ATLANTIC TELEGRAPH CABLE: ADDRESS

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WILLIAM THOMSON

ATLANTIC TELEGRAPH CABLE: ADDRESS

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ATLANTIC TELEGRAPH CABLE.

1866 Oct 22
From the
Boston Daily Advertiser Office.

ADDRESS

OF

PROFESSOR WILLIAM THOMSON,

LL.D., F.R.S.,

DELIVERED BEFORE THE

ROYAL SOCIETY OF EDINBURGH,

December 18*th*, 1865.

WITH OTHER DOCUMENTS.

LONDON:
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1866.

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(A.) Certificate of what has been proved by the Atlantic Telegraph Expeditions of 1858 and 1865.

(B.) Certificate from the Prospectus of Anglo-American Telegraph Company, Limited.

(C.) Estimated Revenue from 1 Cable between Ireland and Newfoundland.

(D.) Ditto do. 2 Cables do. do.

(E.) Extract from Letter of Mr. C. F. Varley to the *Observer*.

(F.) Letter from C. F. Varley, Esq., about the tariff through the Atlantic Cable.

(G.) Letter from Captain Bolton in regard to code for long Submarine lines.

(H.) Mr. Willoughby Smith's new system of testing a Submarine Cable electrically during its submersion.

(I.) List of Voyages by Steamers crossing the North Atlantic yearly.

(J.) Directors and Officers of the New York, Newfoundland and London Telegraph Company.

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PROCEEDINGS

OF THE

ROYAL SOCIETY OF EDINBURGH.

Monday, December 18th, 1865.

SIR DAVID BREWSTER, President, in the Chair.

At the request of the Council, Professor WILLIAM THOMSON, LL.D., of Glasgow, delivered the following Address on the Forces concerned in the Laying and Lifting of Deep-sea Cables.

THE forces concerned in the laying and lifting of deep submarine cables attracted much public attention in the years 1857-58.

An experimental trip to the Bay of Biscay in May, 1858, proved the possibility, not only of safely laying such a rope as the old Atlantic cable in very deep water, but of lifting it from the bottom without fracture. The speaker had witnessed the almost incredible feat of lifting up a considerable length of that slight and seemingly fragile thread from a depth of nearly 2½ nautical miles.* The cable had actually brought with it safely to the surface, from the bottom, a splice with a large weighted frame attached to it, to prevent untwisting between the two ships, from which two portions of cable with opposite twists had been laid. The actual laying of the cable a few months later, from mid ocean to Valentia on one side, and Trinity Bay, Newfoundland, on the other, regarded

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* Throughout the following statements, the word mile will be used to denote (not that most meaningless of modern measures, the British statute mile) but the nautical mile, or the length of a minute of latitude, in mean latitudes, which in electric cable reckoning is taken as 6,073 feet. For approximate statements, rough estimates, &c., it may be taken as 6,000 feet, or 1,000 fathoms.

merely as a mechanical achievement, took by surprise some of the most celebrated engineers of the day, who had not concealed their opinion, that the Atlantic Telegraph Company had undertaken an impossible problem. As a mechanical achievement it was completely successful; and the electric failure, after several hundred messages (comprising upwards of 4,359 words) had been transmitted between Valentia and Newfoundland, was owing to electric faults existing in the cable before it went to sea. Such faults cannot escape detection, in the course of the manufacture, under the improved electric testing since brought into practice, and the causes which led to the failure of the first Atlantic cable no longer exist as dangers in submarine telegraphic enterprise. But the possibility of damage being done to the insulation of the electric conductor before it leaves the ship (illustrated by the occurrences which led to the temporary loss of the 1865 cable), implies a danger which can only be thoroughly guarded against by being ready at any moment to back the ship and check the egress of the cable, and to hold on for some time, or to haul back some length according to the results of electric testing.

The forces concerned in these operations, and the mechanical arrangements by which they are applied and directed, constitute one chief part of the present address; the remainder is devoted to explanations as to the problem of lifting the west end of the 1,200 miles of cable laid last summer, from Valentia westwards, and now lying in perfect electric condition (in the very safest place in which a submarine cable can be kept), and ready to do its work, as soon as it is connected with Newfoundland, by the 600 miles required to complete the line.

Forces concerned in the Submergence of a Cable.

In a paper published in the "Engineer" Journal in 1857, the speaker had given the differential equations of the catenary formed by a submarine cable between the ship and the bottom, during the submergence, under the influence of gravity and fluid friction and pressure; and he had pointed out that the curve becomes a straight line in the case of no tension at the bottom. As this is always the case in deep sea cable laying, he made no further reference to the general problem in the present address.

When a cable is laid at uniform speed, on a level bottom, quite straight, but without tension, it forms an inclined straight line, from the point where it enters the water, to the bottom, and each point of it clearly moves uniformly in a straight line towards the position on the bottom that it ultimately occupies.* That is to say, each particle of the cable moves uniformly along the base of an isosceles triangle, of which the two equal sides are the inclined portion of the

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* Precisely the movement of a battalion in line changing front.

cable between it and the bottom, and the line along the bottom which this portion of the cable covers when laid. When the cable is paid out from the ship at a rate exceeding that of the ship's progress, the velocity and direction of the motion of any particle of it through the water are to be found by compounding a velocity along the inclined side, equal to this excess, with the velocity already determined, along the base of the isosceles triangle.

The angle between the equal sides of the isosceles triangle, that is to say, the inclination which the cable takes in the water, is determined by the condition, that the transverse component of the cable's weight in water is equal to the transverse component of the resistance of the water to its motion. Its tension where it enters the water is equal to the longitudinal component of the weight (or, which is the same, the whole weight of a length of cable hanging vertically down to the bottom), diminished by the longitudinal component of the fluid resistance. In the laying of the Atlantic cable, when the depth was two miles, the rate of the ship six miles an hour, and the rate of paying out of the cable seven miles an hour, the resistance to the egress of the cable, accurately measured by a dynamometer, was only 14 cwt. But it must have been as much as 28 cwt., or the weight of two miles of the cable hanging vertically down in water, were it not for the frictional resistance of the water against the cable slipping, as it were, down an inclined plane from the ship to the bottom, which therefore must have borne the difference, or 14 cwt. Accurate observations are wanting as to the angle at which the cable entered the water; but from measurements of angles at the stern of the ship, and a dynamical estimate (from the measured strain) of what the curvature must have been between the ship and the water, I find that its inclination in the water, when the ship's speed was nearly 6¼ miles per hour, must have been about 6¾°, that is to say, the incline was about 1 in 8½. Thus the length of cable, from the ship to the bottom, when the water was two miles deep, must have been about 17 miles.

The whole amount (14 cwt.) of fluid resistance to the motion of this length of cable through it is therefore about ·81 of a cwt. per mile. The longitudinal component velocity of the cable through the water, to which this resistance was due, may be taken, with but very small error, as simply the excess of the speed of paying out above the speed of the ship, or about one mile an hour. Hence, to haul up a piece of the cable vertically through the water, at the rate of one mile an hour, would require less than 1 cwt. for overcoming fluid friction, per mile length of the cable, over and above its weight in water. Thus fluid friction, which for the laying of a cable performs so valuable a part in easing the strain with which it is paid out, offers no serious obstruction, indeed, scarcely any sensible obstruction, to the reverse process of hauling back, if done at only one mile an hour, or any slower speed.

As to the transverse component of the fluid friction, it is to be remarked that, although not directly assisting to reduce the egress strain, it indirectly contributes to this result; for it is the transverse friction that causes the gentleness of the slope, giving the sufficient length of 17 miles of cable slipping down through the water, on which the longitudinal friction operates, to reduce the egress strain to the very safe limit found in the recent expedition. In estimating its amount, even if the slope were as much as 1 in 5, we should commit only an insignificant error, if we supposed it to be simply equal to the weight of the cable in water, or about 14 cwt. per mile for the 1865 Atlantic cable. The transverse component velocity to which this is due may be estimated with but insignificant error, by taking it as the velocity of a body moving directly to the bottom in the time occupied in laying a length of cable equal to the 17 miles of oblique line from the ship to the bottom. Therefore, it must have been from 2 miles in $17 \div 6\frac{1}{2} = 2{\cdot}61$ hours, or ·8 of a mile per hour. It is not probable that the actual motion of the cable lengthwise through the water can affect this result much. Thus, the *velocity of settling* of a horizontal piece of the cable (or velocity of sinking through the water, with weight just borne by fluid friction) would appear to be about ·8 of a mile per hour. This may be contrasted with longitudinal friction by remembering that, according to the previous result, a longitudinal motion through the water at the rate of one mile per hour is resisted by only 1-17th of the weight of the portion of cable so moving.

These conclusions justify remarkably the choice that was made of materials and dimensions for the 1865 cable. A more compact cable (one for instance with less gutta percha, less or no tow round the iron wires, and somewhat more iron), even if of equal strength and equal weight per mile in water, would have experienced less transverse resistance to motion through the water, and therefore would have run down a much steeper slope to the bottom. Thus, even with the same longitudinal friction per mile, it would have been less resisted on the shorter length; but even on the same length it would have experienced much less longitudinal friction, because of its smaller circumference. Also, it is important to remark that the roughness of the outer tow covering undoubtedly did very much to ease the egress strain, as it must have increased the fluid friction greatly beyond what would have acted on a smooth gutta percha surface, or even on the surface of smooth iron wires, presented by the more common form of submarine cables.

The speaker showed models illustrating the paying-out machines used on the Atlantic expeditions of 1858 and 1865. He stated that nothing could well be imagined more perfect than the action of the machine of 1865 in paying out the 1,200 miles of cable then laid, and that if it were only to be used for *paying out*, no change either in general plan or in detail seemed desirable, except the substitution of a softer material for the "jockey pulleys," by which the cable in entering the machine has the small amount of resistance applied to it which it requires to keep it from slipping round the main drum. The rate of egress of the cable was kept always under perfect control by a weighted friction brake of Appold's construction (which had proved its good quality in the 1858 Atlantic expedition) applied to a second drum carried on the same shaft with the main drum. When the weights were removed from the brake (which could be done almost instantaneously by means of a simple mechanism), the resistance to the egress of the cable, produced by "jockey pulleys," and the friction at the bearings of the shaft carrying the main drum, &c., was about 2¼ cwt.

Procedure to repair the Cable in case of the appearance of an electric fault during the laying.

In the event of a fault being indicated by the electric test at any time during the paying out (as proved by the recent experience), the safe and proper course to be followed in future, if the cable is of the same construction as the present Atlantic cable, is instantly, on order given from an authorised officer in the electric room, to stop and reverse the ship's engines, and to put on the greatest *safe* weight on the paying-out brake. Thus in the course of a very short time the egress of the cable may be stopped, and, if the weather is moderate, the ship may be kept, by proper use of paddles, screw, and rudder, nearly enough in the proper position for hours to allow the cable to hang down almost vertically, with little more strain than the weight of the length of it between the ship and the bottom.

The best electric testing that has been practised, or even planned, cannot show within a mile the position of a fault consisting of a slight loss of insulation, unless both ends of the cable are at hand. Whatever its character may be, unless the electric tests demonstrate its position to be remote from the outgoing part, the only thing that can be done to find whether it is just on board or just overboard, is to cut the cable as near the outgoing part as the mechanical circumstances allow to be safely done. The electric test immediately transferred to the fresh-cut seaward end shows instantly if the electric line is perfect between it and the shore. A few minutes more, and the electric tests applied to the *two ends* of the remainder on board, will, in skilful hands, with a proper plan of working, show very closely the position of the fault, *whatever its character may be*. The engineers will thus immediately be able to make proper arrangements for re-splicing and paying out good cable, and for cutting out the fault from the bad part.

But if the fault is between the land end and the fresh-cut seaward end on board ship, proper simultaneous electric tests on board ship and on shore (not hitherto practised, but easy and sure if properly planned) must be used to discover whether the fault lies so near the ship that the right thing is to haul back