November 27, 1860.

JOHN HAWKSHAW, Vice-President,
in the Chair.

No. 1,030.—“On the Maintenance and Durability of Submarine Cables in Shallow Waters.”¹ By WILLIAM HENRY PREECE, Assoc. Inst. C.E.

IN July, 1859, the late Mr. Robert Stephenson, at a meeting of the Electric and International Telegraph Company, over which he presided, made some remarks respecting the durability of submarine cables, which caused, at the time, much surprise and induced considerable controversy. He stated, that so far as his own experience and opinion went, no cable, over which he had any control, was sufficiently durable, to render it a satisfactory and remunerative speculation. He was supposed to apply these remarks to all submarine cables, and much valuable information was produced to controvert such a conclusion. It is not the intention of the Author to discuss the question at length. He will simply record his own practical experience in the maintenance and repair of a submarine cable; hoping, thereby, to lay a foundation, upon which a discussion can be raised, which will tend to the solution of this important point, and will prove beneficial to the profession, and serviceable to the progress of submarine telegraphy.

The cable alluded to, is that connecting the Channel Islands, Alderney, Guernsey, and Jersey, with England. These islands are situated in the Bay of Avranches, on the north-east portion of the coast of France. The nearest island, Alderney, is 57 miles from the coast of England, and 9 miles from that of France; Guernsey lies 18 miles from Alderney, and 17 miles from Jersey. These islands are accompanied by several smaller ones, and all are closely surrounded by a mass of jagged rocks. Their geographical position renders them peculiarly subject to the full force of the great westerly gales, which prevail during the winter months. The great rolling waves of the Atlantic, as they dash and break upon these wild and rocky shores, the disastrous wrecks that annually strew their coasts, the immense boulders thrown up and rolled about by the irresistible force

¹ The discussion upon this Paper extended over portions of five evenings, but an abstract of the whole is given consecutively.

of the disturbed waters, give some idea of the destructive action to which any submarine cable, landed on such shores, must be liable. Moreover, as these islands are situated in that portion of the Channel where the opposite coasts begin to form, as it were, a funnel for the entrance of the tidal wave, the tides and currents possess great force. The tide, which rises on the English side only 6 feet, here attains an altitude of 40 feet; the currents also, in several localities, acquire a velocity of 7 and 8 knots per hour. It will thus be seen, that the shores upon which it is landed, the bottom of the sea upon which it lies, the heavy tide-ways which it crosses, and the peculiar disturbances of nature to which it is liable, are all calculated to try, to the utmost extent, the qualifications, for permanency and durability, of any submarine cable, connecting these islands with the mainland.

This line of telegraph was projected by the islanders themselves. It is the property of a Company formed under the Limited Liability Act, with a capital of £30,000, upon which a conditional guarantee of 6 per cent. has been given by the Government. The contract for the whole undertaking was let to Messrs. Newall and Co., who submerged the cable, constructed the land lines, and handed over the whole telegraph complete, to the Company. The sample of the cable to be used was submitted to the Directors, but the selection of the route, and the manner of carrying out the work, was left entirely to the Contractors. The connection of the Author, as Engineer, only commenced after its completion by Messrs. Newall and Co.

The line starts from Weymouth, (Plate 2, Fig. 1,) crossing the Island of Portland by underground wires, and connecting that island with Alderney, by a submarine cable $57\frac{1}{2}$ miles long. It crosses the Island of Alderney, and proceeds thence to Guernsey. After crossing Guernsey, underground, it is continued to Jersey, where it terminates at the town of St. Helier's. There is a station at each of these islands. The whole length of submarine cable submerged is $93\frac{1}{4}$ miles, and the length of the underground portion is 23 miles. The latter simply consists of a gutta-percha covered wire, coated with tarred yarn, and laid in a creosoted wooden trough, buried about 20 inches in the ground. The cable consists of two portions, the sea part, and the shore ends. The sea part is a No. 1 gutta-percha covered wire, served with tarred yarn, and protected by ten No. 6 iron wires; it weighs $2\frac{1}{2}$ tons per mile. The shore ends are similar, but they are protected by ten No. 2 iron wires; they weigh 6 tons per mile. The cables were submerged by Mr. Newall, from the steamship 'Elba,' in August, 1858. When completed, the line tested perfectly, and being worked by an improved system of the Morse printing instrument, constructed by Messrs. Siemens and Halske, of Berlin, and slightly

altered by the Author to suit the requirements of English manipulators and the English system, the circuit was admirable for rapidity and efficiency.

The line was opened to the public, on the 7th of September, 1858. On the 23rd of November following, the wire crossing the Small-mouth Sands between Portland Island and Weymouth, was broken, owing to the sand banks being washed away by a succession of severe easterly gales. This accident was speedily remedied by the submersion of a stouter cable, in a more secure position. The second accident took place on the 27th of January, 1859, on the coast of Jersey. The cable was landed upon this island, in a small sandy bay, bounded by precipitous cliffs, and strewn with jagged rocks. It was laid in a zigzag path between the rocks, and was led up the face of the cliff in split iron pipes. The gales that raged at this period, carried away a quantity of the sand upon which the cable lay; and the wash of the breakers tore the iron pipes from their fastenings. The cable being thus loosened, was beaten about upon the rocks, and it was speedily ruptured. As the fracture happened within the line of low-water spring-tide, temporary communication was soon made, by connecting the ends together with a stout chain, and attaching a gutta-percha wire along it. This gutta-percha wire had, however, to be renewed each tide, as the rocks soon wore it away. The communication was permanently restored in the following manner. A fresh piece of stout cable, weighing $7\frac{1}{2}$ tons per mile, consisting of a portion of the Atlantic cable, served with hemp, and surrounded by ten No. 1 iron wires, was manufactured by Messrs. Glass, Elliot, and Co., and spliced on to the old cable, as far out as the tide would allow. This was laid in a straight course, between the rocks, up to the foot of the cliff. In sandy bays, if a cable is not laid perfectly tight and straight, it is sure to become loosened, and be liable to motion, and if it is allowed to scrape upon a hard rock, it must, eventually, give way. The greatest care is, therefore, requisite, in fixing the ends upon rocky shores. In this instance, the cable, from the spot where it first came in contact with the rocks, to its end in the iron testing-post, upon the top of the cliff, was served with spun yarn, saturated with tar, to protect it from detrimental exposure to the spray, and the atmosphere. Where it rested upon the rocks, it was, in addition, served with thick wire, well bound down, to protect it from abrasion, and to give it greater strength. The shore ends of the cable are thus stouter, and stronger than any hitherto made. It is scarcely possible to imagine, that any power in nature could ever exert sufficient force, to make an impression upon such a mail-clad rope; but the Author has seen it seriously injured after having been exposed, during six months, to the violent action of the waves, and constant inspection and attention are

required, to prevent a second rupture. It was clamped in strong iron crutches, (Fig. 2,) leaded into the solid rock. Where it passed between two rocks, it was chained to ring bolts, leaded into the rocks, the chains being fixed to a bell-mouthed pipe constructed in two pieces, and fitting closely to the cable, as shown in Fig. 3. The crutches, though heavy, and well fixed, have, in more than one instance, become loosened, and the chains have broken, but the cable remains secure, and with careful attention, it will probably outlast the other portions.

As the landing-places on the south end of Guernsey, and on the western side of Alderney, are equally rough and precipitous, after the accident at Jersey, the shore ends at those places were also examined. At Guernsey, where the cable is landed in a bay similar to that at Jersey, it bore severe marks of attrition, and in one spot, it could not have lasted many days. The cable was straighter and tighter than at Jersey, for this was the end from which the vessel started in paying out, and consequently, a strain was placed upon the rope. It was protected, strengthened, and fixed, as at Jersey.

The most exposed landing-place is, undoubtedly, that at Alderney. The cable stretches through a series of rocks, lying about half a mile off the shore. It is landed in a small bay, having a sandy bottom, and lofty rocky sides, surrounded by perpendicular cliffs several hundred feet high, up which the cable is taken. It was a hazardous undertaking to attempt the descent of these cliffs, but the Author and two other persons succeeded in accomplishing the task, by the assistance of the cable. It was found, where it lay among the rocks, loose, bent, and injured to an alarming extent. One mass of stone had fallen upon it, and perfectly flattened the iron covering. It was protected, strengthened, and fixed, in the same way as at Jersey and Guernsey. In doing this, the cable had to be cut on the beach, and hauled up to the top of the cliff, while a temporary wire maintained the communication uninterrupted. It has not yet shown any symptoms of decay, which is so far fortunate, as the operation of repairing it would be difficult. It has, probably, fallen between the rocks, and has thus been protected, instead of being destroyed by them.

The next interruption to which the line was subjected, took place off Portland Island, on the 19th of April, in the same year. In paying out this portion of the cable, Messrs. Newall started from Alderney, rather late in the day, and did not succeed in making Portland Island until night. In consequence, the landmarks were missed, or mistaken, and thus the Portland Race was crossed with the cable. The tidal current, when unobstructed, flows, generally, in the English Channel at from 3 knots to 4 knots per hour, but in Portland Race it runs at the rate of 8 knots and 9 knots. The rapid passage of waters extending to

the bottom of the sea, not only affects the placidity of the surface, but scours, roughens, and ploughs up the ground below. The bottom, as far as the Race extends, is extremely rough and rocky. A cable, resting on such a surface, must, necessarily, be very insecure, and so it proved, for on the 19th of April, the cable parted at the distance of $3\frac{3}{4}$ miles from the shore, having been completely severed by abrasion upon the sharp edge of a rock.

All previous accidents at sea to submarine cables, which have come within the Author's knowledge, have been the result of accidents from well-known causes. Ships have either dragged their anchors across a cable, too weak to sustain the strain suddenly placed upon it, or the cable has been brought to the surface, and then wilfully, or accidentally cut. But in this instance the cable was broken, in the short space of six months, by the operation of the great forces of nature. Fig. 4 will explain the probable cause of this accident. When a rope is stretched across a current of water, a quivering motion may be observed. The rush of the tide would give a cable, laid in the position shown, a similar vibration, which would make the rock act like a file, and the iron coating of the cable would be rapidly abraded. The outer iron wires bear distinct marks of this abrasion, and the ends have been worn down to a small diameter. The cable was, evidently, laid so tight, that the instant a few wires had been worn through, the remaining wires, together with the gutta-percha wire, were too weak to bear the strain, and were, consequently, broken. The cable was picked up from the shore, considerably beyond the break, in the hope of removing it from the rough ground, and it was relaid further to the eastward. The original and the present course of the cable are shown upon the chart; (Fig. 1.) A new cable, of larger dimensions, was submerged across the portion of the original ground, which could not, without great expense, be avoided. In repairing this cable, several places were picked out, where this same action had commenced. The first mile from the shore, with the exception of the existence of two bad 'kinks,' was in excellent condition, showing no signs of decay, or wear, and lying undisturbed at the bottom of the sea. The rest of it, however, which lay through the Race, was much decayed, not only by friction upon the rocks, but by rapid oxidation. Shoals of mussels, zoophytes, and rank vegetation were found, clustering on the wire.

The communication was restored on the 18th of May. Much time was occupied in the repairs, owing to the unpropitious state of the weather. This is not of material consequence in paying out a cable, except in the operation of landing the ends, but in repairing cables, it is essential, that the weather be fine, and the sea comparatively calm. During the month occupied in these

repairs, only four days occurred which were at all suitable for carrying on the operations.

In picking up the last portion of the cable, a stone, about 1 foot square, and 3 inches thick, came up attached to it. Across this stone there was a groove, bearing an exact impression of the cable, which appears to the Author to have gradually, by some chemical action, made a bed in the stone. Its substance differs from any stone found in the neighbourhood of Portland Island.

The line continued in excellent working order, during the whole of the ensuing summer, but in September, a serious fracture occurred off Jersey, and in November, another off the Island of Portland. In the latter case the cable was broken in two places, at $6\frac{3}{4}$ miles, and at nearly 12 miles from the shore; each fault was precisely similar in character to that previously described. Off Jersey, the cable became defective on the 16th of September, and the accident was also of the same nature. All the previous fractures had taken place without warning. In one instance, during the transmission of an important message, and while the line was in good working order, the communication was suddenly interrupted. In this case, however, symptoms of failing strength early displayed themselves, and for several weeks, the cable had been working indifferently. A serious defect showed itself in the cable between Guernsey and Jersey, at some spot not far from the Jersey shore, and gave intimation of rapid decay. At last, the communication ceased, and steps were taken to repair the cable. Three faults were discovered within a length of half a mile, two were due to 'kinks,' and the other to abrasion, the last being the cause of the cessation of the communication. The cases of abrasion previously explained, occurred in the smaller-sized sea portion of the cable; but this took place in the heavy shore end. The outer wires, with the exception of one, were completely worn through, the gutta percha was nearly destroyed, and the interior copper conductor had been completely abraded. The cable had, no doubt, been resting on the edge of a rock, and had been sawn through by the vibratory movement given to it by the tide. The 'kinks' were made, when the cable was laid down; the gutta percha had been forced out, causing two considerable faults, which would inevitably, before long, have stopped the communication. Kinks are frequently caused in the operations of repairing, when picking up a cable, but it is very easy to distinguish a kink, made in laying down a cable, from one made in repairing. The one shows signs of oxidation and age, the tar of the serving is washed away, and the gutta percha is frequently visible; the other looks fresh, and of very recent formation. Kinks are not, as a rule, of serious consequence, unless the cable is laid on rough ground, or in a heavy tideway; but on such a line as that to Jersey, they are fatal. Only four kinks have been discovered,

which must be considered as highly creditable to the Contractor ; but the same praise cannot be awarded for the manner in which the end was landed in Jersey. This is the most difficult operation connected with the submersion of cables, and that which requires the greatest care and skill. When once the cable has been started, there is little, or no difficulty in paying out. Attention and care are only required, to see that every part of the machinery works well. But when the landing-place is approached, the coast, the depth of water, the weather, and the tides, have to be consulted. If the coast is rugged, care must be taken to avoid the rocks ; if the water is shallow, the ship must be kept off the ground ; if the weather is boisterous, the end must be cut, dropped, and buoyed, and the operation completed upon a more favourable occasion ; and if the tides run fast, care must be taken to allow for their effect upon the ship, and to steer her course accordingly. At certain times of the tide, a sharp current runs past Cape Grosnez, near which the cable is landed, and the pilot in charge of the 'Elba' evidently overlooked this, for the cable, in place of taking a straight course into the bay, is laid as is shown in the chart ; (Fig. 1.) It thus crosses some rocky ground, which might have been avoided, if proper allowance had been made for the current. It was upon this rocky ground, that the cable failed : it seems, moreover, to have been thrown out loosely, for it was lying zigzag in considerable bends, and a length of half a mile of cable was afterwards saved, by laying it straight ; (Fig. 1.)

The cable was again broken on the 9th of January, 1860. The same kind of accidents which had occurred off Portland, were repeated off Alderney, and the cable was severed by the rocks, at a distance of 6 miles from that island. It was in precisely the same condition, abraded and decayed, so much so, that it was broken in picking up. Five miles of new cable, of a superior description, were submerged ; it was a piece of the Atlantic cable, strengthened with ten No. 6 iron wires, similar to the excellent cable which the Submarine Company have laid between Jersey and the French coast. The cable subsequently failed in September last, at the same place and from the same cause. It has also been broken three times off the coast of Jersey, from having been accidentally caught by ships' anchors. The following Table gives a list of all the accidents that have occurred up to the present time :—

TABLE I. FRACTURES.—CHANNEL ISLANDS CABLE.

No.	Date of Rupture.	Position.	Distance in miles.		Depth of Water.	Nature of Fault.	Ship employed for Repairs.	Duration of Fracture.
			Actual.	By Test.				
1	Nov. 23, 1858	Smallmouth Sands.	..	..	Fms. ..	Washed away by sea.	..	Days. 2
2	Jan. 26, 1859	Off Jersey .	On shore.			Abrasion .	..	3
3	Apr. 19, 1859	Off Portland	3 $\frac{3}{4}$	3	22	" .	Prince .	26
4	Sept. 17, 1859	Off Jersey .	4 $\frac{1}{2}$	1 $\frac{1}{2}$	17	" .	True Briton .	19
5	Nov. 1, 1859	Off Portland ¹	6 $\frac{3}{4}$	5 $\frac{1}{2}$	27	" .	Monarch .	22
6	Jan. 9, 1860	Off Alderney	6	6	35	" .	Resolute .	26
7	Feb. 25, 1860	Off Jersey .	3 $\frac{1}{2}$	3	23	Caught by ship's anchor	Contractor	14
8	June 7, 1860	" " .	2 $\frac{3}{4}$	2 $\frac{3}{4}$	21	" " .	Dumfries .	12
9	July 19, 1860	" " .	5	4 $\frac{1}{2}$	26	" " .	" .	13
10	Sept. 16, 1860	Off Alderney	7	7 $\frac{1}{2}$	40	Abrasion " .	Monarch .	10
11	Sept. 18, 1860	Off Jersey ² .	17 $\frac{1}{2}$	16 $\frac{1}{4}$	25	Caught by ship's anchor	" .	11

¹ Broken also 12 miles off the land.² Tested from Guernsey.

It will be seen, that since the submersion of the cable, in August, 1858, it has been ruptured in eleven different places. Two of these accidents were the result of carelessness, or negligence, in landing the end of the cable on the Jersey shore. Four were caused by ships dragging their anchors, and five were produced by the action of the rocky bottom upon the slender wire. The accidents arising from ships' anchors all took place between Jersey and Guernsey. Those resulting from abrasion, occurred between Alderney and Portland. Between Guernsey and Alderney the cable has never failed. The constant interruptions of this line are attributable, the Author believes, to two causes, weakness of cable, and error of judgment in the selection of the route. The cable should never have been laid between Guernsey and Jersey, but from Jersey to Alderney. It not only crosses ground, where ships are frequently in the habit of anchoring, but also, in a portion of its route, it lies upon a rough uneven bottom, swept by strong tides. A stouter cable might lessen the liability to accidents from the first cause; while by a détour to the westward, this rocky ground would be avoided. But by carrying the wire from Jersey to Alderney, neither danger would be encountered. There is no anchorage along that route, and the ground is smooth and free from rocks, except on the immediate shores of the island. This route was the first selected, but it was objected to by the Government, on account of its proximity to the French coast. In the event of a new cable being laid, this route will be adopted. Neither should the cable have been laid between Alderney and Portland, but from Alderney

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to the Isle of Wight. The bottom here, excepting immediately outside Alderney, is smooth and soft, the whole way across; the run of the tides is not so great; the shores of the Isle of Wight are devoid of rocks; and ships never anchor on any portion of the route. The distance is, certainly, greater, but the liability to accident from every cause, is considerably less. It must, however, be stated, in justice to those who decided on the route adopted, that reliance was, perhaps, unfortunately placed on the Admiralty Charts, which the Author has never found to be correct in describing the nature of the bottom. They truly represent the depth of water, and the currents, but they as frequently show rocks where sand is found, and sand and gravel where there are rocks. This is especially the case off Portland, where ledges of rocks, of which no intimation is given on the charts, extend 15 miles, or 20 miles out to sea. A cable should never be trusted to the unseen and unknown action of the bottom of the sea, without its course having first been carefully surveyed and examined.

The Channel Islands cable is also too weak for the locality in which it is placed. It cannot resist the strain of a heavy ship, nor can it, for any length of time, withstand abrasion from a rock. The run of the tides, and the decomposing action of the water upon such a small cable will, eventually, and indeed very shortly, so weaken and corrode it, that the expense and difficulty of repairing it will be very much increased. The chief defect, however, in the system, cannot be said to be so much in the cable used, as in the route selected.

In conducting the repairs of this cable, it was curious to observe the effect of the water, in different localities, in oxidising the outside covering. In places where the cable had become slightly buried in the sand, it was as perfect as when it was first laid. On rocky ground, where it was swept by the tides, it was being rapidly corroded, and where vegetation and zoophytes adhered to the cable, patches of decay were visible. The Author is of opinion, that in localities where a cable cannot bury itself, it must speedily be destroyed by oxidation, and that the period of its durability will solely depend upon its size. In such places, some outer protection to the iron wire is necessary. Mr. Latimer Clark, (Assoc. Inst. C.E.,) has devised a method of applying hemp saturated with asphalt, on the outside of the iron wires; and it was applied to the Isle of Man cable. This plan, though promising, is liable to cause injury to the inside wires, through the necessity of applying the asphalt at a high temperature. But there should be no difficulty in discovering an equally effective material, which may be used cold. 'The Report of Mr. Cromwell Varley,¹ on the

¹ Vide "The Engineer," July 27, 1860.

attempted repairs to the Atlantic cable, off Newfoundland, described the state of preservation in which the wire was found, wherever it was coated with hemp. No cable should ever be submerged in shallow waters, without some exterior protecting coating, to preserve it from oxidation.

The Channel Islands cable was also laid much too tight; wherever a break has occurred, through abrasion, it has been observed, that after six, or seven wires have been worn through, the rest, with the gutta-percha wire, have parted, being unequal to bear the strain. Cables in shallow water should be laid slack, and be payed out with only sufficient strain, to make them take the sinuosities of the ground, without falling into bends and kinks. Moreover, the slacker they are laid, the easier they are to repair, and repairs must be anticipated and provided for, in all submarine cables. Figs. 4 and 5 exhibit the difference between a cable laid tight and a cable laid slack.

In designing a cable, its durability and maintenance, points at present almost altogether overlooked, should be primarily considered. The present construction of heavy cables is believed by the Author to be defective. These cables depend for weight and strength, on a number of large-sized iron wires, surrounding the insulated conductors. When these outer iron wires are what is technically called 'short,' they break in running over the break drums. If ships accidentally catch the cable, the wires are also broken, and the surging of the anchor along the rope rapidly increases the evil by 'rucking' them up. The outer wires should, in the Author's opinion, either be stranded, or the cable should be surrounded with two servings of smaller-sized wire. The Atlantic cable is, on a small scale, an example of the first, and the Jersey and France cable, of the second.¹

It follows, from what has been said, that in establishing a submarine telegraph for crossing shallow waters, experience has shown, that the Engineer should, first, select a proper route, and secondly, that he should design a cable suitable for that route. He should vary the construction of the cable, according to the nature of the ground to be crossed, as it would be absurd to lay a heavy cable intended to resist anchorage, over soft ground, not frequented by ships. In regard to the route, it would, frequently, be more economical to make a *détour* of fifty miles, in connecting two points by a submarine telegraph, than to take the straight line.

The system which the Author has adopted in conducting his repairs, is analogous to that originated by Mr. F. C. Webb, (Assoc. Inst. C.E.), in repairing the cables in the North Sea,

¹ The Electric and International Telegraph Company have adopted this suggestion, in their new cable to Holland. —AUTHOR. February, 1862.

belonging to the Electric and International Telegraph Company, and described by him in his Paper, read before the Institution, in 1858.¹ Having, by a system of careful tests, determined the position of the fault, a steamer was fitted up for the purpose of grappling the cable, as close to the fault as its position, and the nature of the ground would allow. The cable, when raised, was cut, and the end which was perfect between the ship and the shore, was carefully buoyed. The portion of the cable leading towards the fault was then picked up, and was coiled down until the fault came on board. The other end was then grappled for, and when secured, a fresh piece of cable was spliced to it, and payed out to the buoyed end, to which it was also spliced, and the communication was thus restored.

The operation of grappling, picking up, buoying, and paying out, having been already described in the Paper alluded to, the Author will confine himself to a description of the system adopted by him, in testing cables.

There is no operation connected with the submersion and repair of submarine cables, which requires greater skill, more experience, and a more intimate knowledge of the laws that regulate that subtle force, electricity, than testing. It qualifies the Engineer to become thoroughly acquainted with the electrical condition of the wire from end to end, permitting him to glance, as it were, along the rope, however deep it may be submerged, to learn its imperfections, and to know its condition. It enables him to direct his ship with almost unerring accuracy, to the spot where any failure exists. It gives him a confidence in his operations, which astonishes the uninitiated, and pleases the men employed under him, and it considerably reduces the expense of repairing cables. To give an idea of the accuracy with which testing can be conducted, it may be mentioned, that on one occasion, the Author pronounced a fault, (No. 6 of Table I., page 33,) to be at 6 miles from Alderney, and that $2\frac{1}{4}$ inches of copper were exposed to the action of the salt water. The fault was ascertained to be exactly 6 miles off, and 2 inches of copper were found to be exposed. He has never been more than one mile wrong in his calculations, although the tests have been made at 5 miles, at 20 miles, and sometimes, at 30 miles from the broken end. Messrs. C. F. Varley and G. Preece, have been equally accurate in the North Sea. On one occasion, Mr. Varley pronounced a defect in the Zandvoort cable of the Electric and International Telegraph Company, to be 61 miles from the English shore, and it proved to be at the exact spot indicated. Mr. G. Preece, in testing on board ship, 13 miles from land, while repairing a break at that spot, found the cable again severed at a

¹ *Vide* Minutes of Proceedings Inst. C.E., vol. xvii., page 262.

distance, according to his tests, of 50 miles towards Holland, and the break was found at $50\frac{1}{4}$ miles.

Mr. Webb, in his Paper, has referred to and described his system of testing, but considerable improvement in the instruments used, and the manipulation required has been effected since that period. The study of testing has been generally neglected, in the education of telegraphists, and little care has been taken by the companies, to keep a careful register of the electrical condition of their cables and lines.

The principles employed in testing may be divided into those dependent upon the laws of resistance, and those dependent upon the laws of induction. Resistance is the obstruction which materials offer to the free passage of electricity, and it may be said to represent both conduction and insulation. A perfect conductor is one which offers no resistance to the transmission of an electric current; a perfect insulator is one whose resistance to the passage of the same current is infinite. No absolutely perfect conductors and perfect insulators, however, are as yet known; and thus the perfection of an insulator, or a conductor, depends, at present, upon its amount of resistance. If a wire conducts badly, its resistance is great, and if an insulator conducts well, its resistance is slight. It is, therefore, easy to express the degree of insulation, or conduction of a substance, in units of resistance; and this is frequently done in practice. It has been usual, hitherto, in describing the condition of a wire, or cable, to say, that it gives a° of earth, with n number of cells; that is, that a current being applied to one end of a wire, and the other end being disconnected, its imperfect insulation, or faulty places, allowed a° of current to flow to the earth, through a galvanometer. This a° is supposed to represent the insulation of the wire. It gives an approximate idea of the condition of the wire to the electrician who manipulates his own instrument, but to convey to others the state that a° represents, it is necessary to describe the instrument employed, the power used, and various other complicated details of construction and design. Every electrician must reduce this quantity to the standard of his own instrument. It will be subsequently seen, that it is easy to reduce to one universal standard, the insulation and condition of every wire and cable, in existence, or under construction.

The basis of all resistance tests, is the fundamental law of Ohm, which is expressed by the formula:—

$$R = \frac{LC}{S},$$

where R = the resistance;

L = the length of wire;

C = the specific resistance of the material employed;

S = its sectional area.

The specific resistance of different metallic bodies (C), varies considerably, as will be seen from the following relative conducting powers of different metals, according to Becquerel:—

Copper	100	Platinum	16·4
Gold	93·6	Iron	15·5
Silver	73·6	Mercury	3·45
Zinc	28·5		

The relative conducting powers of iron and copper, which are the materials usually employed for télégraphic purposes, are, consequently, as 15·5 to 100, or as 1 to 6·45 nearly.

The resistance of a wire is directly as its length (L), and inversely as its sectional area (S). If A B represents a copper wire 1 mile in length, and C D one 10 miles in length, both being of the same dimensions and material, the resistance of C D will be exactly ten times that of A B; but if the sectional area of A B is reduced to one-tenth, then the resistance of A B will exactly equal that of C D. Again, if the wire A B is made of iron instead of copper, the same dimensions being retained, the resistance of A B will be six and a half times greater than that of C D. If now, A B is reduced to six and a half times its length, its resistance will again equal that of C D. Thus a short length of fine iron wire, will offer the same resistance to the passage of an electric current, as a long length of ordinary-sized copper wire, and will produce the same phenomena. One mile of No. 40 iron wire offers the same resistance as about five hundred miles of No. 16 copper wire. Short lengths of this iron wire, are cut to represent any separate lengths of copper wire of the usual dimensions, and are wound round bobbins, forming a series of what are called, ‘resistance coils.’ They can be made to represent any length of cable, but the series usually constructed consists of two hundred and twenty-one miles of No. 16 copper wire. By these means, the resistance of any cable can be ascertained, it being only necessary to compare the resistance of the material of which it is made, with that of No. 16 copper wire. Thus the resistance of the Channel Islands cable is to that of No. 16 copper wire, as 36 to 17; consequently, 17 miles on the Author’s resistance coils are equal to 36 miles of the Channel Islands cable. In the case of the Gibraltar cable, 1 mile on these coils would represent 8 miles of that cable.

The coils, used by the Author, are constructed by Mr. Cromwell Varley, and the standard employed is one mile of the No. 16 copper wire, which was in use four, or five years ago. The quality of copper, however, owing to the presence of alloys and other imperfections, varies considerably, and its resistance differs accordingly. The best selected copper varies as much as 20 per cent.

in its conductivity, and the purer it is the better it conducts. Even annealing makes a difference; annealed copper wire conducts 2·5 per cent. better than that which is hand-drawn. This subject has been carefully investigated by Dr. Matthiessen, and the results were communicated to the Royal Society in a Paper, "On the Electric Conducting Power of Alloys."¹ In the copper wire supplied to the Atlantic Telegraph Company, some lengths varied as much as 40 per cent. The attention of the Gutta Percha Company having been called to this fact, a considerable improvement in the quality of copper supplied, has been the result; every mile of copper as it enters the works, is now carefully tested by the Company. The No. 16 copper wire of the present day, conducts better than that of the standard used, in the proportion of 3 to 2. The old standard is, however, adhered to, and it is only necessary to obtain the ratio between it, and the wire under examination, to obtain the relative resistance. Messrs. Siemens, Halske, and Co., of Berlin, employ a different standard. Their unit of resistance is a column of mercury, one mètre in length, and one square millimètre in sectional area, taken at the freezing point of water. Professor Wheatstone's standard of resistance is one English foot of copper wire, 0·071 inch in diameter, and intermediate to Nos. 15 and 16. But these standards can easily be applied to that used by the Author, by employing the proper ratio to reduce one to the other. The Author's resistance coils can only directly represent 221 miles of No. 16 copper wire, or 1,768 miles of the Gibraltar cable, but by the instruments employed, and the systems adopted in comparing the relative resistance of the coils and cable, they can be made to represent any resistance from unity to infinity.

The instrument usually employed, in comparing the resistance of two wires, is the common differential galvanometer of Becquerel, shown, at G, in Fig. 7. Two wires of equal length, and equal resistance, are wound round a magnet in the usual manner. One current passes along one wire, round the needle in one direction; the other current proceeds round the needle, through the other wire, in the opposite direction. When the two currents are exactly equal, or when the resistance of one wire is equal to that of the other, the needle is neutralised, and it remains at zero.

Another arrangement is that generally known as Wheatstone's parallelogram, shown in Fig. 6. A simple galvanometer is placed in circuit between B and C. When the resistance of A B is equal to that of A C, the needle remains at zero, but any inequality in the resistance affects the galvanometer.

¹ *Vide* Phil. Trans. 1860, p. 161.

The Author has modified the common differential galvanometer, by which many useful and practical results can be obtained. It is a simple differential galvanometer, G, (Fig. 7,) and if connected up as represented, without W and P, it will show, that the resistance of R R' will exactly represent that of D D'; but if a coil P, called a 'derived circuit,' is inserted between A and A', so that its resistance is to that of half the coil, as 1 to 10, it will be obvious, that when the current divides itself between the two wires of the galvanometer, the whole of one-half will go through B B', but only one-tenth of the other half through A A'; consequently, the current passing through the first half, will be ten times greater than that passing through the other half. Now, if the resistance of R R' is reduced in the same proportion, it follows, that 1 mile of resistance in R R', will exactly balance 10 miles of resistance in D D'; consequently, the ordinary coils can be made to represent any resistance from 1 mile to 2,210 miles. By reversing the position of the coils and the cable under examination, tests of short distances can be obtained to decimals of units. Thus the coils can be made to represent any length from $\frac{1}{10}$ th of a mile to 2,210 miles. By making the resistance of the coil P, so that its resistance to G bears the same proportion as the relative resistance of the standard coils to the cable under examination, the length of cable being tested, can be read off, at once, on the coils, without the necessity of any calculation. With a coil, whose resistance is to that of half the coil of the differential galvanometer, as 36 to 17, the Author is able to read off his own standard coils, the length of the Channel Islands wire under test. The resistance of his galvanometer is 20 miles, consequently, the resistance of half is 10. Now with a set of coils, giving a resistance up to 10 miles, and a Wheatstone's rheostat, whose total resistance is equal to 1 mile, he can obtain any ratio from equality to infinity. In practice, however, it is found, that the effects of temperature, and the heating properties of currents, traversing short lengths of wire, produce such variable results, that a greater proportion between the two coils than 1 to 10, is scarcely admissible.

The proportions named are not strictly those employed in practice, nor are they correct in theory, because some allowance must be made for the reduced resistance of the galvanometer. To render them correct, additional resistance must be inserted at W, to make the combined resistance of the derived circuit, and the differential half, equal to that of the other half. But the Author has found it more convenient to obtain experimentally, that proportionate resistance between the two coils which will give the requisite multiplying power, without the necessity of employing additional compensating resistance coils. This instrument he calls the 'multiplying differential galvanometer.' It is not, however, advisable to

attempt very high resistances with the multiplying differential, as the heavy power required might damage the coils. When the resistance exceeds 1,500 miles, the Author prefers reading off the resistance from the deflection of a delicate galvanometer. The plan he adopts is the following. He observes, on a delicate galvanometer, (Fig. 8,) the deflection of the needle, reducing, or increasing the power until the deflection amounts to 30° . He then inserts a known resistance, say 500 miles, at A B, and by the use of the derived circuit, D, reduces the deflection of the needle, until it reads the same as before; the power remaining the same. The ratio between the resistance of the derived circuit, and that of the coil, will give the ratio between the known and the unknown resistance. The same effect can be produced, by altering the battery powers to obtain the same reading on the coils and the wire. Thus, if with one cell, the galvanometer shows α° through 10 miles of resistance, and the same with one hundred and twenty cells through the wire, then :—

$$(10 + r \text{ of galvanometer}) 120 = \text{Resistance of wire.}$$

It will now be seen how simple it is to express, in units of resistance, the state of the insulation and condition of a wire. If a wire, when submerged, represents upon the coils the exact resistance of its length, it insulates, and conducts well, and it is very perfect. If it gives a resistance less than its proper standard, there is a leakage, or fault, and if it gives a greater resistance than its proper standard, there is a bad joint, or imperfect continuity. If the end is disconnected, the leakage, or loss of insulation can be measured,—by the coils direct, if the loss is great,—and by the multiplying differential, or simple galvanometer, if the loss is slight. If the cable is broken at any spot, say at D', (Fig. 7,) the resistance of DD', or in other words, the distance of D' from D, is shown upon the coils RR'. Thus in testing, from the office in Jersey, for the break marked No. 8 in Table I., (page 33,) the coils RR' showed the resistance of DD' to be $10\frac{2}{3}$ miles, which placed the fault $2\frac{2}{3}$ miles from the Jersey shore, at which spot it was found. Cables should be carefully tested by such processes, not only when laid down, and at work, but also during their construction and submersion. The Engineer in charge, would thus always possess a complete knowledge of the electrical qualifications of the cable. Had the Atlantic and Red Sea cables been so treated, the present condition and prospects of submarine telegraphy would have been considerably better.

The laws of induction are much more intricate than those of resistance. Electricity develops itself in two forms, dynamic and static. A dynamic current is a very different phenomenon from

a static charge. A flash of lightning cannot be compared to the gentle current, generated by the tongue, between a shilling and a penny-piece ; but they are one and the same thing under different forms. A thunder cloud can be dissipated as a dynamic current, and a dynamic current can be developed into a thunder cloud. Conduction performs the first, induction the last operation.

The insulated conductor of a submarine cable is a Leyden jar, of which the wire is the inside, and the outer iron wire, the earth, or the sea, the outside coating. Before this Leyden jar can conduct a current, its whole surface must be charged statically, by induction. When a current is thrown into a wire, its first influence is absorbed, as it were, in raising the surface of the conductor to a certain static tension, where it remains latent as long as a current flows through the conductor. But immediately the current ceases, and the end of the wire is placed to earth, the static charge flows out of the conductor at both ends, as a dynamic current. It matters not whether the end be to earth, or be disconnected, the phenomenon is the same in effect, though different in degree. If only one end is placed to earth, the other being disconnected, the whole charge flows out at that end. If both ends are to earth, the discharge is divided between the two. It is for this reason, that, in passing a current through a long submarine cable, it takes an appreciable period before it appears at the distant end, and when the current is stopped, it continues to flow out at that end, for some time after contact has been broken, while at the same time, another current of the same duration flows out at the near end ; hence the speed of signalling through long cables is reduced.

The first rush of electricity into an open wire, is called the 'charge.' Its return, when the end is disconnected, is termed the 'discharge.' The current flowing out at the near end, when the distant end is to earth, is the 'return current.' The delay of the appearance of the current at the distant end, is its 'retardation.' The drawing out, or lengthening, of the current as it appears at the distant end, is its 'prolongation.' These different properties have, each, their own independent laws, and have recently received full examination and development ; but as the testing, and not the working of submarine cables is now under consideration, the Author will abandon the inquiry into those laws affecting retardation and prolongation, and apply himself strictly to the charge, the discharge, and the return current.

The charge and discharge obey the same laws ; the one is only a reflection of the other. Whatever, therefore, is said respecting the charge, is strictly applicable to the discharge. The return current is simply a modification of the discharge.

Now the charge of a wire depends :—

- 1st. Upon the distance between the inside and the outside coatings, the ratio of which is expressed by— d^1 .
- 2nd. Upon the specific inductive capacity of the insulating medium— s .
- 3rd. Upon the surface of wire exposed to induction— S .
- 4th. Upon the length, or resistance of the conductor— R .
- 5th. Upon the power of the battery— n .

The law which regulates it may be expressed by the formula :—

$$C = \frac{n S R s}{d}.$$

But as all induction tests in submarine cables are, simply, comparative effects between certain phenomena, upon known and unknown lengths of the same wire, the consideration of the thickness and inductive capacity of the insulating medium may be discarded, and attention be alone directed to the surface exposed, the length of wire under examination, and the power of the battery used. The formula therefore becomes :—

$$C = n S R = n l,$$

when S and R remain equal, l being the length of wire.

Thus if it is desired to compare the charges of two separate wires :—

$$C : C' :: n l : n' l'$$

or, when the same power is used in each case :—

$$C : C' :: l : l'$$

and, if the lengths of the cable are the same :—

$$C : C' :: n : n'$$

From these proportions it follows, that, if a wire 10 miles long, gives a discharge of 10° , with one hundred cells, it will give 20° with two hundred cells, or 5° with fifty cells; and, if the power remains the same, it will give 5° with 5 miles, and 20° with 20 miles. Hence, if the discharge of any unit length of wire is known, the length of wire under manipulation can easily be calculated, by the above proportion. An example may be interesting, and more explicit. The cable between Guernsey and

¹ This ratio (d) is expressed by Professor Thomson^a thus: $2 \log. \frac{D'}{D}$; where D is the diameter of the wire; D' , the diameter of the insulating medium; and $\log.$ the Napierian logarithm. Professor Wheatstone's ratio^b is, $\sqrt{\frac{r}{t}}$; where r is the radius of the wire; and t , the thickness of the coating.

^a Vide "Report of the Joint Committee appointed to Inquire into the Construction of Submarine Telegraph Cables." Folio. London, 1861. Minutes of Evidence, p. 126.

^b *Ibid.*, p. 281, *et seq.*

Jersey was recently broken, the ends being completely disconnected, and it was tested from Guernsey. Between Guernsey and Alderney, $23\frac{1}{2}$ miles, thirty-six cells gave 28° ; from Guernsey to the fault, the same power gave 20° :—

$$\therefore 28 : 20 :: 23\frac{1}{2} : 16\frac{1}{4}$$

The actual fault was $17\frac{1}{4}$ miles off, being an error of scarcely half a mile in the test.

The return current differs from the discharge, in name only. The term 'discharge,' is simply applied to the return current, when the distant end of the wire is disconnected. The term 'return current,' is applied to the discharge when the end is to earth, or when resistance is interposed between the end and the earth. The discharge formula becomes :—

$$C = \frac{n l r}{a},$$

a being a co-efficient depending upon the length of wire, and the time that elapses between the breaking and making contact, whence it follows that, as the resistance of the end r is increased, the return current is also increased, until r is infinite, when the return current equals the discharge. The converse of this would occur, when the resistance lies between the submerged wire and the testing place, but as in practice it is always possible, and indeed essential, before commencing operations, to make the tests at one end of the cable, this question need scarcely be examined.

The instrument, which the Author employs for the purpose of measuring and registering the discharge, is either a vertical galvanometer of great delicacy, or a peculiar arrangement of his own design, called a 'reduction inductometer.' With short lengths of wire, and low power, the simple galvanometer gives very true results up to 30° , when applied to the formula :—

$$C : C' :: n l : n' l'$$

the discharge being registered by the swing of the needle. But for longer lengths, the following plan is used. A, (Fig. 9.) is a simple galvanometer, through which the discharge flows to earth. Now if a unit length, say 1 mile, of submerged wire, gives 30° of deflection with n cells, 10 miles could not be registered with the same power. But if, between C and D, a derived circuit, or resistance coil, B, is inserted, whose resistance is to that of the galvanometer coil, as 1 to 10, nine-tenths of the discharge current will traverse the derived circuit B, and one-tenth the galvanometer. Thus, the deflection of the needle will be the same for 10 miles as for 1 mile. By varying the distance of the derived circuit by a set of resistance coils and rheostat, as in Fig. 8, and altering the power and unit of deflection, as may be necessary, it is possible to measure the discharge of any length

of cable, for one mile and upwards. This is a valuable instrument for measuring the discharge of wires up to lengths of two hundred miles, or three hundred miles, but beyond that distance, the time of the discharge and the absorption of the charge would materially interfere with any measurement upon the needle. The thin line produced on a Bain's instrument, by the action of prussiate of potash on a steel wire, is a valuable test for the discharge of longer lengths of cable.

It will thus be seen that, by comparing the resistance with the discharge, it is easy to calculate the position of a fault, however distant from the testing place; the one is a check upon the other. But the experiments are liable to many errors, which, if not duly allowed for, produce serious mistakes. The most important relates to the resistance of the end, or fault. When the wire is completely severed, which is almost always the cause of the interruption to the working of submarine cables in shallow waters, the resistance of the end can easily be determined, as it depends entirely upon the surface of copper exposed in the water. By a series of careful experiments, detailed in the following Table, the Author is able to give the exact value of the resistance of the end, to any break in the cable under his charge.

TABLE II. RESISTANCE OF ENDS.—CHANNEL ISLANDS CABLE.

Length of Copper exposed, in inches.	Deflection of Needle from Water Battery.	Resistance, in Miles.		Difference.
		Positive Current.	Negative Current.	
4½	20°	1	1½	½
3½	15	1	1¾	¾
2½	10	1	2	1
1½	20	1	2½	1½
½	5	1½	3½	2
¼	22	1½	3¾	2½
1/8	22	2½	4	1½
Flush.	18	3½	5½	2½

* Gas currents* observed immediately after breaking contact.

Positive primary gave a negative gas current of 15°.

Negative " positive " 20°.

No great variation. Duration, about one minute: declining rapidly in the first and second, then gradually. Power, forty-eight cells.

A similar tabular statement could easily be obtained for any cable.

When the resistance of the end of a cable is small, and the break is not very distant, it is impossible to place any reliance upon the discharge of the wire, to verify its resistance, because a very peculiar effect is produced. When a negative current is sent through the wire, it is well known, that its end is covered with

hydrogen gas, by the electrolytic action of the current upon the water, and, by the same means, the end becomes coated with oxygen, when a positive current is used. Now these two gases, acting upon the exposed end, themselves generate weak currents, which are often mistaken for discharge. The Author designates them 'gas currents,' to distinguish them from the 'water current,' which is always generated by the voltaic arrangement of the exposed copper end, the sea water, and the outside iron covering. A positive primary current generates a negative gas current, and *vice versa*. The duration of this current is but momentary, and it varies little with the surface of the copper exposed. Its electro-motive force is slight, but it renders perfectly nugatory any attempt to verify the resistance tests of short lengths, by those of induction. These gas currents are identical with 'currents of polarisation.' When the copper wire is in contact with the outer iron wire, a case of very rare occurrence, these currents are not observed, nor does the end give any resistance, a fact which is also corroborated by the resistance given to the positive and negative currents being equal. This was the case in No. 8, Table I.; (page 33).

The occurrence of partial faults is another cause of error, and great care is requisite to maintain a thorough knowledge of the condition of the wire, and the position of these partial faults. A partial fault is a leakage, or imperfection, in the insulating medium, which does not interrupt the working of the wire, but which reduces the efficiency of the working currents. In practice, daily observations should be made, at each end of a submarine cable, to detect and determine the position of these faults, as the errors they produce are very serious. In testing from Weymouth, the Author calculated the fault No. 10, Table I., to be at 15 miles from Alderney. This arose from the existence of a partial fault near Weymouth; on testing from the other end, he found the result shown on the Table.

If AB (Fig. 10) represents the wire to be tested, and AC a fault near at hand, then the resistance of the two together will be, by Ohm's law, calling the one x and the other y :—

$$\begin{aligned} & \frac{x y}{x+y} \\ \text{Now if} & \quad y = B \\ \text{and} & \quad \frac{x y}{x+y} = A \\ \text{then} & \quad x = \frac{A B}{A - B} \end{aligned}$$

From this, it is evident, that the less the resistance y is made, the

greater it will make the difference between A and x , and consequently, the greater the error produced in the test.

It can be similarly shown, that the further the fault is from A, and the greater its resistance, the less will be the error introduced. Hence, before the correct resistance of a wire can be definitely proved, the value of y must always be known. To show, practically, the serious error a partial fault may produce :—

Suppose $y = 100$,—by no means a very serious fault,—

and
$$\frac{xy}{x+y} = 48$$

then
$$x = 92\frac{4}{13} :$$

reducing the distance of the fault by nearly one-half.

There are several methods of testing for partial faults. The following are those usually adopted :—

First, When the two ends are at hand ;—by inserting resistance at A, (Fig. 11,) until the differential galvanometer marks zero ; and calling R the resistance of the cable, when perfect ;

“ x “ of the longer length ;

“ y “ of the shorter length ;

“ r “ of the coils ;

then
$$x + y = R$$

and
$$x = y + r$$

$$\therefore 2y = R - r$$

$$y = \frac{R - r}{2}.$$

Secondly, When only one end is obtainable :—

Let $x + y = R$, resistance of the cable, when perfect ;

$x + z = A$, the resistance, when the end is disconnected ;

then $x + \frac{yz}{y+z} = B$, the resistance, when the end is to earth ;

from which x , y , and z can easily be resolved ; x and y being the distances of the fault from the ends, and z , the resistance of the fault. This method requires great care, and is liable to serious errors through the variability of the resistance of the fault. The test should be verified by repetition at the other end, but the Author prefers to obtain simultaneous tests, at both ends, by two manipulators, who possess instruments precisely similar in every respect, by which method great accuracy is obtained, and the variation of the resistance of the fault is of little, or no, consequence.

The methods of testing by resistance and induction, which have now been detailed, will enable the Engineer to possess a thorough knowledge of the condition of the wire under his charge, and to

detect, at once, the existence and position of any fault, however distant, which may occur to interfere with the proper working of the cable.

Faults are of various kinds, and result from various causes. There are faults arising to the insulating material, from adulteration in its composition, and imperfections in its manufacture. There are mechanical injuries sustained by the gutta percha in its transport from the manufactory to the machine, or in the process of making it into a submarine cable. The cable is liable to injury, in every stage of its existence; and when submerged, it is in the greatest danger. In shallow waters, rocks destroy it, and ships damage it with their anchors. Atmospheric electricity plays an important part in its existence, in deep as well as in shallow waters; one flash of lightning, entering the wire, would speedily destroy its utility. The immoderate use of battery power would irretrievably destroy a damaged wire. But there is no imperfection which cannot be detected, and no accident which cannot be provided against. If the cable is thoroughly examined and tested, before it enters the machine; if it is completely supervised, and tested under water, before being coiled in the ship; if it is payed out, with due regard to the course taken, and the nature of the bottom; if in shallow waters it is made so strong, that no ship can injure it, and it is laid along such a route, that no rocks can damage it; if it is properly protected against lightning and other natural causes; and if it is constructed, and worked, upon true principles; then submarine telegraphy may hope to flourish. But when all experience is ignored, and the true principles of the science are neglected; when a red line is drawn across a chart, and a cable is laid along that route, without any reference to the currents, and the bottom; when cables, which, in their design, are scarcely fit for unfrequented rivers, are laid in rough channels; and when no regard whatever is paid to their durability and maintenance; then no surprise need be felt, that opinions should be expressed unfavourable to the permanence and efficiency of submarine telegraphy.¹

The Paper is illustrated by a series of diagrams, from which Plate 2, (Figs. 1 to 11,) has been compiled.

¹ It is gratifying to the Author to find, that the conclusions he had arrived at, and the opinions he had expressed in this Paper, were corroborated and confirmed by the Joint Committee in their Report to the Government, issued in 1861. Several accidents of a similar nature to those described, have occurred to the Channel Islands cable, and the undertaking is now being abandoned.—AUTHOR. February, 1862.

[Mr. HAWKSHAW,

CHART OF A PORTION OF THE ENGLISH CHANNEL.