the current may be changing, at any moment, in one of these conductors it is always changing in the opposite way in the other. Thus the two fields neutralize each other, and the cable is said to be " non-inductive."

So the automatic pilot must consist of a single cable, with the " return " a long way off ; for, if the

" return " be near, it will either neutralize the effect of the " flow " altogether or else produce a sound of its own which will be very confusing.

One way to overcome this difficulty is to place a cable along the channel or course to be indicated, insulated all the way along except at the far end. There it would be made to terminate in a copper plate or other good conductor from which the current would flow into the sea-water. Salt water is quite a good conductor, and the current thus escaping at the end of the cable so spreads itself out that its field is too feeble at any one spot to have any effect. A cable so arranged, therefore, would guide anyone with a suitable coil and telephone, from end to end, without any interference at all from the returning current.

At or near the mouth of a river or harbour, the cable might be laid in the form of a letter Y or else a very elongated letter V, so that a ship entering would be caught, as it were, between the two limbs, either of which would lead him as he followed it towards the centre of the course.

To avoid collisions, it would be necessary to have an inward course and an outward course, but this can be done by means of parallel cables, so long as it is easy for a ship to distinguish between the one and the other.

This, again, is quite easy. Suppose, for example, that the current employed is the alternating current from the public mains or from a little generating station erected for the purpose. It is quite easy to pass this current through a mechanical interrupter, a little mechanism operated either by a tiny motor or by clockwork which periodically breaks the circuit. It is thus quite simple to break up the current into long or short signals. Let us suppose that the incoming cable at some port is thus fitted, and that the signals made by the interrupter are all long. The listener upon an incoming ship should hear a steady series of long signals. If he hears any other sort, he knows that he is wrong.

Suppose that the outgoing cable is likewise controlled by another circuit-breaker which makes long and short signals alternately. Then any ship, either inward bound or outward, would be able to pick up his own cable and avoid the other. The variations possible are so numerous that every cable along a certain coast could give signals quite different from those of any other.

To use this system of guidance a ship would need to be fitted with suitable coils to pick up the energy from the magnetic fields and convert it into sound audible in a telephone. A difficulty arises here in that the steel hull of the ship itself has an effect upon a magnetic field, distorting it, pulling it out of shape, so to say. This fortunately can be avoided by placing the coil a little way away from the hull. The simplest way, probably, is to fix the coil to the end of a projecting beam so that it would be held far enough away from the ship to avoid this interference.

For some things it would be convenient to have such an arrangement on each side of the ship, the two being connected together in such a way that when the vessel is right over the cable nothing can be heard, but the sound would come on as soon as ever she strayed away from it. As a general principle, however, silence is not a good signal, since it may result from the apparatus being out of order.

Another way in which this cable can be employed is to use it as a warning of danger, instead of a guide to safety. A dangerous shore, sand-bank, or reef could be surrounded by a cable, and every properly equipped ship on coming within a certain distance would receive a warning.

Probably the best arrangement for guiding into a harbour, river mouth, or channel is for the cable to run through the entrance and then straight out to sea for a considerable distance. A ship wishing to enter would steam along the coast until it picked up the "leader," then turning, it would follow the cable right in.

The distance between the cable and the coil can be quite considerable. All depends upon the strength and nature of the current in the cable and the size of the coil. The "alternating current" described just now is quite good, but the rate at which the changes take place is gradual, which, for this purpose, is a drawback. The effect produced in the telephone depends upon the suddenness of the change in the current, and by the use of induction coils of a certain type it is possible to produce currents which change in such a manner as to be particularly effective for this purpose. With a suitable coil and a small accumulator, currents can be produced capable of being detected by the telephone at a depth of 60 to 100 feet easily.

And now a word as to the weaknesses of this system. In the first place, it indicates one course under all conditions. The human pilot knows that at one state of the tide he ought to take one course and at another state a different one. He varies his actions, also, in accordance with the changes in the direction of the wind or the force of the waves. Then, the cable may be moved by the shifting of the sands under the influence of the currents. Or some vessel may drag its anchor across it and break it. This last appears to be the greatest danger of all, for think of the consternation upon a ship following its way by means of the cable if suddenly the signals ceased. Or what of the ship searching about at the harbour mouth to find the cable while the latter lay dead beneath it ?

It is quite possible to arrange things so that damage of this kind would at once be known to those in charge of the cable and the necessary repairs could be done in a very short time, but during that brief interval a catastrophe might happen.

Altogether, then, we may conclude that this " automatic pilot " has a great future before it, but as the assistant to and not in place of the human pilot.

CHAPTER XXIII

THE LIFE-SAVING BOOK

SO far, all the life-saving or safeguarding devices that have been described are of a mechanical nature. The subject of this chapter, while possibly the most valuable of all, the one that has saved more lives than all the rest put together, is a book. The name of the book is *Lloyd's Register of Shipping*.

In order to understand how this wonderful book has come into being, and how it has grown from a small beginning into the wonderful institution which it is to-day, we have to go right back to the origin of insurance.

When a shipowner sends a ship to sea he usually "insures" it. A few of the biggest and wealthiest shipowning companies take all the risk themselves, but they are quite rare. The shipowner almost always gets someone else to share the risk of the voyage with him, and when he does that he is said to "insure" his vessel.

Insurance is exceedingly old, how old no one knows. There is evidence that nearly 1000 years before Christ the people of the island of Rhodes practised marine insurance; while there is extant one of the laws of

Ancient Rome dated about 500 years before Christ which relates to the insurance of ships.

Indeed, we may safely assume that insurance began almost as soon as men built ships large enough to venture upon any voyages beyond just creeping along a coast, as soon, in fact, as any really serious risk became involved of getting caught in a storm.

It no doubt came about in this way. A man who owned a ship was about to send it, or more likely take it himself, for a longish voyage during which it would be out of sight of land, liable to be taken unawares by a sudden storm or to run upon unknown rocks. This man would say to himself, "Now, if the ship be lost, even if I get safely to land myself, I shall lose all I have. My ship is worth £1000, and I hope to make £100 as the result of the voyage. Suppose I offer a friend £25 of the profit, on the understanding that he shares the risk with me, and if the ship be lost pays me £500 towards building a new ship."

Of course, the old mariner of whom we are thinking would not really talk to himself about "pounds," but in the currency which was in use in his time and in his country, but it is simpler for us to think of pounds and the principle is just the same.

So he goes to his friend and makes the proposition, *which we must suppose the friend accepted.* The voyage was, probably, a prosperous one for all. The shipowner had the comfort all through the voyage of knowing that he could not lose all he had—that £500, at all events, was safe, and the friend when the voyage was over had £25 in his pocket as the result of the transaction.

The friend—the " underwriter " he would be called to-day—was no doubt very pleased at so profitable an arrangement, so he sought out other shipowning friends and suggested that they too should insure their ships with him, and so arose the first man to do a regular business in marine insurance. Before long other men would see the first underwriter doing good business and would start in the same business themselves, and so it would go on.

Of course, the underwriter would sometimes have to pay, but he would soon find from experience and calculation what would be a fair rate to charge, so that even with an occasional loss he would in the long run make a nice profit.

And not only the owners of the ships themselves, but the owners of goods carried upon the ships, would get into the habit of insuring their goods against loss upon the voyage. And not only would owners of ships and goods insure their property for a part of its value, as we have suggested was done by the inventor of insurance, but would cover the whole value, so that in several ways we may safely assume that the business of insurance grew rapidly in volume and in importance.

As the business thus grew it would happen as a matter of course that men interested in it would find a convenient meeting-place where they could deal with each other. A common meeting-place for men in any business is such a great convenience that there are in London and all large cities such places as the Royal Exchange, the Stock Exchange, the Metal Exchange, the Corn Exchange, and the Commercial Sale Rooms, while certain towns specially connected with a special trade have an Exchange for that special business.

A simple example of this tendency for people with a particular interest to get together came to the writer's notice many years ago. There were employed in offices in a certain part of the City of London a number of office-boys whose hobby was the collecting of stamps, and these boys got into the way of exchanging with one another, as so many boys do or have done in their time. Of course, there is nothing strange in boys exchanging stamps with one another —thousands of boys do that—but these particular boys found a quiet corner in an old-world square now done away with, where they used to meet nearly every fine night for ten minutes or so. In other words, they had established a veritable "Stamp Exchange," where they did business with quite as much, if not more, solemnity than is to be found on the Stock Exchange.

In much the same way, about the year 1668, the shipowners, merchants, and underwriters of the City of London began to form the habit of dropping in at a coffee-house in Tower Street, whenever they wanted to discuss a matter of marine insurance. The coffee-house was kept by a man named Lloyd, and so was called Lloyd's Coffee House, and one can picture the merchant of those days, on being reminded by his clerk that certain goods were about to be shipped and ought to be insured, saying, "*Right. I will just* run round to Lloyd's Coffee House; I shall be sure to find someone there who will insure them." And so the habit of running round to Lloyd's whenever marine insurance needed to be done became more and more a recognized custom in the City.

In course of time, the people who thus frequented Lloyd's Coffee House formed themselves into an association or society, with a code of rules and a regularly recorded membership, and so there came into being the society which is now called "Lloyd's," the greatest organization for the carrying on of the business of marine insurance in all the world.

But we are concerned not with Lloyd's, but with *Lloyd's Register*, which is now quite a different institution altogether.

When a man is asked to insure a certain ship or some goods carried upon that ship, he naturally wants to know something about her. If she be a large ship, fairly new, well built and well equipped, with an experienced skipper, then he will know that the risk is small, and he will be quite content with a low "premium," as the money paid for insurance is termed. If, on the other hand, she be small or old or not well-built, or poorly equipped, or has shown herself in the past to give trouble, then he will want a higher rate, or he may even refuse to insure her at all.

Moreover, underwriters would naturally prefer not to rely upon what owners told them about their ships, but would like to have information of their own, gathered from independent sources. So the custom gradually grew up of insurers putting what they knew of a ship upon a list hung up in Lloyd's Coffee House, each underwriter probably adding what he knew, and so forming a fund of information available for all of them. Unfortunately, none of the earliest lists survive, because when "Lloyd's" grew from a few gentlemen doing business over a cup of coffee into a well-organized society, they moved to rooms in Pope's Head Alley and later to the Royal Exchange, and when this building was burnt down in the year 1838 many interesting old documents were thereby destroyed.

The oldest existing example of one of these ship's lists or registers is singed, showing that probably it was one of the few things saved from the fire. It covers the years 1764, 1765, and 1766, and gives particulars of about 4500 ships.

The particulars recorded include the name of the owners, the name of the captain, the ports with which the ship usually traded, where she was built and when, the tonnage, the number of guns carried (for many ships were armed in those days), and miscellaneous notes about her.

The ships were grouped into classes according to the nature of the hull, each class being denoted by a letter, the vowels A, E, I, O, and U being used. The best ships were in class A, the next best in class E and so on.

They were also classed according to their equipment, the classes being called G, M, and B.

In a later specimen of a ships' register dated 1770 the vessels were still classed by letters so far as their hulls were concerned, but the equipment was indicated by a number, No. 1 being the best. From this has arisen the practice of calling a thing of the very best sort A 1. It originally meant a ship whose hull was first class and which was equipped in a first-class manner.

There is still in existence a very complete file of registers from the year 1775 onwards called the *Underwriters' Register*, or shortly the "Green Book," because of the colour of its cover.

This book was established not by the society called "Lloyd's," but by a number of separate people, mostly members of Lloyd's, who realized how useful it would be. Each of these subscribers paid twelve guineas a year for the right to have the book.

In the year 1799, however, the shipowners, who were not satisfied with the underwriters' book, started one of their own and called it the *Shipowners' Register*, and this, because of its colour, came to be known as the "Red Book."

The chief grievance seems to have been that the earlier book favoured London-built ships unduly. They seemed to go on the principle that if a ship were built in London it must of necessity be a better ship than one built, say, in Hull, and the owners of good ships built in Hull and elsewhere did not see why their ships should be put in a lower class than those built in London, and therefore have to pay higher rates of insurance. They wanted their vessels to be classed on their merits wherever they might have been built.

The subscribers to the "Red Book" paid only eight guineas per year, and so, to compete, the older book had to be reduced to that price.

That, however, brought about a further trouble. Because of the low subscription to the book it was impossible to examine the ships thoroughly, for there was not enough money to pay for competent surveyors, and the custom was adopted of classing the ships largely by their age, which was evidently unsatisfactory to everyone.

So in 1834 a conference was called of all sorts of people interested in shipping — merchants, shipowners, underwriters, and the rest, and as a result the "Red Book" and the "Green Book" were amalgamated under the style of *Lloyd's Register of Shipping*, and arrangements were made which provided ample funds for doing the work well, so that to-day whatever the *Register* says about a ship can be relied upon by all concerned. The subscribers to the *Register* constitute a society which, although it shares part of its name and its origin with Lloyd's, is in fact quite a separate institution. Its officers inspect ships and classify them. They keep the most careful records of the doings of ships; they have formed rules for the building and equipment of ships; they inspect and test materials, chains, ropes, anchors, and other important parts; in fact, they form a most perfect organization for keeping up the standard of construction and equipment.

Because of the vigilance of this society it is practically impossible to-day for the most unscrupulous shipowner, supposing any such to exist, to send a vessel to sea in an unseaworthy condition.

Thus it safeguards the lives of many thousands of people whose business takes them to sea and who, without its aid, might often have to run needless peril.

INDEX

INDEX

INDEX

INDEX

The Mayflower Press, Plymouth. William Brendon & Son, Ltd
1925

THE ROMANCE OF THE SHIP

THE STORY OF HER ORIGIN AND EVOLUTION FROM THE EARLIEST TIMES

By E. KEBLE CHATTERTON, B.A.(Oxon.)

Author of "Sailing Ships & their Story," "Fore & Aft, the Story of the Fore and Aft Rig," "Through Holland in the *Vivette*," &c. &c.

With Thirty-three Illustrations. Extra Crown 8vo.

"Entertaining and instructive."—*Spectator.*

"A fascinating volume, full of information and stirring incident."—*Queen.*

"A very delightful story of the evolution of the ship."—*Sheffield Telegraph.*

"A veritable mine of information and instruction."—*Standard.*

THE ROMANCE OF MODERN CHEMISTRY

By JAMES C. PHILIP, D.Sc., Ph.D.

Assistant Professor of Chemistry in the Imperial College of Science, South Kensington, London

With Forty Illustrations. Extra Crown 8vo.

"Should be one of the most sought-after of the series."—*Liverpool Courier.*

"The volume is interesting to young and old: it would make an admirable gift-book for a youth."—*Western Daily Press.*

"A fascinating exposition in popular language."—*Illustrated London News.*

"Well written, accurate, and interesting, it deserves nothing but praise."
—*Standard.*

"Dr. Philip has given us a book covering a very wide field of chemical science, expressed in language so simple and untechnical that it cannot fail to reach the understanding of readers who have little or no knowledge of scientific things, and this without a single chemical formula. Throughout this really fascinating book the author never loses an opportunity of showing the applications of the facts of chemistry to the ordinary requirements of life. Simplicity of exposition and interest of subject-matter are characteristic of almost every chapter in the book."—*The Nation.*

THE ROMANCE OF BIRD LIFE

By JOHN LEA, M.A.

With Thirty Illustrations. Extra Crown 8vo.

"Most fascinating, suggestive, and readable."—*Spectator.*

"Truly delightful account of the habits, instincts, friendships, and other aspects of the life of birds, and is beautifully illustrated."—*Record.*

"A genuinely interesting work, full of instructive information, and valuable to all interested in the many aspects of the life of birds."—*Northern Whig.*

SEELEY, SERVICE & CO. LIMITED