SCIENTIFIC AMERICAN SUPPLEMENT

Vol. XXIII.

JANUARY—JUNE, 1887.

New York:

MUNN & CO., PUBLISHERS.

Scientific American Office, No. 361 Broadway.

G. A. AVERY. SC.

SCIENTIFIC AMERICAN SUPPLEMENT No. 574

Scientific American Supplement, Vol. XXIII., No. 574. Scientific American, established 1845.

NEW YORK, JANUARY 1, 1887.

Scientific American Supplement, $5 a year. Scientific American and Supplement, $7 a year.

TELESCOPIC PHOTOGRAPHY.

In a preceding number we gave an account of some curious results obtained by Mr. Lacombe in long-distance photographing, by means of a field telescope adapted to a photographic apparatus. Several of our readers having asked for further details on the subject, we shall now revert to the question, in order to give all amateurs the method of operating this interesting process.

Mr. Lacombe thus describes the arrangement that he employs:

"It is simply a question of fixing a telescope in front of the objective. Mine is held in place by means of a disk, A (Fig. 1), which is screwed upon the tube of the objective at B. A diaphragm with a wide aperture, placed at C, prevents it from abutting against the objective lens at D.

"The telescope that I use magnifies about fifteen times. As an objective I use a Darlot 'trousse,' consisting of four lenses of 10, 11½, 13, and 18 inch focus. I use any of these at random, since the difference in focus does not seem to me to have any influence. The size of the image depends upon how far the camera is drawn out. The farther this is drawn, the larger the negative; but, on the contrary, the less sharp it is. Focusing is effected by means of the eyepiece of the telescope (Fig. 2), which it would be well to provide with a rack in order to facilitate the operation. The presence of a photographic objective does not seem to me to be indispensable, seeing that I have obtained negatives (although weak ones) without an objective. It would suffice to have an absolutely achromatic telescope, exempt from chemical focus. The want of sharpness of my negatives seems to me to be due merely to this cause. But there will always be one obstacle to great delicacy, and that is the haze that constantly exists in the atmosphere.

"I believe that this process would be useful to military science. Moreover, I conceived the first idea of it during the siege of 1870, but had entirely forgotten it, when the experiments in balloon photography brought it to my mind again."

Along with his communication, Mr. Lacombe sends some specimens of long-distance photographs, especially of the Trocadero and of the dome of the Invalides, taken from the top of the tower of St. James.

Another of our readers, Mr. E. Mathieu, has had excellent success in taking these long-distance photographs. This gentleman, after focusing his photographic apparatus, brings the telescope near the objective, to which he applies it by means of a cloth bandage.

"Properly speaking," says Mr. Mathieu, "I do not fix the telescope to the objective, but merely unite the two by means of an antiphotogenic tube of red cloth. As the red rays interfere with the seeing of the image, I wrap a black veil loosely around the tube. I operate as follows: I place the telescope in the desired direction, and then focus it. I have used three modes of suspension of the telescope, viz., a surveyor's tripod, a board provided with two screw rings, and, finally, the arrangement shown in Fig. 3, which is for use in a room, and which permits of the sighting being easily effected. The suspension wires are of brass, and very fine. A vertical direction is given the telescope by twisting the wire around pins."

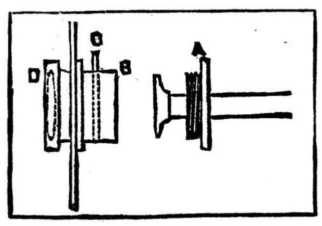


FIG. 1.—DIAGRAM OF MR. LACOMBE'S PHOTOGRAPHIC APPARATUS.

Mr. Mathieu operates with a telescope that draws out to 24 inches. Our correspondent sends us the excellent results that we reproduce herewith, consisting of a general view of the environs of Culoz, where at A (Fig. 4) we see the castle of La Flechere. After the photographic apparatus had been provided with its telescope, the details of the castle were obtained in another photograph, which we reproduce in Fig. 5. Our two engravings are facsimiles of the photographs, and of actual size therewith. The view of the castle of La Flechere was taken from a distance of over half a mile.

"I hope," says Mr. Mathieu, "to obtain much better results, as I am now using a telescope of very inferior quality. I believe that there are but two conditions absolutely necessary for reaching such a result: (1) That there shall not be the least luminous ray between the telescope and the camera objective; and (2) that the time of exposure be properly regulated. My apparatus is a Joute one. The objective is a Darlot No. 2 hemispherical lens. For the first photograph (the one made without a telescope, Fig. 4), I made an exposure of five seconds, with a diaphragm of 0·08 in. diameter, which is a little too large. For the long-distance photograph (Fig. 5), the exposure was ninety seconds. I used Franck plates."

In conclusion, Mr. Mathieu tells us that he has got some slight results in operating from a distance of 3½ miles.

Mr. Narciso de Lacerda, one of our Lisbon correspondents, has also succeeded in obtaining long-distance photographs, and sends us specimens of them. These were taken with an astronomical telescope at a distance of 1½ mile.

"The apparatus that I use," says this gentleman, "consists simply of a camera to which is added an astronomical telescope of 4·3 in. diameter with its objective and ocular, the latter magnifying, according to need, 80, 100, 150, or 200 times.

"The camera objective is done away with. I have obtained likewise in this way very satisfactory negatives of the moon, although astronomical negatives are more difficult to take, on account of the displacement due to the revolution of the earth, my telescope having no clockwork motion. It is clear that the operation may be performed with any sort of telescope whatever.

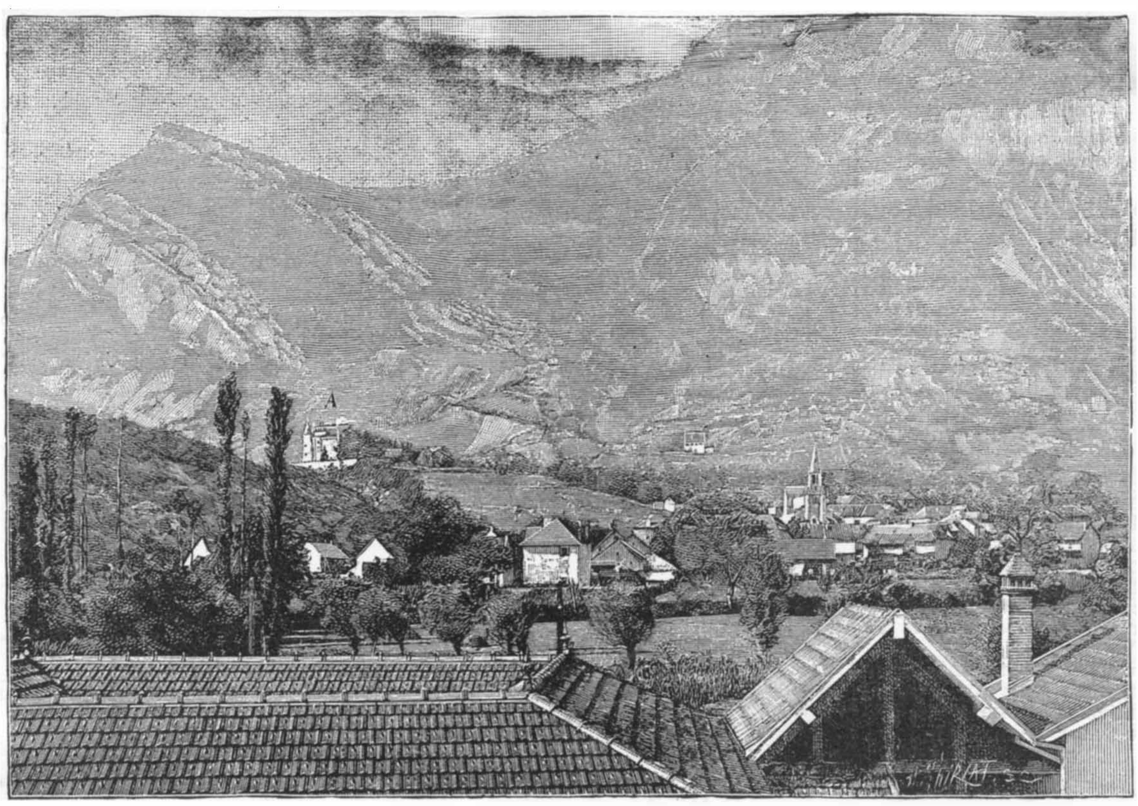


FIG. 4.—VIEW OF THE ENVIRONS OF CULOZ. (FROM A PHOTOGRAPH.)

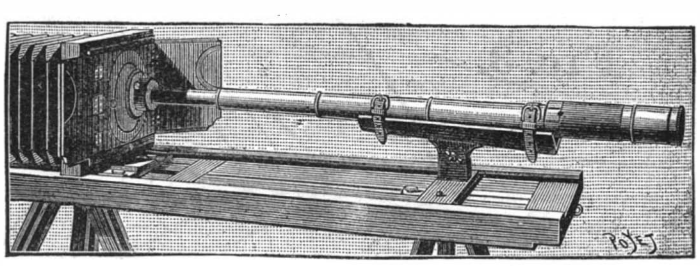


FIG. 2.—APPARATUS FOR TELESCOPIC PHOTOGRAPHY.

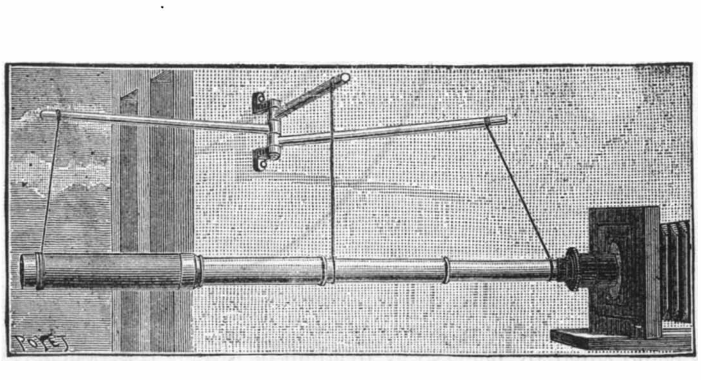


FIG. 3.—MR. MATHIEU'S APPARATUS FOR THE SAME PURPOSE.

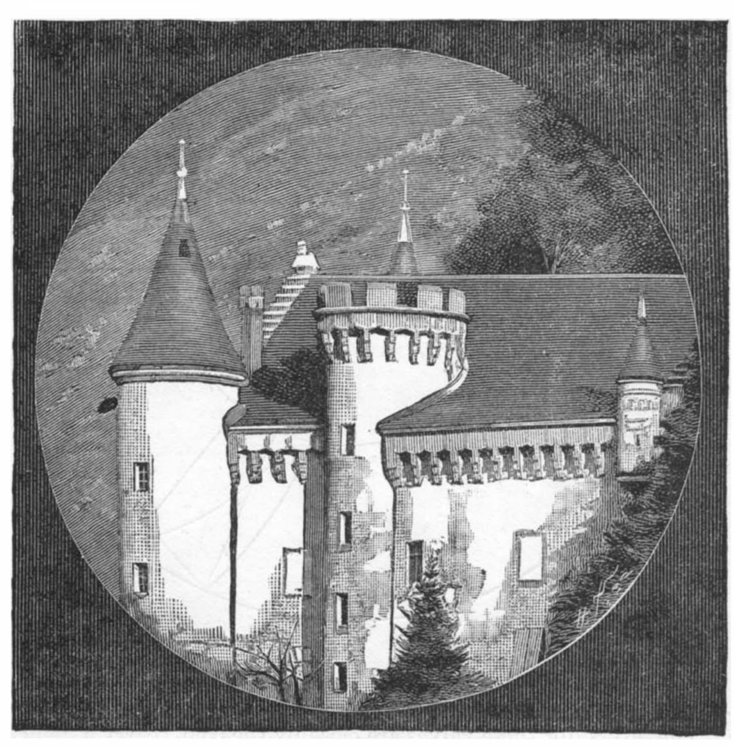


FIG. 5.—CASTLE OF FLECHERE PHOTOGRAPHED THROUGH A TELESCOPE.

PHOTOGRAPHIC APPARATUS WITH TELESCOPE ATTACHED.

"The *modus operandi* is the same as in micro-photography. Here the telescope is substituted for the microscope. My arrangement is somewhat primitive. The camera bears slightly against the ocular of the telescope. Since the lens of the camera is dispensed with, the focusing has to be done somewhat in the dark, as the objective of my telescope is designed for visual observation, and consequently is not achromatized for the chemical rays, like those that are used especially for photography."

It seems certain that, with apparatus specially constructed, we might obtain more important results than those of which we have just spoken. This is a new field for constructors and operators.

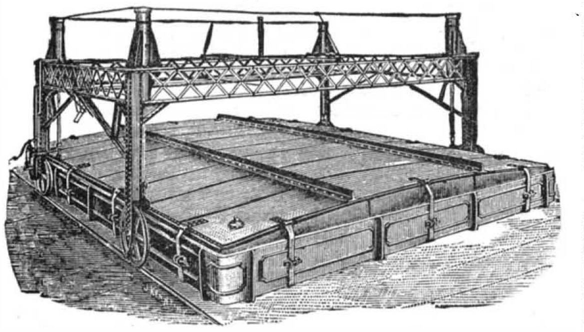
Long-distance photography, it appears to us, is destined to render service to officers charged with military reconnaissances in captive or free balloons. Finally, it seems to us that it may prove useful to the explorer for obtaining accurate data in regard to inaccessible localities across rivers, at the base of precipices, or at the top of mountains.—*La Nature.*

HYDRAULIC HOISTING CARRIAGE FOR PURIFIER COVERS.

Any improvement which tends to save time and lessen the labor involved in the raising or hoisting of the covers to purifying boxes will no doubt be appreciated and welcomed by gas engineers and gas works superintendents; and particularly so in the case of large plants, which necessarily require purifiers of large dimensions in order that the gas consumer may be assured of receiving a clean illuminating agent.

The accompanying illustration represents a new device for the rapid and easy lifting of purifier covers, known as the Nock & Floyd patent, which is controlled, and is now being introduced to the notice of gas engineers, by Mr. Jas. R. Floyd, of the Oregon Iron Works, of this city.

In the view given a floor carriage is shown, the cut



NOCK & FLOYD'S HYDRAULIC HOISTING CARRIAGE FOR PURIFIER COVERS.

being reproduced from a photograph of one of the two hoisting carriages just completed by Mr. Floyd at the new station of the Equitable Gas Light Company, foot of East 42d Street, New York city. At the station there are four boxes, each 24 feet wide, 30 feet long, and 37 inches deep, with 24 inch cups. The cover is raised by the agency of four piston rods working in the hydraulic cylinders at each corner of the carriage. From the tank, which is secured to one of the lattice girders of the carriage, the water or other liquid is forced by means of a one and one-half inch compression pump to a two and one-half inch standpipe, fixed at the center of the carriage, and from there it is distributed, through one-half inch tubes, to the lower sides of the piston head of each cylinder. The weight of the cover shown is 7,500 pounds, the lift accomplished is 3 feet 9 inches, and the time consumed or taken up in the operation is ten minutes.

As there are four points of support, to prevent straining the cover when moving it, while only three would be necessary to raise it perpendicularly, one of the pistons has a tendency to move faster than its fellows. For this reason four valves are provided to regulate the rise. The levers for these valves are close by the compression pump.

The space above the piston in each cylinder is kept filled with liquid in order to prevent the slow leakage from the under side of the piston, which is unavoidable in steam or hydraulic pressure. As the piston rises, the liquid above it is carried off by means of the pipes tapped into the caps of the cylinders. The cover is lowered by its own weight, the liquid being discharged into the tank from whence it originally came. A commercial glycerine is used in preference to water, on account of its low freezing point, the advantage of its greater specific gravity, and its value as a lubricator.

The carriage and raised cover are easily moved, the bearings being constructed out of brass and steel. One man can operate the machine, but two men will undoubtedly work to better advantage.

A hoisting carriage, on the plan described, was originally erected for the Equitable Company in December, 1885, by Mr. Floyd, which worked on boxes of a dimension of 21 feet by 24 feet. So well did it answer the purpose intended, that its success caused its application to the boxes spoken of above. It may be further noted that the Nock & Floyd hydraulic hoist can be applied to boxes otherwise equipped without any difficulty.—*Amer. Gas Light Jour.*

INSTRUMENTS FOR DRAWING CURVES.

By Prof. C. W. MacCord, Sc.D.

III.—THE LEMNISCATE.

In Fig. 1, A C, B D, are two levers turning about fixed centers at C and D, and connected by a link A B, equal in length to A C. Let this link be prolonged to carry a pencil at P, the distance A P being equal to A B: also let B D be equal to C D, and greater than A C. Then the revolution of the shorter lever will cause the longer one to vibrate through a definite angle, and the pencil to trace the symmetrical looped curve shown, which is the lemniscate.

Fig. 2 shows in detail the arrangement of the parts in a practical working instrument of which the preceding diagram is the skeleton; the link P B being made in the form of a bell-crank by having the reverted arm B A secured to the same pin at B, in order that the link may perform the complete revolution without having the pencil come into contact with B D.

The pivot at D is not fixed directly to the frame, but is secured to a socket sliding upon a bar, to which it can be clamped in various positions, thus varying the distance C D. By similar means the length of B D can be correspondingly varied, so that as shown in Fig. 1, lemniscates of different breadths may be drawn, the length remaining always equal to 4 A C. As we increase B D and C D, the breadth of the loops will diminish, and *vice versa*. If B D = A C, the pencil will trace a circle with a radius equal to A C; but as the lever B D cannot reverse its direction after reaching the extreme right-hand position, the loop on the right will disappear.

On the other hand, as the length of B D increases, the curvature of the path of B grows less and less; and if that lever become infinite, the point B will rise and fall in a vertical line through C; under which circumstances a vertical guide practically replaces the lever, and the point P will evidently trace a right line whose length is 4 A C.

It need hardly be pointed out that the perfect symmetry of the lemniscate depends upon the equality of A B and A P. The instrument might as easily be made so as to admit of placing the pencil at different points of the link at pleasure; thus greatly modifying the form of its path, as illustrated in Fig. 3. As there shown, if A P be increased, one loop becomes larger than the other; if the pencil be placed nearer to A than before, as at P', it will trace an elongated curve without a loop; if between A and B, as at P", or beyond B to the right,

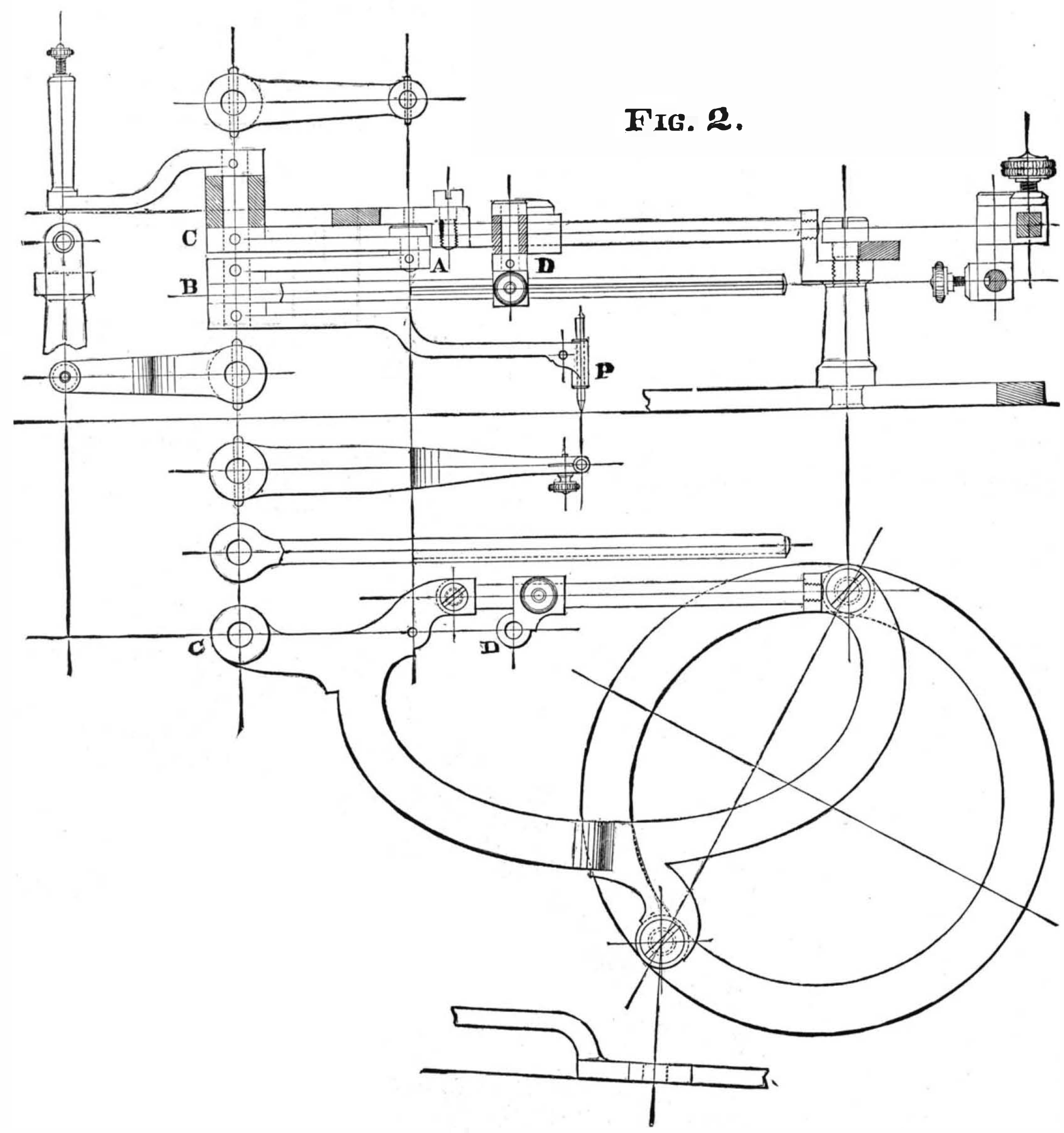


Fig. 2.

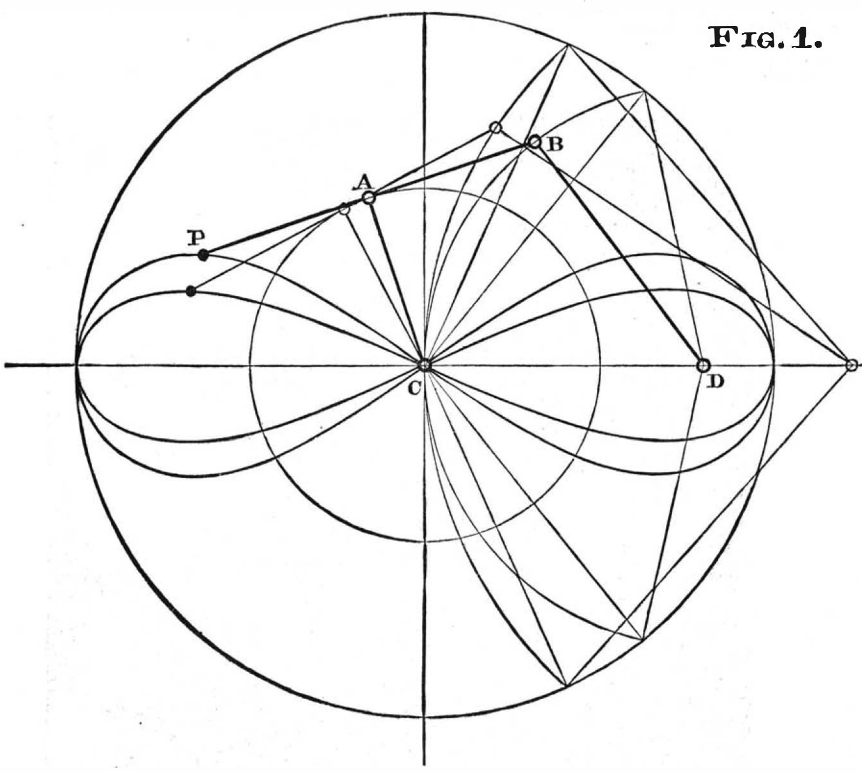


Fig. 1.

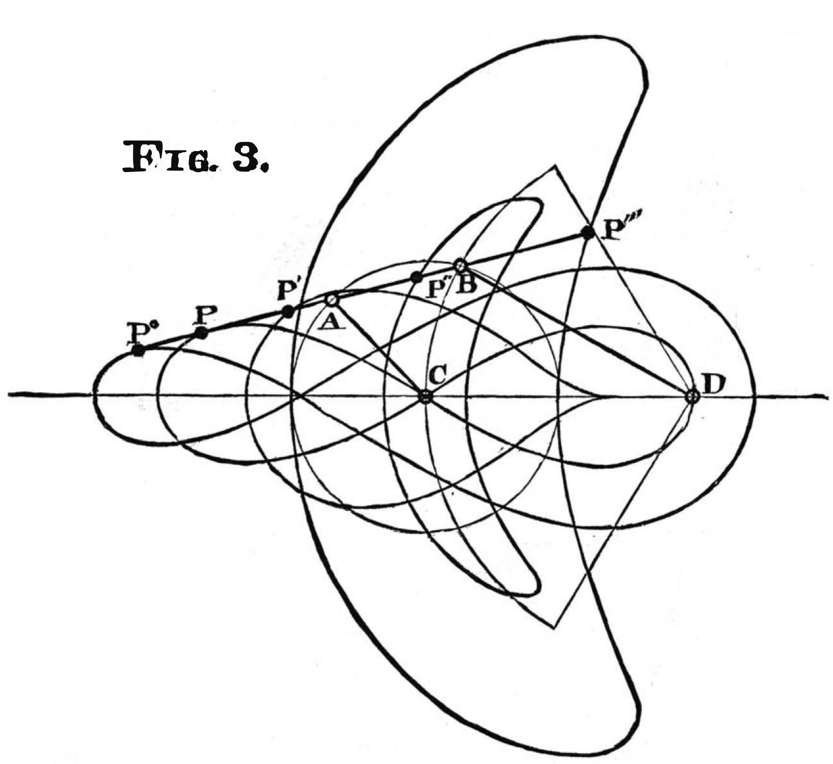


Fig. 3.

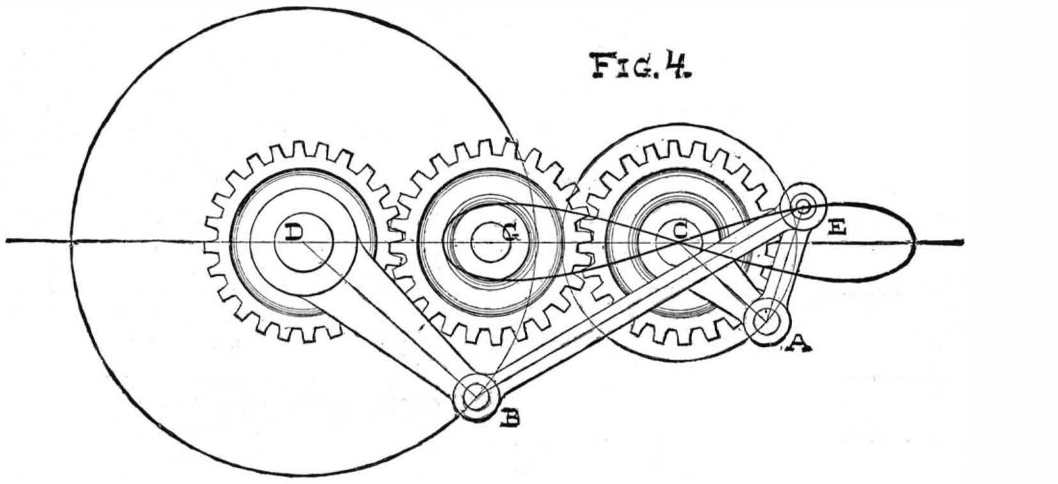
as at P‴, it will trace a reniform curve, bearing no resemblance to the lemniscate, which alone is symmetrical with respect to the vertical line through C, though all of these curves are symmetrical with respect to the horizontal line through that point.

If B D become infinite, the vertical guide being substituted for it, all these curves will be true ellipses, the instrument in fact being then simply an elliptograph. And it may be remarked that if B D be made only moderately long, the curve produced in some positions of the pencil will lose its reniform shape, the concavity disappearing and being replaced by a convex outline; so that the difference between it and a true ellipse might escape notice unless careful scrutiny were made. Two instruments purporting to be accurate elliptographs have come under our observation, in which this approximate movement was employed.

The lemniscate may also be described by means of the combination shown in Fig. 4. In this arrangement,

This, however, is not the case with the arrangement shown in Fig. 5, which consists of a link connecting the free foci of a pair of equal and similar ellipses revolving around their fixed foci. The center point of the link describes the lemniscate; and since both directional relation and velocity ratio are determined by the elliptical wheels, whose teeth also establish compulsory rotation, and carry the link past the dead points, the result is absolute. But if simplicity be the desideratum, and it be regarded admissible here also to help the system by hand over the dead points, then two equal levers, connected by a link whose length is equal to the distance between the fixed centers, are all the parts required.

The substantial identity of these combinations will be seen by an examination of Fig. 6, in which C D are the fixed foci of the pitch ellipses shown, whose point of tangency is at the intersection of C D, the line of centers, with the line A B joining the free foci. The mid-



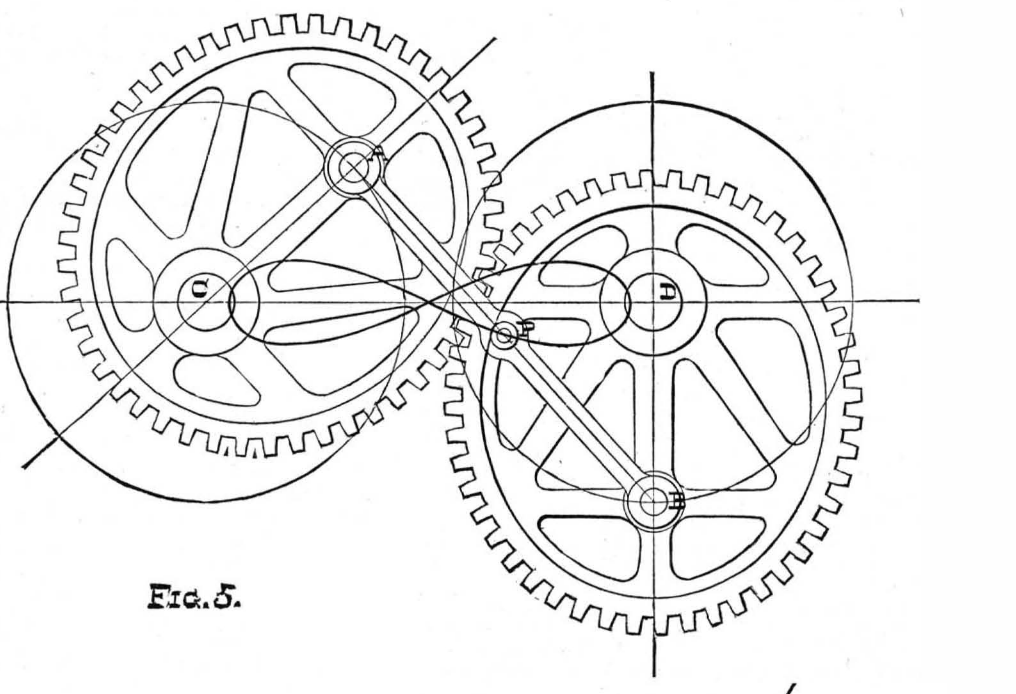


FIG. 5.

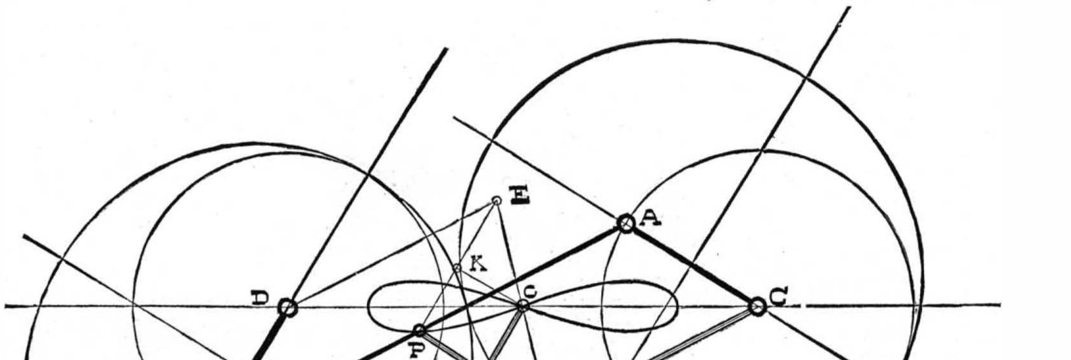


FIG. 6.

the length of the lever B D is twice that of A C, and these levers are made to revolve in the same direction and with the same angular velocity by the two equal wheels whose centers are C and D, in connection with an idle wheel whose center is G. To A C is pivoted a link A E equal to it in length, and to B D a link B E whose length is equal to C D; these two links are pivoted to each other at E, which latter point is made to travel in the desired curve by the combined action of the levers and links. In this case the length of the curve will be equal to 2 B D or 4 A C; the greatest breadth will be $\frac{2\,A\,C^2}{B\,P}$: so that without changing C D or B E, different proportions might be drawn by providing adjustments for varying the lengths of A C, A E, and B D.

In both these combinations, there are positions in which it is necessary to help the parts over dead points, and it is also possible that in either of them the pencil will trace a circle whose diameter is 4 A C, if this extraneous assistance be not afforded.

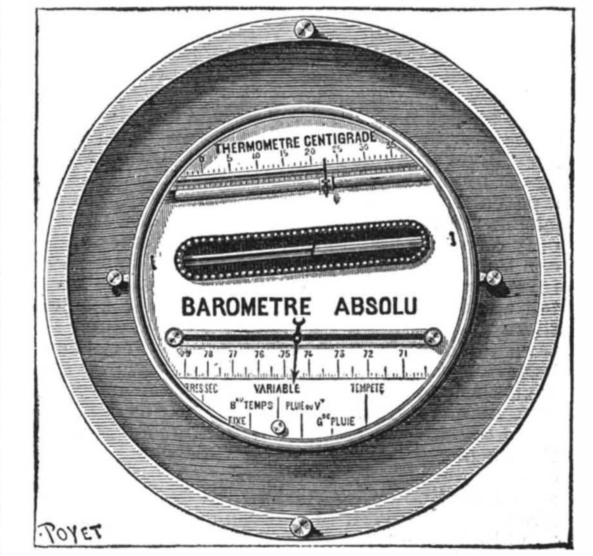
dle point P of A B traces the lemniscate, and would do so were the ellipses removed and replaced by the levers A C, B D, each of length equal to the distance between the foci of one of the ellipses. Now, drawing D E, C F, each parallel and equal to B P, it is clear that E F will bisect C D at O, also P E will be parallel and equal to B D, and P F to A C. Bisect P E at K, and P F at H, then O K will be parallel and equal to P H, and O H to P K; whence O H is parallel to B D, and equal to ½ B D, as in Fig. 4. And the system O H, C F, F H P, is identical with that used in Fig. 1.

INSTANTANEOUS PHOTOGRAPHY.

M. MAREY has devised an arrangement by means of which the light coming from the background against which the quickly moving objects are photographed can be cut off. This light has hitherto affected the sensitive plates and often injured the clearness of the impression. By means of certain precautions, M. Marey has been able to reduce the time of pose, for each image, to 0·002 of a second, and hopes to still further reduce it. The new photographs show an extraordinary clearness of impression under the shortening of the time of exposure. The pivoting of the wings of birds upon their longitudinal axis is clearly shown, and also other and various peculiarities of their flight. The author expresses his obligation to certain suggestions of Chevreul.—*Comptes Rendus.*

AN ABSOLUTE BAROMETER.

IN 1879, two artillery officers, Messrs. Hans and Hermary, constructed a very remarkable absolute barometer based upon the simultaneous observation of an ordinary thermometer and an air one, whence the instrument showed variations in pressure. A skillful manufacturer, Mr. Lesperut, has succeeded in completely modifying the form of this apparatus and in rendering it much more accurate and practical. The new instrument (see figure) consists of a frame containing a circular



ABSOLUTE BAROMETER.

concavity in which all the apparatus are inclosed, thus dispensing with a metallic box, the appearance of which is not pleasing. The button at the top of the frame operates the index of the Centigrade thermometer. In order to make an observation, we move the index by means of this button and place its point opposite the liquid. After this, the lower index is moved, and a connection is made with the wire that moves with it opposite the extremity. It only remains to make a reading opposite the index needle which slides along with the wire.

The two other buttons, to the right and left, serve to fix the apparatus to the frame. These two buttons should be unscrewed in order to make the variable (760) agree with the altitude of the place, thus permitting of making an immediate observation. The plate on which are inscribed the words "very dry," "variable," and "stormy," is movable, and consequently the renewal of it is a simple matter.—*La Nature.*

[THE INLAND PRINTER.]

SOME TYPE WRITERS—THEIR ORIGIN AND USES.

By J. B. HULING.

AN invention of comparatively recent years, which met a demand doubtless existing for centuries, is the type writer. The use of language among human beings was followed by the creation of signs wherewith to record and preserve the expressed ideas. To spread written knowledge, copying by hand was resorted to, and, in the crudeness of characters and lack of system, it must have been infinitely more tedious than the same kind of work is to-day. To lighten the labor, and to hasten the completion thereof, became desirable. The earliest attempts in that direction are transmitted to us in the accounts of the ancient block-books, one page being a single block, the characters engraved on one surface. The gain there was something, but appreciated less as the world progressed and the craving for knowledge increased. The cutting of the blocks was both expensive and slow, and the genius of Gutenberg ultimately obviated the necessity for further pursuit of that art, when movable types were designed and employed. Thus was the birth of "the art preservative of all arts." We may conjecture that the need which the type writer now fills was really what was first recognized; but, most fortunately, it was not gratified in such a limited way, and, in consequence, the human race forever has the inestimable benefits of the typographic art.

A practical type writing machine seemed hardly possible before it was produced. It could not have come at any time without the invention of typography, for most of the necessary principles and devices are similar. Type writing is actually a new system of printing, and the experiments of years in one field saved relatively the same efforts in the other. To accomplish the invention of a type writer had not sufficient incentive to conquer the problems overcome in trying to perfect the art of printing. The close relation of one art to the other is illustrated by the fact that the first type writer to be received with favor by the public was a variation of a machine designed by printers, and being made for the purposes of their craft. Before doing more than to refer to this fact, however, let us go back, and see how the noble invention of Gutenberg, and the extension of its practice, obscured the old desire for rapid and legible occasional copies.

Inventive genius in the sixteenth and seventeenth centuries was not so active as it became afterward, but was steadily growing, under the stimulus given by the development of printing, and its liberalizing effects. The leading governments of that time were not so disposed to foster domestic inventions in the practical and useful arts as to encourage discovery and conquest in foreign lands. When there was less room for the latter, the former seemed to receive an impulse, and one of

the earliest results was in the field of our subject. There are no known records of any type writing device prior to 1714. The archives of the British patent office show the issue of a paper on January 7 of that year, beginning as follows:

"WHEREAS, our trusty and welbeloved subject, Henry Mill, hath, by his humble peticon, represented vnto vs, that he has, by his great study, paines, and expence, lately invented and brought to perfection 'An Artificial Machine or Method for the Impressing or Transcri bing of Letters Singly or Progressively one after another, as in Writing, whereby all Writings whatsoever may be Engrossed in Paper or Parchment so Neat and Exact as not be distinguished from Print; that the said Machine or Method may be of great Vse in Settlements and Publick Recors, the Impression being deeper and more lasting than any other Writing, and not to be Erased or Counterfeited without Manifest Discovery," etc.

Henry Mill was born in London about 1680. He had a liberal education, and early developed great skill in mechanics. While quite young he was chosen chief engineer for the New River Company, one of the oldest and largest corporations supplying London with water, his selection before older men being a recognition of his great genius. He also designed the system of water supply for the town of Northampton. He was with the New River Company till his death, at the advanced age of ninety years. The British patent office records a patent issued to Henry Mill in 1706, for a carriage spring. Any biographical information we can obtain only mentions his engineering achievements, and we can but inferentially conclude that he was the worthy inventor of the first type writing device. We cannot tell what was the particular form of his machine, for there was no drawing supplied, and the quotation contains the only description. There is every reason for believing that it was not thoroughly practical, and went the way of inventions of the same nature in the present day. The want of something to assist the blind to read was early felt, and, but for Mill's description, it might be imagined that his device was to that end, as were many afterward. In fact, the first instrument known to succeed Mill's anywhere was a French one, in 1784, to make embossed characters for the blind. It is not within the scope of this article, however, to more than mention anything but writing machines proper. In Great Britain, Mill had no recorded imitator until 1841. Then a patent was obtained for printing in connection with telegraphy, but the device was of small utility. Of such, also, there have been a number designed, and some are in successful operation; but we place them out of the class of inventions to be treated here. Several years later there was another patent in the direction of our subject, and since then they have been comparatively frequent. Strange to say, not one of the hundred or more original British patents up to the present time has been for a practical working machine of marketable value. Mill's countrymen to-day have to take the product of foreign minds.

American inventive talent was not awakened to the demand for a type writing machine, so far as any records show, before 1843. In that year Charles Thurber, then of Worcester, Massachusetts, secured a patent. Two years afterward he took out another. But his inventions did not possess the merits to recommend them to common adoption, and were put aside. They have been generally characterized as "slow and tedious, and good for nothing." Following this were other machines a few years apart, but only to be treated in the same way. The first device of any sort in the way of positive improvement was the invention of A. Ely Beach, now one of the proprietors and editors of the SCIENTIFIC AMERICAN, of New York. He secured a patent in 1856 for a machine to print raised letters for the blind. It is worthy of special mention, because it covered a principle which was pursued to success in the regular type writers, undoubtedly contributing more than any other feature to their early practicability and utilization. All the printing was designed to be at one point, the center of a circle, and the machine was planned with bars converging as the spokes of a wheel. In order to make the raised letters, there were to be two sets of bars, one coming up and the other falling, grasping a strip of paper between a male and female die, meeting at the common center.

Beach was followed by S. W. Francis, who was the first to really complete a type writer. His invention as a whole was so much in advance of everything known, and was so similar to those which first became generally acceptable, that we have made careful inquiry, and describe more in detail. The principle of the pianoforte action seems to have been taken as a basis for experimenting, and that construction modified for the new purpose. In his rearrangement he hit on the idea of arraying hammers, each with the face of a letter, in a circle, and throwing them up, as piano hammers act, but to print in a line at a common center. The mechanism, complete, in a fancy wooden case, stood within two feet square. The inking was by a silk ribbon several feet long, impregnated, passing under the paper and the impression point across and over the circle of hammers, which struck against the ribbon, pressing it upward, and leaving the impress of their faces in succession through on the paper. This ribbon was so adjusted as to move with each impression, and thus present a fresh inked spot to the next letter. There was a frame on the top of the printing apparatus to receive and hold paper, and it traveled from side to side over the type circle. The common center was at a point in a circular platen, upheld by suitable supports from the sides of the machine, being removable when it was desired to insert new paper. The frame was propelled by the unwinding of a coiled spring in a drum, round which was a cord connected with the frame. Another spring on the opposite side of the machine was connected by a cord, and had a device for releasing the frame to move but one space at a time, as an impression was struck. There was an alarm bell attached to the frame to sound four spaces from the end of a line, indicating to the operator if a word should be divided or completed. At the finish of a line, the frame was drawn back, rewinding the spring, and the paper was moved forward from the operator, by another action, to present a clear space for the next line. A blank key made the spaces between words. Two copies were printed at once by letting the inked ribbon run between a thick and a thin sheet of paper. There was a device to prevent several keys touched at once bringing up more than one hammer to the center, which was obviously necessary, as the interference of two bars with the incidental shock was injurious to the machine. There was but one instrument made under Francis' patent, and that printed clean and more rapidly than hand writing; but it seemed too bulky, was intricate and delicate in some of its parts, and could hardly stand practical use, nor could it be made at a cost to let it be sold to advantage. Dr. Francis was an eminent medical man of New York, was wealthy, and only made his invention as a diversion. If any efforts whatever were made to construct his type writer in quantities and sell them, we are not able to learn of them.

Fig. 1 is a plan of the printing action. K is a key connected with lever, L, from the upper part of which proceeds a wire, S, to the rocking pin, p'. Depressing the key actuates p' to draw away from the direction of

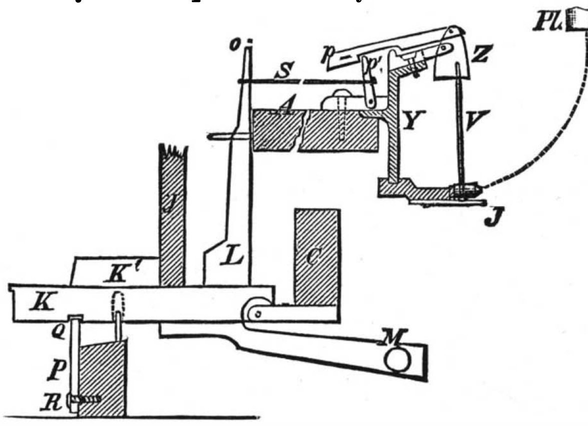
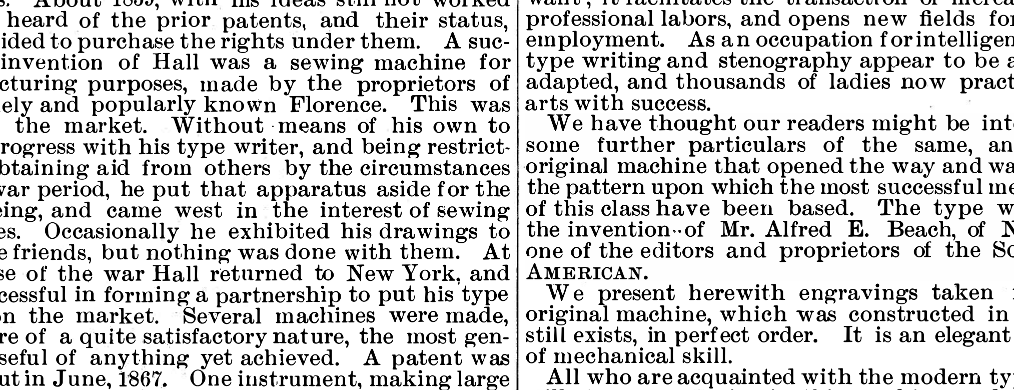


FIG. 1.

the type circle the bar, p, which it is easily seen causes the type hammer to follow the dotted line to the platen, Pl. M is a counterweight to be raised by the depression of the key, falling when that is relaxed, and causing the key and type hammer to return to their original stations. Touching the several keys in succession effected the printing.

Thomas Hall now of New York, was an inventor who had been experimenting with a type writing apparatus at the same time that Beach and Francis were working, but without any suspicion of them and their intentions. About 1859, with his ideas still not worked out, he heard of the prior patents, and their status, and decided to purchase the rights under them. A successful invention of Hall was a sewing machine for manufacturing purposes, made by the proprietors of the widely and popularly known Florence. This was then in the market. Without means of his own to make progress with his type writer, and being restricted in obtaining aid from others by the circumstances of the war period, he put that apparatus aside for the time being, and came west in the interest of sewing machines. Occasionally he exhibited his drawings to intimate friends, but nothing was done with them. At the close of the war Hall returned to New York, and was successful in forming a partnership to put his type writer on the market. Several machines were made, and were of a quite satisfactory nature, the most generally useful of anything yet achieved. A patent was taken out in June, 1867. One instrument, making large and small letters, with many miscellaneous characters, was sent to the Paris Exposition of that year. Another was shown by the inventor in the government departments at Washington, being greatly admired, and orders were given for duplicates. This machine was



THE HALL TYPE WRITER.

about eighteen inches square, and stood six inches high. It would print well about four hundred letters per minute. The paper was placed on a table, which was slid into the bottom of the machine on a frame working from side to side by an original device, and spacing for letters according to their thickness, giving the work a close appearance to letterpress printing—not a characteristic of every type writer, as will be seen. On return of the table to begin a fresh line, it was drawn forward by pressing a knob on the top of the machine, and clear paper was shown in the common center. The type faces were on hammers standing in a circle, and falling to the center as the corresponding keys were depressed in a keyboard on the top of the machine. Each hammer was on the end of an individual bar, the other end of which had a counterweight, peculiarly adjusted to facilitate the general action of the impression and recoil. An important feature was a cushioned ring suspended in the type circle, through which all the letters fell, and by which an even impression was preserved. A blank key made a space between words. The printing was through an inked ribbon. An attachment prevented two letters falling in conflict at the common center. It would successfully make manifold copies, by the insertion of either inked ribbon or carbon-faced sheets of paper to be printed on. This machine was apparently a perfect success, so far as regards the variety and character of its work, and the amount it would perform. It was of great interest to capitalists, and plans were laid for developing a trade in it, when a difference of opinion arose among the proprietors, and the machine was abandoned. Hall had exhausted his means, and contributed his best efforts. Although he could not utilize the ideas he had struggled so long and patiently to shape, he had seen their concentration, and had the benefit of many intelligent criticisms and expressions respecting the need of such an invention. He conceived that his machine as it then stood could be excelled in the variety of work it would execute, and the necessary expense of construction would require too high a retail price, confining the machine to limited circles. Something else only would become more popular, and he had already set himself to work to blend other ideas, or to find new ways to work out the established principles.

(To be continued.)

THE FIRST TYPE WRITING MACHINE.

WE commence on another page an interesting paper on type writers by Mr. J. B. Huling, written for the *Inland Printer*, in which brief mention is made of the Beach invention.

Although the production of type writing machines, as an industry, at the present time has reached large proportions and obtained permanent footing among the great manufactures of the day, still it may be said only to be in its infancy. The utility of the type writer is so great, its success so marked, its applications so numerous, that no prophetic vision is required to perceive that, ere long, it will become spread throughout the civilized world, like the clock and the sewing machine. The type writer supplies a great public want; it facilitates the transaction of mercantile and professional labors, and opens new fields for popular employment. As an occupation for intelligent women, type writing and stenography appear to be admirably adapted, and thousands of ladies now practice these arts with success.

We have thought our readers might be interested in some further particulars of the same, and in the original machine that opened the way and was, in fact, the pattern upon which the most successful mechanisms of this class have been based. The type writer was the invention of Mr. Alfred E. Beach, of New York, one of the editors and proprietors of the SCIENTIFIC AMERICAN.

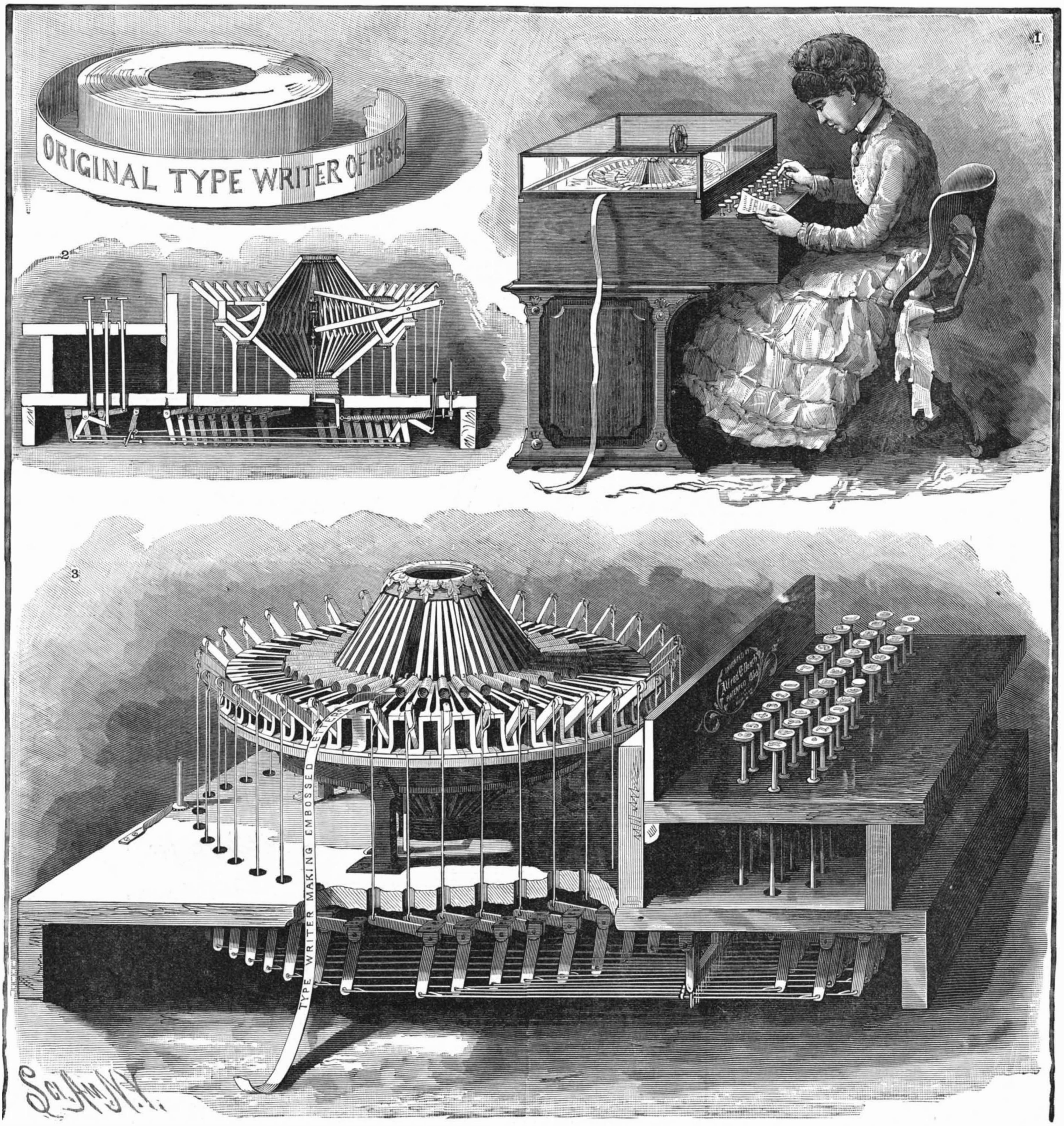
We present herewith engravings taken from the original machine, which was constructed in 1856, and still exists, in perfect order. It is an elegant specimen of mechanical skill.

All who are acquainted with the modern type writers will at once recognize in this machine, as here delineated, the underlying principle upon which they work, namely, the basket of type levers arranged on a circle, so as to strike or deliver their impressions on a common center, forming printed lines. The moment this system or principle was embodied in a working machine, the modern type writer became possible.

From that time onward the talents of good inventors were employed in adapting its form, perfecting details of construction and adding new improvements, until now the market is supplied with the most splendid machines, such as the Remington, by which printing from written copy or dictation is done almost as fast as one can speak; and thirty duplicates may be simultaneously printed. Besides the mechanism just named, there are on the market the Caligraph and other most excellent machines, working on the same principle. Moreover, there are various forms of type writers,

acting on different principles and doing good work, though perhaps lacking in speed or means for duplication.

The first example of a type writer was a model machine made by Mr. Beach in 1847. It printed upon a sheet of paper, supported on a roller, carried in a sliding frame, worked by ratchet and pawl, had a weight for running the frame, letter and line spacing keys, paper feeding device, line signal bell, and carbon tissue. It had a series of finger keys, connected with printing levers, which were arranged on a circle, and struck at a common point on the roller. This machine worked very well, but the quality of its printing did not satisfy the inventor's critical eye. So he laid it aside for improvement at a future time. Meanwhile, he constructed another form of the invention, namely, a type writer to print in raised letters, without ink. This is the machine illustrated in our engravings. It was first publicly exhibited in operation at the Crystal Palace Exhibition of the American Institute, in the fall of 1856, where it attracted great attention and took the highest prize—the gold medal—as one of the most novel exhibits of the occasion.



THE ORIGINAL TYPE WRITING MACHINE, FOR WHICH THE GOLD MEDAL OF THE AMERICAN INSTITUTE WAS AWARDED IN 1856.

Referring to our engraving, it will be seen the embossed letters are printed on a strip of paper, which runs centrally through the machine.

The printing levers are arranged in a circle, in pairs, one riding on the other. When the operator, Fig. 1, presses a letter key on the keyboard, a pair of printing levers, answering to the letter key, are brought together, the paper being between them. The printing types are at the extremities of the levers, one lever having a raised letter and its mate a sunken or intaglio letter. The construction and action of the machine will be readily understood by an examination of the engraving. The paper is drawn from a reel (seen in Fig. 1) by a ratchet wheel that feeds the paper on each up stroke of the printing levers.

Any desired change in the spacing of the letters is effected by turning the pin seen at the right, Fig. 2. Fig. 1 shows the machine as it appears in operation; Fig. 2, a central sectional elevation of the mechanism removed from its case. On the roll of paper above is shown the style of letter produced. Fig. 3 is a perspective of the machine removed from its case. This machine does elegant work, operates with great rapidity, and the alignment of the lettering is almost perfect. It is made in brass, and presents an ornamental appearance.

The patent drawings show both the single and double printing keys, for doing either ordinary ink or rubber printing or embossed letters; also the carbon ribbon, device for moving the same, a paper feeding device, with which all the keys are connected in common, whereby the paper is moved whenever any key is pressed.

The patent for this invention was granted June 24, 1856, expired and became public property in 1870.

THE STRENGTH OF FLY-WHEELS.

THE destructive failure of a fly-wheel not long since at Brymbo calls attention once more to the somewhat reckless fashion in which fly-wheels are worked. The bursting of a fly-wheel is usually due to a failure on the part of the governor to prevent undue acceleration of the engine. In the Brymbo case it appears that something went wrong with the throttle valve, and the engine ran away. A fruitful cause of such catastrophes is the breaking down of the gear by which the governor is driven. The governor ceases to revolve, the balls fall together, the throttle valve—or its equivalent—is thrown wide open, the engine races, and the fly-wheel bursts. To overcome this difficulty, the governor is sometimes so made that when it stops and the balls are in their lowest position, the throttle valve is closed. In order to start the engine, the throttle valve is disconnected from the governors. As soon as the engine has acquired its proper speed, the connection between the two is re-established. Fly-wheels, however, burst now and then without any failure on the part of the governors; and there can be no doubt that they are often run within an inch of their lives, especially in iron-works, where very many wheels are driven at a great pace in order that they may have momentum enough to overcome the resistance offered by the iron to the rolls. We propose to say here something on this subject which may serve to open the eyes of certain of our readers to the dangers which they incur.

The centrifugal force tending to burst a fly-wheel is very easily calculated. It operates in all cases radially, and can be resolved into a circumferential strain in more ways than one. That which we shall use in the following article is not that usually adopted, but it possesses, we think, several advantages. Assuming that the rim is symmetrical in cross section, then the circle of rotation will fall half way between the inside and outside of the rim. The centrifugal force will be found by multiplying together the radius of the wheel, its weight, the number of revolutions squared, and 0·00034. Let the weight of a wheel rim be 10 tons, or 22,400 lb., let the mean radius be 9 ft., and the revolu-

tions 70 per minute. A little calculation will serve to show that the cross section of the rim must be about 130 square inches. We are entirely neglecting the weight of the arms and boss. The action of centrifugal force will be precisely the same as that of steam tending to burst a boiler, because the steam acts radially, just as centrifugal force does. We may imagine the whole rim to be cut up into very small segments, and each held to the center by a wire. If any wire broke, the segment previously held in place by that wire would fly out. Instead of wires, the fly-wheel rim is held together by the cohesion of the segments. The wheel rim may be conceived as cut up into segments, each with a mean thickness of 1 in., and weighing about 33 lb. The centrifugal force will then be $9 \times 33 \times 70^2 \times 0.00034 =$, omitting fractions, 495 lb. That is to say, if each segment were held to the shaft by a wire, the strain on that wire would be 495 lb. Let us suppose that our fly-wheel is 12 in. wide by 10·8 in. thick, then the conditions will be precisely the same as that of a boiler with a shell 18 ft. in diameter and 10·8 in. thick submitted to a pressure of $\frac{495}{12} = 41$ lb. in round numbers per square inch.

Now it may be worth while here to explain that in calculating the strength of a boiler, it is right to regard it as composed of halves, and to calculate the bursting strain on each in terms, not of the semi-circumference, but of the semi-diameter. For a mathematical demonstration of the truth of this proposition, we may refer our readers to Wilson on "Steam Boilers," Chapter II.

In the case of our fly-wheel, then, we have a rending pressure of 41 lb. per square inch exerted over a surface equal in width to the breadth of the fly-wheel rim, and in length to the diameter of the wheel. The first dimension is 12 in.; the second is $12 \times 18 = 216$, and $216 \times 12 \times 41 = 106,272$ lb. But there are two sections of the rim to sustain this, because, before the wheel could be fairly broken in two, the rim must be torn asunder in two places. Therefore, the rending strain on any section of the rim will be half 106,272 lb., or 53,136 lb. As the section is 130 square inches, then the strain will be $\frac{53,136}{130} = 409$ lb. nearly. As two tons per inch is considered to be sufficient tensile stress to be put on cast iron, it will be seen that our fly-wheel has a considerable margin of safety. As the centrifugal force increases as the square of the velocity, if the number of revolutions was doubled, becoming 140 instead of 70, stress would reach 1,636 lb. If the speed reached 280 revolutions, the stress would be 6,544 lb. on the square inch, or considerably beyond the limit of safety. We have entirely neglected the assistance which the arms give, and properly so. The arms, by setting up initial strains in cooling, are often a direct source of weakness instead of strength. A fly-wheel must depend for strength on its rim, and if this is not ample, then the wheel is unsafe. When it is borne in mind that the rims, especially of large wheels, are usually cast out of very common, cheap iron, that they may be full of blowholes, and that the cross section is sometimes made up of mouldings and fillets of very variable thickness, it becomes obvious that a large factor of safety ought to be always allowed.

We once heard it urged that if a wheel of one section was too weak, it was easy to improve it by adding on to the pattern, so as to put more metal in the rim. This is a mistake into which founders sometimes fall. It is enough, however, to mention the error to correct it. The bursting strain is a function of the weight of the rim, and any addition to the cross section must augment the weight, and therefore the stress, in just the same proportion. A wheel may be strengthened by casting it as a disk, great care being taken, however, that it is cooled very slowly and equably to prevent contraction, strains being set up which will sometimes burst such a wheel when it is put in the lathe to be bored. A far better plan is to hoop it with wrought iron or steel. We augment the section in this way, it is true, but with a metal about three times as strong as cast iron. Such expedients, however, are only applicable to small fly-wheels, such as those fitted to plowing and traction engines, which are sometimes run at dangerously high speeds. It is easily shown that there is a certain velocity of rim which must not be exceeded. Thus, for example, the wheel which we have cited has a circumference of 56·5 ft., and makes seventy revolutions per minute, or 66 ft. per second very nearly. At this the wheel is quite safe. If the diameter were halved, then the number of revolutions might be doubled and the wheel would still be safe, because the velocity of the rim would remain 66 ft. per second. A speed of 80 ft. per second is generally regarded as about the highest at which it is safe to run a fly-wheel, but this velocity is often exceeded in rolling mills. We have said nothing concerning the method to be adopted in securing the halves of a wheel to each other, such as by dowels and cotters, or hoops shrunk on, or bolts and nuts. It is not necessary to do more than call attention to the necessity which exists for making these very strong. It must not be forgotten that when heavy wheels, such as those used in sheet mills, sometimes weighing as much as 60 tons, are used, there is a very great strain brought on the bolts, etc., by the weight of that half of the wheel which happens to be below the shaft, in addition to the stress caused by centrifugal force. One case is mentioned in which just after an engine had been started, before more than a revolution had been made, half the wheel dropped into the pit, while the other half, turning over, fell with a crash on the crank and connecting-rod and so smashed up the engine. Several cases are on record in which wheels have gone to pieces entirely through the failure of the cotters in the dowels. A fly-wheel is now and then looked on as a very unscientific and simple piece of work, but its proper construction and use demand something more than a superficial acquaintance with certain natural laws, and ignorance or neglect of these laws may result in loss of life and serious destruction of valuable property.—*The Engineer.*

It is the production of seed that exhausts the vital powers of a plant; an annual becomes a perennial when not allowed to seed.

THE SS. NULLI SECUNDA.

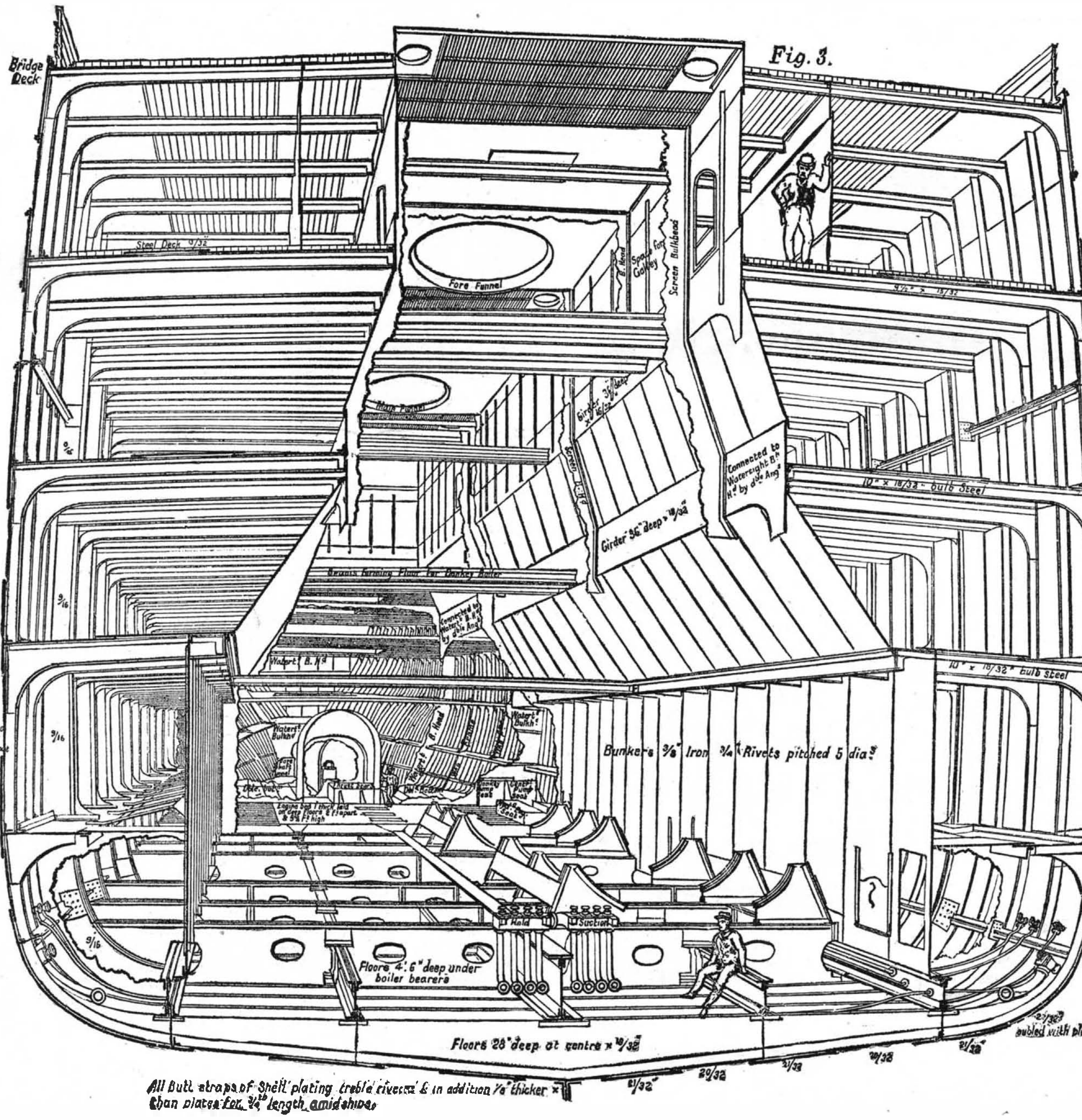
At the recent Liverpool Exhibition, Messrs. William Doxford & Sons, of Sunderland, exhibited a full model, on a large scale, of their new steel screw steamer Nulli Secunda, which claimed considerable attention and favorable comment for its general design and finish. This vessel is the largest cargo steamer yet built, and an account of her economic working and general facilities deserves special notice. We give a perspective view of the vessel, prepared from a water color drawing which the builders also exhibited at Liverpool, also a longitudinal section and plan, a cross section, with illustrations showing the triple expansion engines and boilers with which the vessel has been fitted, her machinery having been constructed by Messrs. William Doxford & Co.

The Nulli Secunda is 440 ft. over all, 48 ft. beam, and 32½ ft. hold, and has a gross register of about 5600 tons. She has two steel decks, fore and aft, the upper one being sheathed, and also a third deck of pine, and in the fore hold a fourth deck is laid, so that as the vessel is further subdivided by the water-tight bulkheads (seven of which are fitted), there is ample subdivision of cargo. It will also be seen, by reference to the plan, that the capacity of each of these holds is practically the same, and to each is fitted a large hatchway and two patent swinging hydraulic cranes. The midship hold being further subdivided by the ballast tank there is a third crane fitted to it, so that giving one man to each crane, and laborers in each side of each hold to supply the cranes, the whole cargo will be discharged with the greatest facility and in about the same time from all the holds.

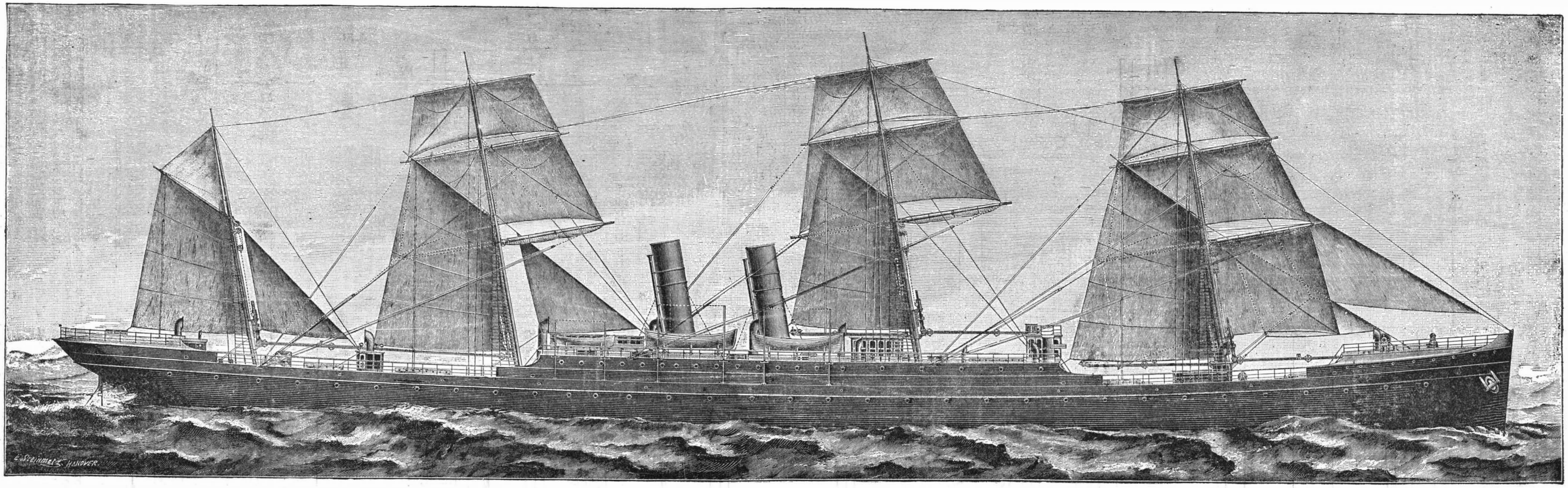
The 'tween decks of the vessel are exceptionally high, being 8 ft. 6 in., giving a most roomy space for passengers, cattle, or troops, any of which the vessel can be readily fitted for, and of which she will carry a large number. The ventilation is worthy of particular note, as it is entirely permanent, the air shafts being built 7 ft. above deck, and carried down the bulkheads, and made of $\frac{5}{16}$ iron, so that there is no need to close them up in bad weather, or to fear the crushing in of tubes in the holds.

The vessel is capable of lifting a deadweight cargo of 6500 tons on a draught of 26 ft. 3 in., or 7000 tons on 27 ft. 6 in., and her engines are capable of driving her 12 knots loaded on a consumption of little over 50 tons per day, or 14 knots should the vessel be fitted as a passenger boat. This most desirable result is attained by the vessel having a fairly fine entrance and a good, clear run, giving her easy steaming lines. While being built entirely of steel, the weight of the hull is considerably below that of an iron vessel, although she has considerable extra strengthening, as detailed further on.

The Nulli Secunda is spar decked, with a bridge amidships, hood and steering house aft, and top-gallant forecastle forward. She is rigged as a four-masted bark, with pole masts and square sails, the topmasts being telescoped into the lower masts. There are ten additional pairs of web frames fitted in holds from floors to spar deck, while the spar deck sheer strake is



CROSS SECTION OF THE STEAMER NULLI SECUNDA.



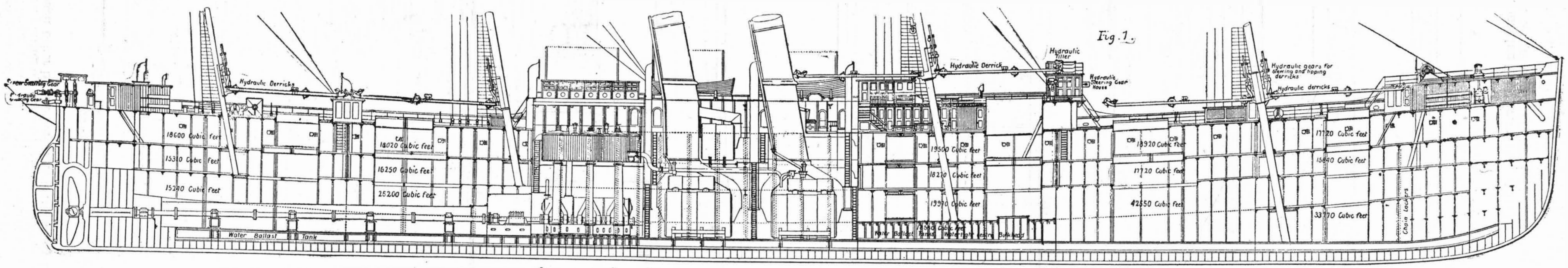


Fig. 1.
Hydraulic Derricks
Hydraulic Derrick
Hydraulic Tiller
Hydraulic Steering Gear House
Hydraulic gears for slewing and hoping derricks
Hydraulic derricks
18600 Cubic feet
15310 Cubic feet
15280 Cubic feet
18020 Cubic feet
16250 Cubic feet
25200 Cubic feet
19500 Cubic feet
18270 Cubic feet
19970 Cubic feet
13920 Cubic feet
17720 Cubic feet
42550 Cubic feet
17720 Cubic feet
15640 Cubic feet
33770 Cubic feet
Chain Lockers
Water Ballast Tank

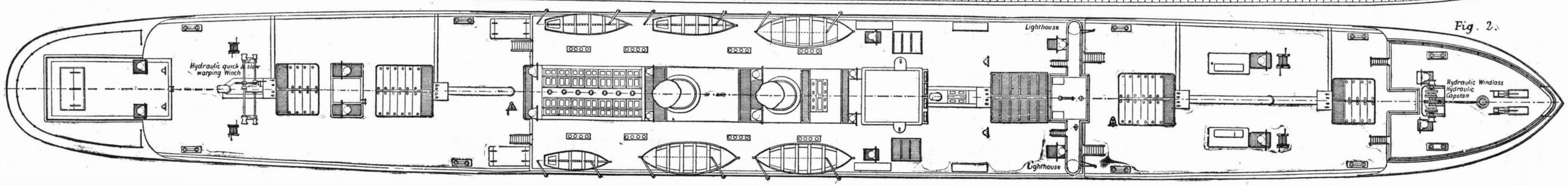


Fig. 2.
Hydraulic quick & slow warping Winch
Lighthouse
Lighthouse
Hydraulic Windlass
Hydraulic Capstan

stronger than usual, being not only increased in thickness, but also doubled, making a total thickness of $1\frac{3}{8}$ in. The whole of the shell plating is treble riveted all fore and aft, the straps for three-fourths of the length amidships being $\frac{1}{8}$ in. thicker than the plates. The bilge is double plated, the reverse bars all extend to spar deck, and the vessel is double framed at after end. at each side of the openings, extending from the after engine room bulkhead to the fore boiler room bulkhead, to which these girders are connected by large knees and double angles. The girders are all formed of steel plates, which, in addition to being firmly riveted to beams, are connected to the deck plating by fore and aft angles, and are connected to each other by the ver- The fore peak may also be used for trimming purposes. The tunnel, 7 ft. high and $5\frac{1}{2}$ ft. wide, has its entrance from the engine room guarded by a water-tight door, the thrust recess being open to engine room.

The whole of the vessel is entirely constructed of Siemens-Martin steel, bunker, deck-houses, and such like fittings only being built of iron.

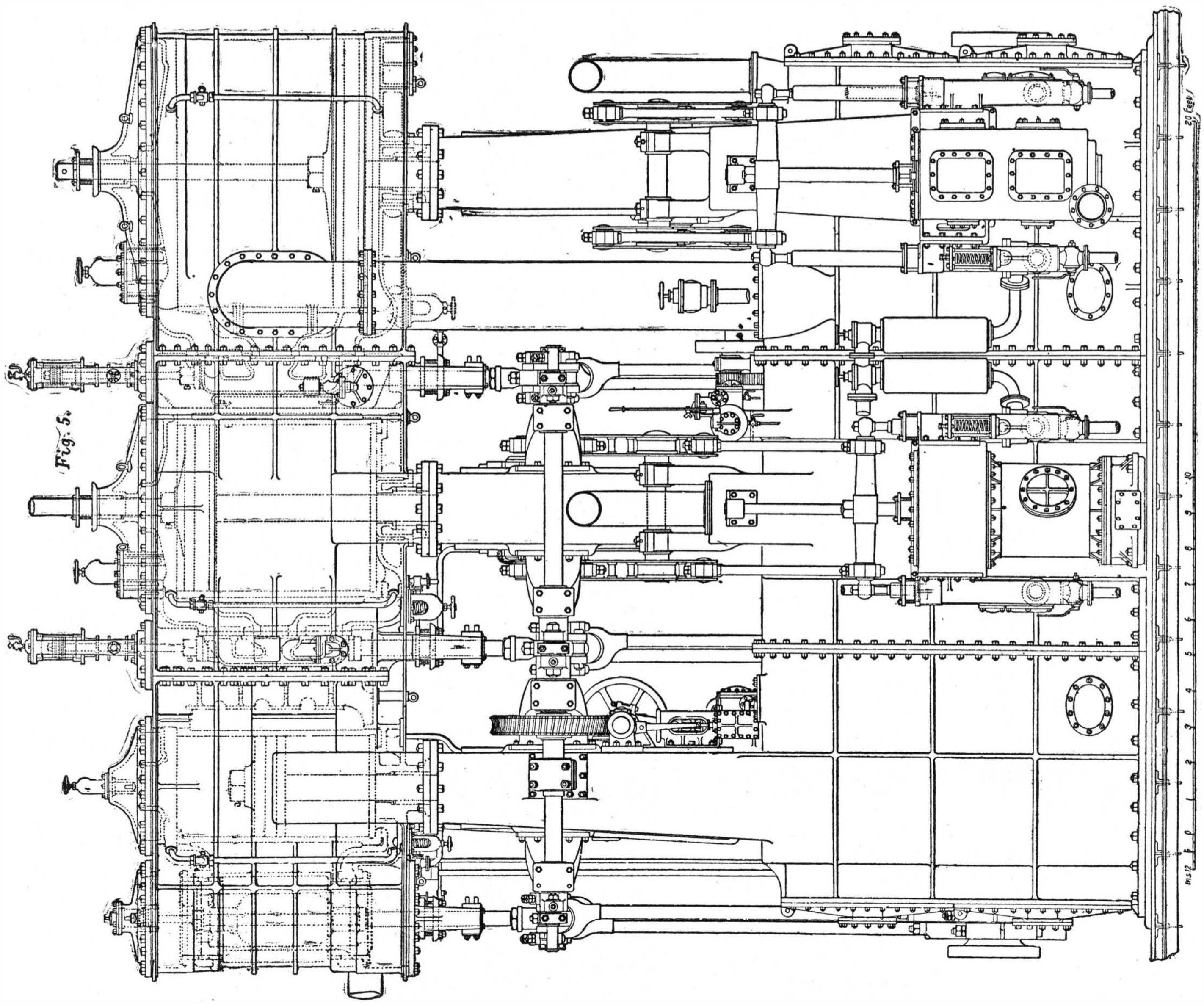


Fig. 5.

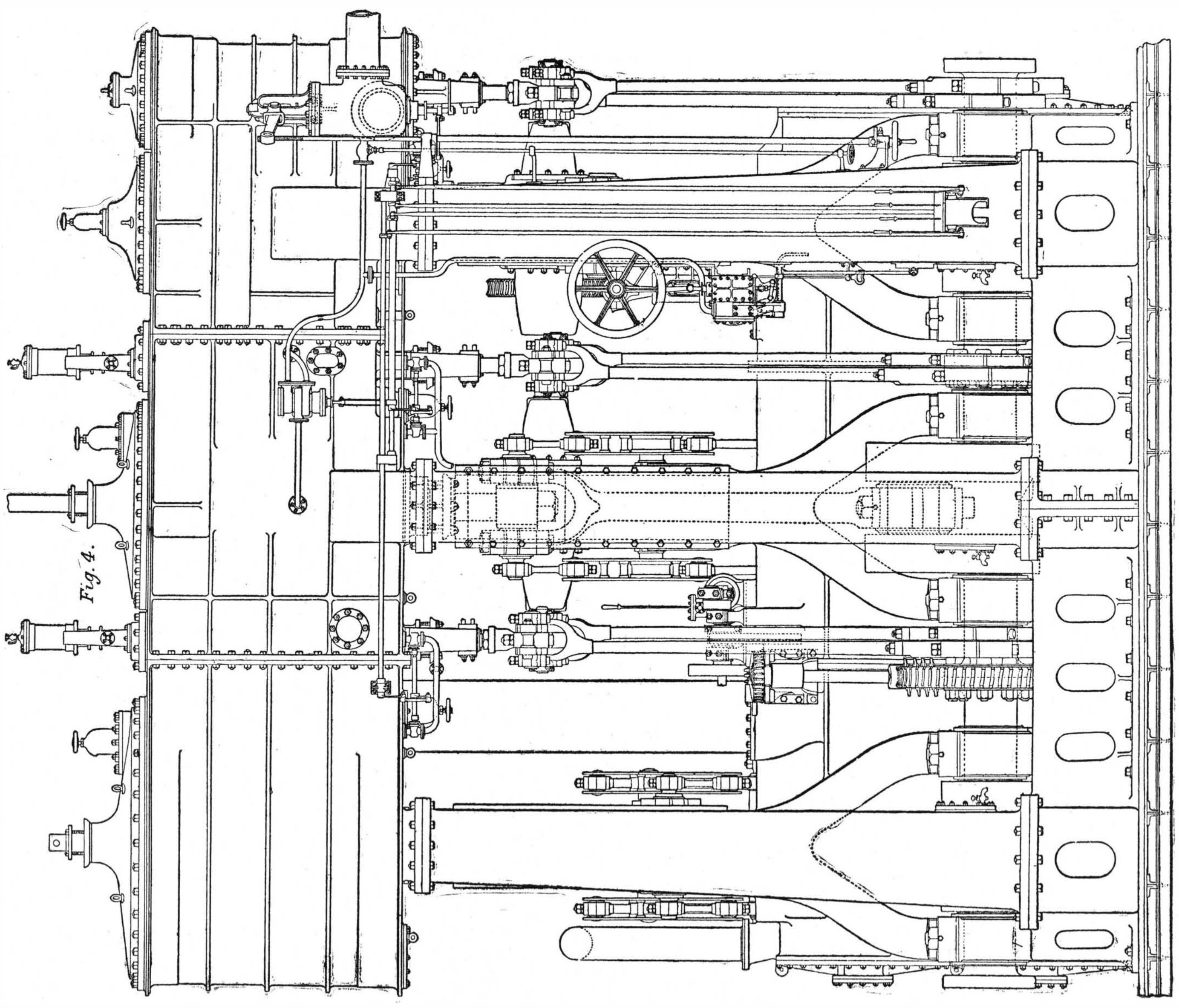


Fig. 4.

TRIPLE EXPANSION ENGINES OF THE STEAMER NULLI SECUNDA.

Both stern and bow plates are doubled up to spar deck, and a double strake of deck plating runs along each side of hatches all fore and aft, and we may here mention that the entire ship is riveted with steel rivets. The spar deck stringer is 58 in. wide and doubled, making a total thickness of $\frac{7}{8}$ in. The main deck stringer plates are 60 in. wide by $\frac{18}{32}$ in. thick.

On the bridge, spar, and main deck, in engine and boiler room, there is fitted a strong longitudinal girder tical casting and bunker plates, making in all an extra strong continuous girder the full length of the engine and boiler space.

The vessel has a double bottom aft, capable of containing 240 tons of water ballast. The deep tank amidships, containing about 660 tons, is kept as low as possible consistent with the getting in of merchandise, when it is required to be used for such ; it is divided at the center line by a fore and aft water-tight bulkhead.

A hydraulic steering gear fitted in the after wheelhouse is actuated by an oak tiller on valves in the midship steering-house ; also by an oak tiller on brass column on the flying bridge. The hydraulic winch placed in front of the jigger mast has a slow purchase of 8 tons and quick purchase of 2 tons, the slack of the rope being taken in by the 2 ton purchase on the small drum, while the rope runs loose on the heavy power drum ; when required to put the heavy purchase on to

the rope, it is only necessary to throw a clutch into gear without stopping the winch. The windless and capstan are driven together or separately by a 50 horse power hydraulic engine inside the forecastle, a 3 ton purchase for warping being given on the windlass end.

Hydraulic derricks, eleven in number, are fitted on the masts, each hatch having two derricks (one swinging to either side of vessel) except the small hatches on bridge, which has only one derrick to swing to both sides. These derricks are actuated by valve levers placed at hatch coamings, and connected to the derricks by pressure and exhaust pipes. The derricks are fitted with hoisting sling, giving lift of 60 ft., and also with swinging cylinder, which swings the derrick over the ship's side, and at the same operation lowers the head of the derrick so that the cargo is discharged clear over the side. The derricks are fitted with cast steel bedplates, curved to shape and fitted to masts, and they are connected to mastheads by steel wire ropes, running on large sheaves fitted with brass bushes and steel turned pins. Three ash hoists are provided, one to each stokehole; these are also worked by hydraulic power. Pumping engines for driving all the hydraulic gear just mentioned are placed in the engine room on the port side, and consist of a pair of compound, surface-condensing, automatic, 100 horse power engines, working with a steam pressure of 150 lb. per square inch, and having cylinders 12 in. and $20\frac{1}{2}$ in. in diameter, with stroke of 20 in. These engines are fitted with steam accumulator, and are capable of driving all the cranes at full working power at once. The engines are entirely automatic in their action, only pumping the amount of water required according to the number and rate of cranes working. The whole of this hydraulic gear and pumping engines were constructed by Messrs. Brown Brothers & Co., of Edinburgh. The auxiliary boiler is of the multitubular type, and is of large size, with two furnaces; it has a working pressure of 150 lb.

The ventilation of holds and 'tween decks is accomplished by two downcast and two upcast ventilators to each hold, arranged as we have already mentioned, so that they can be safely left open in the heaviest weather, the air gratings being from 7 ft. to $8\frac{1}{2}$ ft. above the spar deck. Each ventilator admits a column of air 12 square feet in area, there being thus an area of 24 square feet downcast and 24 square feet upcast to each hold; this column of air is subdivided by inner tubes for lower 'tween decks and holds, the larger portion of air going to the 'tween decks for perfect ventilation should emigrants or troops be carried there.

As few doors as possible are permitted through the water-tight bulkheads, for, however well they may work, they are always a source of danger in a sudden emergency; the only places where water-tight doors are fitted are at the entrance to the tunnel and in the upper 'tween deck; these latter doors will rarely be open, for, when emigrants are carried in the 'tween decks, the different sections will be divided by these bulkheads, making it unnecessary to have the doors in use.

A very good idea of the proportions of this vessel, also the arrangements for strength, both in hull and engine and boiler space, is given by the perspective cross section, published by us on page 9164. This represents the vessel cut through at the fore end of forward stokehole, and viewed at a distance of 50 ft. away, 14 ft. to starboard side and 15 ft. above the keel, the various bulkheads which would otherwise obstruct the view being broken away, and also the starboard boiler seats, to allow of the engine bed being seen.

The engines of the Nulli Secunda, of which we publish engravings this week, are designed to indicate and are called by the builders 4,000 horse power. They are of the triple expansion type, and the high pressure, intermediate, and low pressure cylinders are respectively 34 in., 56 in., and 90 in. in diameter, the stroke of each being 60 in.

The sole plate, which is composed of two castings bolted together in the center line athwartships, provides six bearings for the crankshaft; it is of the "box" type, and extends under the whole of the engines, carrying the condenser and columns on its upper surface.

The crankshaft is in three duplicate and interchangeable pieces; the main bearings are $17\frac{1}{2}$ in. in diameter and $17\frac{1}{2}$ in. long, the crankpins being of the same diameter, and $17\frac{3}{4}$ in. long. The turning wheel, it will be noticed, is fitted on one of the center couplings of the crankshaft, and the turning gear is of the double worm type, the auxiliary wormshaft being driven by an independent engine having a cylinder 8 in. in diameter and 8 in. stroke, and which is capable of turning the main engine one complete revolution in seven minutes.

The connecting rods, which have 11 ft. 3 in. centers, and are therefore $4\frac{1}{2}$ cranks long, are fitted with adjustable brasses on each jaw at the top end double eyes. The gudgeons are forged solid on the crossheads, while the latter are fitted to the tapered bottom ends of the piston rods and secured by nuts. This arrangement is adopted because of the facility which it affords, as compared with the very common plan of having the crossheads forged solid on the piston rods, for overhauling the top end brasses. When these are made so that, along with their cap, they lie between the jaws of the solid double eyes on the connecting rod, there is no doubt considerable difficulty in getting at them; and when it is difficult to overhaul any part of an engine, there is always fair reason for assuming that that part is more or less neglected or inefficient. The arrangement adopted has the further advantage that the piston rod can be taken out and tried in the lathe, if there is any suspicion of its being bent through accident, without it being necessary to remove the piston from the rod, always an undesirable and often a troublesome operation. The main bearings, the bottom ends of connecting rods, the crosshead shoes, and the tunnel shafting are all fitted with Parson's white metal.

Passing next to the valve gear, the eccentric straps are of cast steel, lined with brass, and all the pins work in adjustable brasses. The valve spindle eyes are in each case separate from the spindles themselves, which are screwed into them, so as to allow of the slide valve and spindle being lifted out of their places without the necessity of taking down the remaining portion of the valve gear.

The eccentric rods, as well as the drag links, are made of a circular section, which the makers consider a stiffer form than the flat bar section. The reversing links are of the double bar type, with the eccentric rod and drag link pieces forged on them.

The sliding blocks, the slide spindle eyes, and the slide spindle guides are made adjustable. The reversing gear is of the "all-around" type, the weigh shaft being turned by a wormwheel and worm, the shaft on which the latter is fitted being a continuation of the reversing donkey crankshaft. This arrangement has the advantage of doing away with all stops and buffers necessary to the direct-acting type, and prevents the possibility of overrunning. The reversing donkey is a double-cylindered engine, each cylinder having a diameter of 8 in. and a stroke of 8 in. When the reversing donkey is running at its proper speed, the operation of reversing from full speed ahead to full speed astern can be easily performed in twenty seconds. The arrangement of the starting, drain, and regulator gears is clearly shown by our engravings, and needs no comment. All the handles are placed so as to be worked from the starting platform on the starboard side of the vessel.

Each of the main cylinders has a double bottom, and the high pressure and intermediate cylinders have separate hard cast-iron liners. All three cylinders have separate hard cast-iron valve faces. Particular care has been taken to arrange the passages, as well as the relief valves, so as to keep the cylinders and parts clear of water.

The intermediate and low pressure slide valves are of the ordinary double-ported type, while the high pressure cylinder is fitted with a piston valve. The regulator valve chest contains both a diaphragm valve, worked by the governor and by hand, and also a stop valve. The latter consists of a small central valve forming part of the spindle, which first rises with the spindle, and a large annular valve, which is thus thrown partially into equilibrium, and is lifted by the spindle as soon as the small valve has risen to its full lift.

The surface condenser consists of three principal castings, and has the columns for supporting the cylinders on the port side, cast on it. The tubes are arranged in two sets or nests, an upper and a lower, the circulating water passing first through the latter and then through the former before going overboard.

The air and circulating pumps are attached to the back of the condenser, the air pump being driven by levers, etc., from the intermediate crosshead, and the circulating pump driven in a similar manner by the low pressure crosshead. There is also a separate 7 in. centrifugal pump, to act as an auxiliary circulating pump, and also for pumping out tanks and bilges. The circulating pump, which is driven by the main engines, is double-acting, and is fitted with a 6 in. easing valve, for use in heavy weather; it and the auxiliary pump both draw from the sea, and force the water through the tubes.

The air pump is of the ordinary single-acting bucket type, and is arranged so as to work the condenser as a common jet condenser, the center column then forming an air vessel for the pump. It will be noticed that all valves, both in the air and circulating pumps, are thoroughly accessible. The bucket and foot valves of the air pump are got at through a 15 in. manhole in the side of the brass barrel.

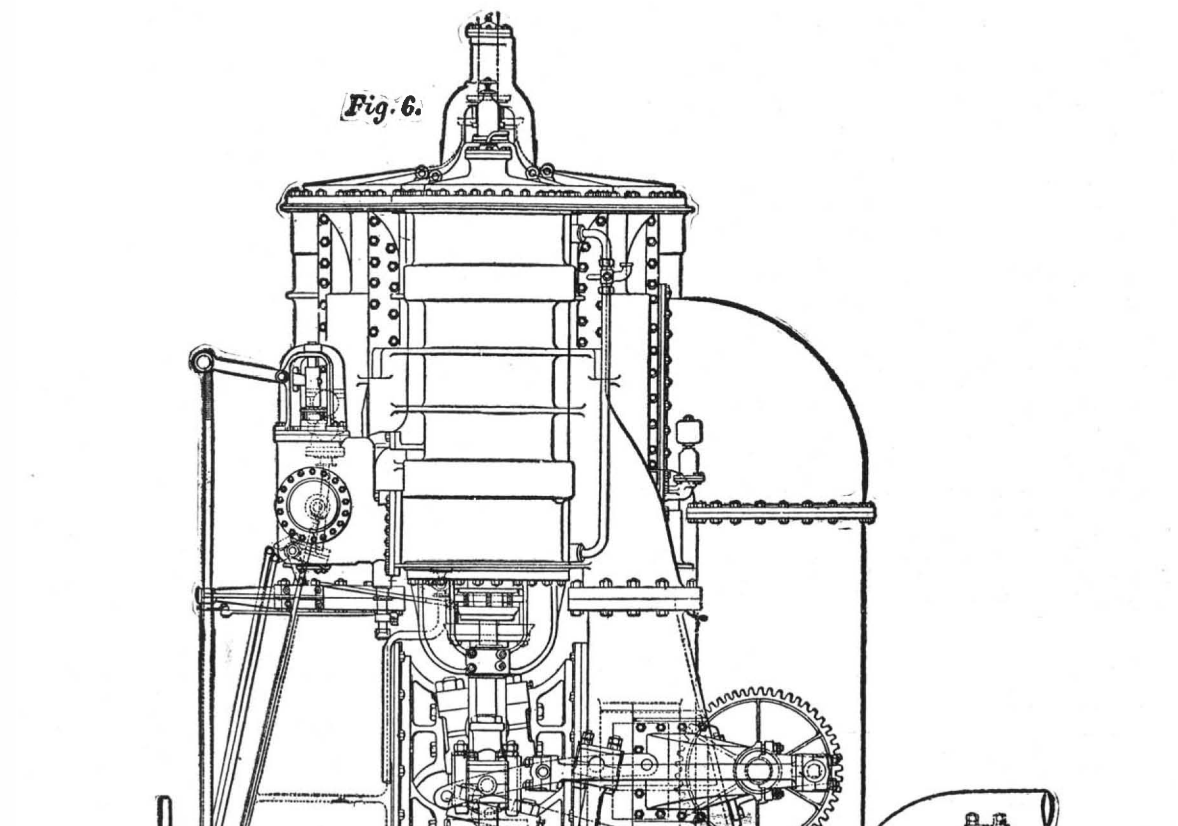
The condenser contains 1,074 tubes, 1 in. in diameter, which have a collective cooling surface of 6,045 square feet. The condenser is well provided with sightholes, manholes, mudholes, etc., both in its upper and lower portions, so that its condition can be at all times seen. The tube plates are of rolled brass $1\frac{1}{8}$ in. thick.

The boilers are shown by our engravings. Each boiler contains four Fox's corrugated furnaces, two at each end, 4 ft. external diameter, each having a separate combustion chamber. Each boiler contains 280 $3\frac{1}{2}$ in. tubes, No. 8 B. W. G. thick, and 108 stay tubes of the same diameter, and varying in thickness from $\frac{1}{4}$ in. to $\frac{3}{8}$ in., the distance between tube plates being 6 ft. 3 in.

The shells of the boilers are $1\frac{3}{32}$ in. thick, the front tube plates $\frac{3}{4}$ in., and the back tube plates $\frac{3}{4}$ in. thick. The working pressure is 150 lb. per square inch, and the boilers are arranged in the ship as shown by our engravings, each with a separate steam receiver.

The propeller is of the four loose-bladed type. Its leading dimensions are included in the list of chief dimensions of the machinery given below:

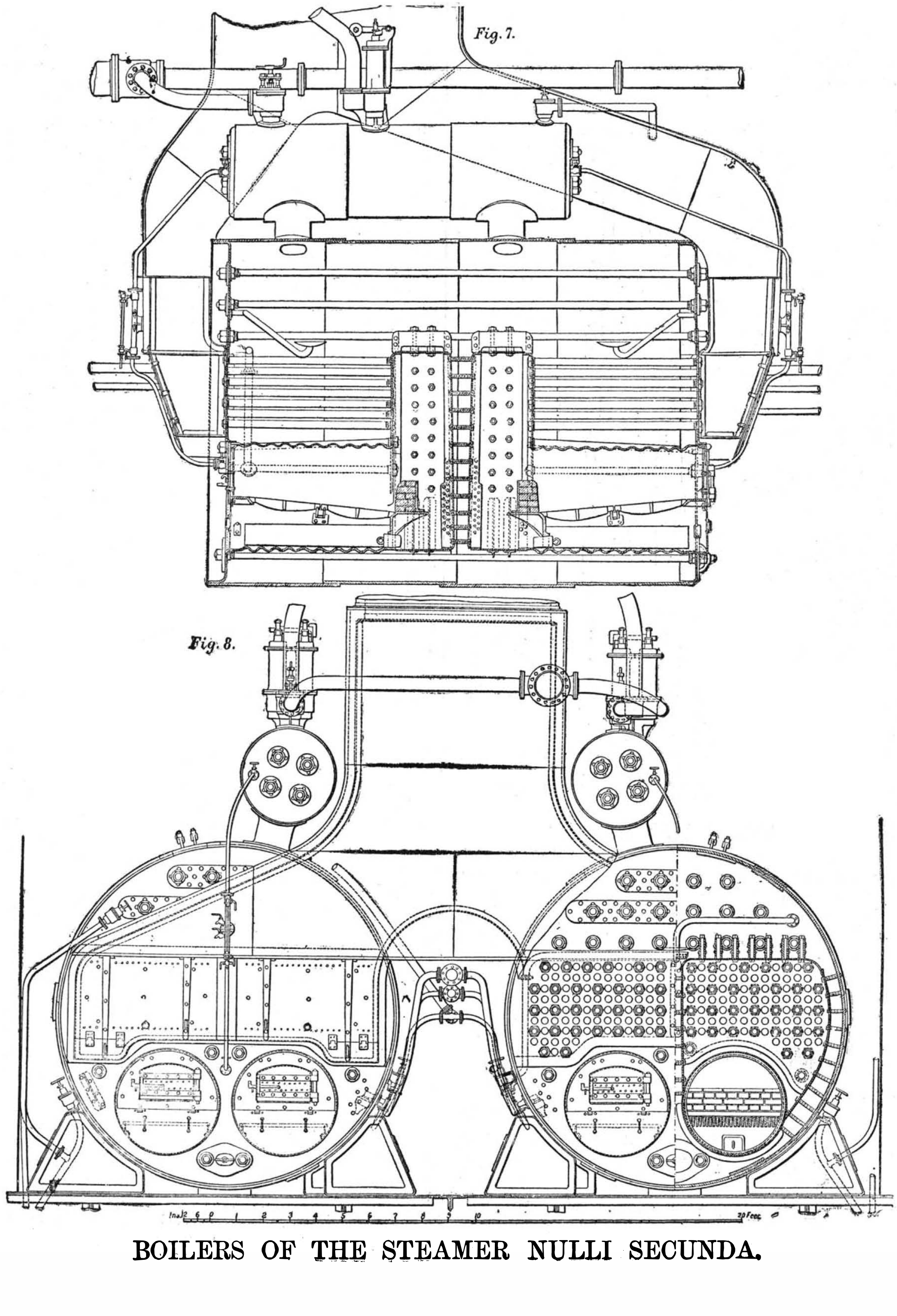
Diameters of cylinders	34 in., 56 in., and 90 in.
Length of stroke	60 in.
Diameter of piston rods	9 "
" tail rods	$5\frac{1}{4}$ "



TRIPLE EXPANSION ENGINES OF THE STEAMER NULLI SECUNDA.

Thickness of H. P. liner		2 in.
" I. P. "		1⅞ "
Diameter of connecting rods		10½ in. to 9 in.
" top gudgeon (two on each rod)		8 in.
Length of top gudgeon		9 "
Diameter of connecting-rod bolts, top end		4 "
Diameter of connecting-rod bolts, bottom end		4¾ "
Diameter of main bearing bolts		4¾ "
" crankshaft and crank-pin bearings		17½ "
Length of main bearing		17½ "
" crank-pin		17¾ "
Diameter of slide spindles		4¾ "
Travel of valves, H. P.		8 "
" " I. P.		7 "
" " L. P.		9 "
Ratio of area valve openings to cylinder area, H. P.	top	1 to 11·287
	bottom	1 " 9·782
Ratio of area valve openings to cylinder area, I. P.	top	1 " 19·923
	bottom	1 " 16·97
Ratio of area valve openings to cylinder area, L. P.	top	1 " 23·793
	bottom	1 " 19·935
Diameter of air pump		30 in.
" circulating pump		18 "
" feed and bilge pumps		5 "
Stroke of all pumps		39 "
Diameter of circulating pump suction		9 "
Diameter of circulating pump discharge		11 "
Diameter of condenser tubes		1 "
Number " "		1,074
Effective length of condenser tubes		21 ft. 6 in.
Condensing surface		6,045 sq. ft.
Length of boilers		17 ft. 9 in.
Diameter of boilers		12 ft. 9 in. mean.
" furnaces		3 ft. 10 in. "
Total grate surface with 5 ft. 6 in. bars		334 sq. ft.
Total heating surface		11,378 "
Ratio of grate surface to heating surface		1 to 34
Steam space		2,508 cu. ft.
Size of each funnel		8 ft. 6 in. by 7 ft.
Diameter of propeller		18 ft. 10 in.
Pitch " "		23 ft.
Surface of blades		100 sq. ft.

—*Engineering.*



BOILERS OF THE STEAMER NULLI SECUNDA.

CONCRETE IN HARBOR WORK.

AT the ordinary meeting of the Institution of Civil Engineers, London, on Tuesday, November 16, six papers were read on "Concrete as applied in the Construction of Harbors," at Greenock, Girvan, and Quebec; Colombo; Newhaven; Wicklow; Fraserburgh, Sandhaven, and Portsoy; and Lowestoft; by Messrs. Kinipple, Kyle, Carey, Strype, Willet, and Langley, MM. Inst. C. E.

Mr. Kinipple, in his paper on "Concrete Work under Water," described the methods he adopted for depositing partially set or plastic concrete under water at various harbor works, having found that plastic concrete, when sufficiently set to resist the action of a current of water, was capable of uniting into a solid mass under water, though deposited in separate lumps. At Greenock, the concrete was deposited behind sheet piling, in depths of from 8 ft. to 38 ft. At Girvan, a pier and quay wall were constructed of plastic concrete, deposited behind a facing of small dovetailed concrete blocks grouted together at the joints; and a concrete groin was formed under the shelter of a movable wrought-iron shield. The head of the Wick pier was rebuilt with blocks of plastic concrete of 60 to 140 tons, formed *in situ* under the protection of sailcloth. Quay walls were constructed at Quebec Harbor of cribwork filled with plastic concrete, the cribs being floated into position and sunk on bearing piles. Some experiments showed that cement grout, poured down pipes, could unite shingle, 20 ft. under water, into a solid mass; and this method was successfully adopted for filling up the fissures and open joints in a graving dock at Greenock which had given great trouble with leakages. The paper concluded by descriptions of novel expedients which the author proposed for the construction of breakwaters in concrete with little plant, and independently of the state of the weather.

Mr. Kyle, in his paper on the "Colombo Harbor Works, Ceylon," described the various stages by which the western breakwater, 4,212 ft. in length, was constructed, from Custom House Point, for sheltering a water area of 502 acres at low water. The works were commenced in 1874 and completed in 1885, at a total cost of 705,207*l.* The breakwater was formed by laying sloping courses of large concrete blocks, by means of a traveling titan, on a rubble mound previously deposited from an 80-ton steam hopper-barge and leveled by divers. The titan could carry a load of 40 tons on an overhang of 28 ft., and cost 5,562*l.* The first 1,326 ft. of pier, 50 ft. wide, consisted of two walls with an intermediate hearting of rubble; but the rest of the pier was built solid, 34 ft. in width, with four or five courses of blocks, weighing from 16½ to 31 tons each. The foundation of the pier increased in depth from 13 ft. below low water, near the land, to 23½ ft. at the head. Each row of sloping blocks was connected with the adjacent ones by filling the joggle grooves, left between each row, with concrete in bags; and the pier was capped all along the top with concrete in mass. The pierhead was built of concrete in mass, the lower portion being deposited inside a circular wrought-iron tank; and it was surmounted by a concrete lighthouse 36½ ft. high. Twenty-five steamers of the largest class could moor in depths of from 26 ft. to 40 ft. in the harbor; and there was room, at low water, for a large number of vessels drawing from 6 ft. to 26 ft. The works were designed by Sir John Coode, vice-president Inst. C. E., and carried out by the author.

Mr. Carey commenced his paper on "Harbor Improvements at Newhaven, Sussex," by a history of the successive improvements effected from 1767 down to the commencement of the new works, begun in 1878. These new works, of which he was the resident engineer, and Mr. Banister, M. Inst. C. E., the engineer-in-chief, consisted of a curved breakwater, 2,800 ft. long, to form an outer harbor, and to protect the entrance to the river, constituting the old harbor; the rebuilding of the entrance piers, and widening the water-way between them; the erection of a new quay on the eastern side of the river; the construction of a sea-wall along the shore; and dredging in the river and the approach channel in the outer harbor. The western sea-wall was commenced first, and was formed of concrete deposited within framing, with a hard skin of cement-charged concrete on the face to withstand the attrition of the shifting shingle beach. The breakwater was begun in 1880, and consisted of a monolithic mass of concrete raised, from low water, on a foundation of concrete sack-blocks, weighing 1[illegible] tons each, deposited transversely in layers by a special steam hopper-barge. A concrete mixing machine was designed by the author and Mr. Latham, which measured, mixed, and delivered 100 tons of concrete in twenty minutes for filling the bags; and, besides securing a more uniform mixing, it effected a great economy in time and cost. A portable continuous mixing machine was also designed, capable of delivering 70 cubic yards of concrete per hour into the timber framing, erected on the top of the bag-work, for the construction of the portion of the breakwater above low water in lengths of 40 ft. By this means, 300 lineal feet of superstructure were erected in three months. A gallery, raised above the quay level on the western side of the breakwater, provided protection to the quay and a sheltered access to the extremity of the breakwater; it was mainly built of concrete *in situ*. A lighthouse was built of plastic concrete *in situ*, on a pilework foundation, at the extremity of the west pier. The total expenditure on the whole undertaking, including land, two short railways connecting the works with the London, Brighton, and South Coast Railway, dredging, and various other works, was 403,000*l.*, out of which the works described cost 254,000*l.* When the works were suspended in 1885, 1,482 ft. of the breakwater had been completed, and 300 ft. of foundations laid in advance, and a dock of 24 acres, which formed part of the scheme, had not been commenced.

Mr. Strype, in his paper on "Wicklow Harbor Improvements," described in detail the methods he adopted in the construction of a breakwater, 750 ft. long, for sheltering the mouth of the River Leitrim, and the improvement in depth of the entrance channel to the port. The breakwater was built solid, of concrete deposited *in situ*, and, starting above low water, extended into a depth of 18 ft. at low water spring tides, being founded partly on rock and partly on marl. Staging was erected in advance of the work, secured at the bottom with shoes of concrete round the piles, and carrying two lines of railway on the top, along which the titan and crane for depositing the concrete ran. At first, paneling was employed, reaching down to the bottom, for protecting the concrete carried up in layers inside it; but subsequently a large central mound of concrete was deposited under water, by means of skips, on which the paneling was erected, which reduced the exposure of the paneling and facilitated the progress of the work. Divisions were left at intervals in the work, increasing in number in the upper part, to prevent irregular cracking. Richer and finer concrete was placed in the face near low water level; rubble was not used below low water, and it was kept away from the face above, as its projections caused eddies and consequent disturbance of the concrete. The total expenditure on the breakwater, steam packet pier, and dredging, including cost of land, amounted to 40,000*l.* Ordinary plant sufficed for the work, which consisted of huge masses of concrete, resting uniformly on the most irregular bottom, and secure from the attacks of the sea on account of their size. The author considered that a larger central mound might be adopted with advantage, thus reducing still more the amount of paneling required.

The new works carried out at Fraserburgh, Sandhaven, and Portsoy, as well as the previous condition of these harbors, were described by Mr. Willet in his paper on "The Fishing Boat Harbors on the Northeast Coast of Scotland." The works at Fraserburgh consisted of a breakwater 860 ft. in length, for sheltering the entrance to the basins, and the widening of the old Balaclava Pier. The breakwater, 30 ft. wide, extending into a depth of 19 ft. at low water, was built below low water with bags of concrete, of 28 to 50 tons, deposited from a hopper barge. Above low water, the concrete was tipped from wagons into a framing up to the quay level; and the parapet was formed by filling the framing with concrete from tipping boxes lifted by a derrick crane on an overhead traveler which was also used in erecting the frames. The Balaclava East Pier was widened 16½ ft. on the sea side, along its whole length of 1,400 ft. with solid concrete, which protected the old dry rubble wall from the sea; and as a parapet was raised 9½ ft. on its outer side, and 19 ft. above high water, like the parapet on the breakwater, an additional protection was afforded to the quay, and an increased shelter to the harbor. The widening of the pier was commenced at the end of 1875 to provide a roadway to the breakwater without interference with the quay space; and the breakwater was begun in 1878, after the completion of the widening, and was finished in 1882. The average yearly rate of deposit of concrete was 8,000 cubic yards; and under

favorable conditions, 400 cubic yards could be deposited in a day. The concrete in the pier cost 17s. per cubic yard, and in the breakwater 26s. 5d. in bags and 19s. 5d. in frames; and the total cost of the works was 69,000*l*. Some damage was done to the breakwater, after its completion, owing to defects in the method of construction; and the pier was somewhat abraded by the shifting shingle along its sea face. These damages were repaired at a cost of 1,184*l*. A new pier, 1,395 ft. long, was erected at Sandhaven to increase the accommodation in the harbor by inclosing a water area of five acres. The pier was mostly built between walls of concrete, deposited from barrows within framing, with intermediate hearting, resting on rock; and where the bottom was clay, a concrete toe was added. An exposed portion of the outer arm was made of solid concrete. The average cost of the concrete was 18s. per cubic yard; and the total expenditure on the works, including deepening the harbor, was 17,500*l*. The piers of dry rubble masonry protecting the east harbor of Portsoy having been damaged by the sea, rendering the harbor useless, their repair was undertaken in 1882. The piers were reconstructed and extended in solid concrete, deposited within framing from an overhanging crane resting on staging, at an average rate of 60 cubic yards in a tide. The works were completed in eighteen months, at a cost of 9,000*l*. The author considered that the proportion of 1 part of cement to 9 parts of gravel and sand, adopted for concrete at Fraserburgh, was too weak, and that the proportion of 1 to 6, adopted by him at Sandhaven and Portsoy, formed concrete of more suitable strength for such exposed works.

Mr. Langley, in his paper on the "Lowestoft Harbor Works," described the works carried out by him for forming a new basin of 10 acres, along the foreshore to the north of the harbor, excavated to a depth of 14 ft. at low water. The west quay was built up to low water, by sinking thirty-eight hollow rectangular monoliths of concrete, 18 ft. long and 10½ ft. wide, to a depth of from 7 ft. to 9 ft. below the bottom of the basin. The hollow blocks were built up within framing, on a wedge-shaped cast iron shoe. The block was gradually sunk by excavating inside it; and its descent was guided by long hanging bolts at each corner. The blocks were connected together by passing iron rails through two holes left in the adjacent sides of each block, and filling up the intermediate space between the blocks with concrete; the well inside was also filled with concrete. A block 21 ft. to 23 ft. high was sunk in forty-two days; and the block foundation cost 30s. per cubic yard, or 45*l*. per lineal yard. A concrete quay wall was built, from low water, on the top of the blocks, 13¾ ft. high, and 8½ ft. wide at the base. The eastern and northern sides of the basin were inclosed by embankments surmounted by a wall of concrete in mass. The excavations were effected by excavators, steam grabs, and a Bazin sand pump dredger, which latter raised and delivered an average of 1,000 tons of sand and gravel per day. The works were completed within twelve months, at a cost of 60,000*l*.

BENZ'S GAS MOTOR.

WHEN it is desired to obtain a great regularity in motion and a saving in gas, the conditions demanded of a good gas motor are complex and delicate. To this end, it is necessary to have at least one stroke of the piston per revolution of the shaft, to suck up the gas, to compress it, and to light it when about compressed. In the first Lenoir gas motor, the first condition alone was satisfied, the motor being a double-acting one, but since the gaseous mixture was not compressed before being lighted, the amount of gas used was very large. The Otto motor, which effects a compression of the mixture, is more economical, but, as an offset, is less regular, since there is but one stroke of the piston per two revolutions of the shaft—a drawback that has to be remedied by the use of flywheels, and in the more powerful types by two cylinders coupled an angle of 360°.

In the Clerk motor there is one stroke of the piston per revolution; and the compression of the mixture which is indispensable for the saving of gas is effected by adding to the system a special compressing cylinder, thus, in reality, making it a machine with two cylinders, each of which performs a special function that is always the same.

The Benz motor, which we are about to make known te our readers, possesses, with a single cylinder, all the advantages of the Otto and Clerk motors, that is to say, it compresses the mixture for effecting a saving, and makes one stroke of the piston per revolution for regularity.

After such preliminaries, it will be easy to understand the special arrangements of this new motor, which is shown in perspective in Fig. 1 and in longitudinal, vertical, and horizontal section in Figs. 2 and 3.

Let us consider the instant at which the piston has reached the end of its stroke to the right under the action of the explosion, and it is crossing the dead point through the effect of the flywheel. At this moment, the exhaust valve, *b*, opens and allows of the escape of the gases burned in the atmosphere. It being the inventor's design to completely expel these gases at the retrograde half-stroke of the piston from right to left, he injects into the cylinder a certain volume of air, which expels the products of combustion, and which substitutes itself for them back of the piston. At the center of the back stroke, then, the cylinder contains nothing but pure air. At this moment, all the communications with the exterior are closed, and the period of compression begins. The question now is to form an explosive mixture through the introduction of a charge of gas. Such a result is obtained through the action of a small pump, A'. At the end of the stroke, the compression chamber therefore contains a charge of explosive gases, and it will be possible to effect an explosion. A is the motive cylinder, P is its piston, A' is the cylinder for compressing the gas, P' is its plunger, *b* is the exhaust valve, *a* connects the cylinder with a reservoir, E, of compressed air. The valve, *b*, is the first to open, and *a* opens almost immediately afterward to clear the cylinder; *a* and *b* close at the same time, when the piston, A, has reached the center of its stroke.

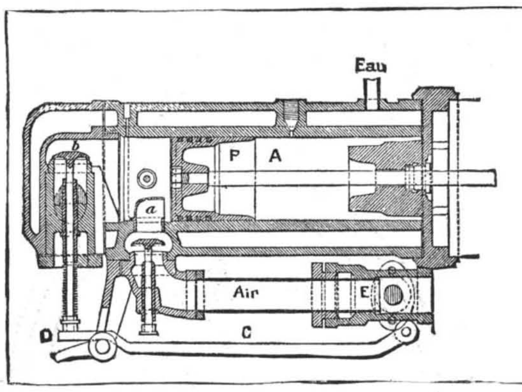


FIG. 2.—VERTICAL SECTION.

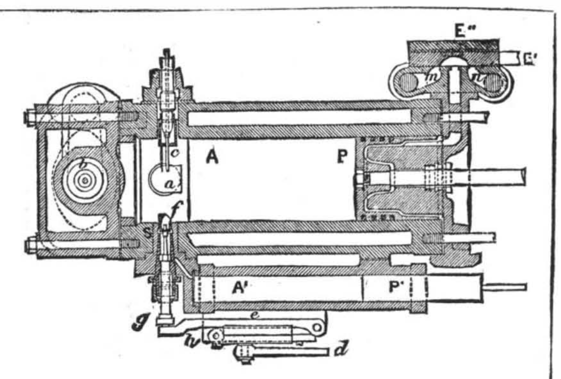


FIG. 3.—HORIZONTAL SECTION.

These various motions are obtained through a crank on the main shaft and an oblique connecting rod (Fig. 1), which actuates a lever, C, beneath the cylinder, through the intermedium of a transverse shaft and of a tappet, D. This latter gently lifts the lever, C, and consequently the spring valves, *b* and *a* (Fig. 2).

The pump, A', injects the gas into the cylinder, beginning with the moment at which the piston, P, has got beyond the center of its stroke.

The plunger, P', is fixed by a cross piece to the piston rod, and consequently partakes of the latter's motion. The gas is taken from the conduit by a pipe above, through a suction valve under the direct control of the regulator, and is forced through *i* and *s*. The compression of the gas is effected during the entire time of the plunger's travel; but the check valve does not open until after the valves, *b* and *a*, are closed. The valve, *s*, remains upon its seat, through the pressure of a spring, until the lever, *h*, which is set in motion by an eccentric keyed to the crank shaft, and by a rod, *d*, acts upon the head, *g*.

The lighting is effected through the fuse, C, between points of which an electric spark appears.

In order to obtain a constant pressure in the reservoir, E, Mr. Benz utilizes the front part of the cylinder, which is converted into a force and suction pump, thus dispensing with the compressing cylinder of the Clerk motor. Owing to the play of the slide-valve, E, the motive piston sucks in the air from outside during its travel backward, and during its forward travel forces the entire cylinderful into the receptacle, E, which supplies the air orifice, *a*. This method of operating presents the advantage of utilizing both surfaces of the piston. Moreover, the air that cools the inner surfaces of the cylinder performs a certain role as regards the lubrication of the rubbing surfaces.

The normal velocity varies between 120 and 136 revolutions per minute, and is regulated by a centrifugal governor, which regulates the admission of gas into the pump, A', according to the mechanical power required at every instant by the apparatus that the motor is actuating. The cooling is effected through a circulation of water around the cylinder at the rate of about six gallons per hour and per horse—a quantity sufficient to keep the temperature from exceeding 75° C. The lubrication is very simple, and the substitution of valves for a slide-valve produces a certain amount of saving, and facilitates the surveillance and use of the motor.—*La Nature.*

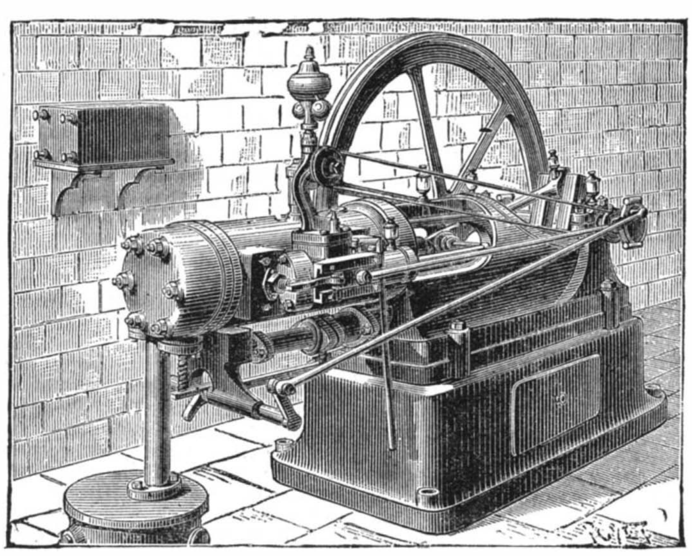


FIG. 1.—BENZ'S GAS MOTOR.

[Continued from SUPPLEMENT, No. 573, page 9151.]

FRICTION.*

By Professor H. S. HELE-SHAW.

Lecture III.—Delivered February 1, 1886.

THE MECHANICAL APPLICATIONS OF FRICTION.

THE difficulty of treating in a satisfactory manner the subject of the mechanical applications of friction, even when all consideration is excluded of those cosmical phenomena in which friction plays a part, arises not from any want of material, but from the vast array of examples which present themselves. The numerous and divers purposes for which friction is employed, and the impossibility of dealing in this one lecture with more than a comparatively few examples, render it necessary to consider the nature of those applications with a view of arriving at some convenient kind of classification.

In the first lecture, we saw that the resistance of friction existed not only when the surfaces were actually moving over each other, but when there was a tendency to motion. Now the objects for which frictional resistance is employed are either (1) to prevent the relative motion of the surfaces, or (2) to take advantage of the results of frictional resistance when such relative motion actually takes place. Thus we have two classes into which the applications of friction are naturally divided:

1. Where the resistance is sufficiently great to prevent the surfaces from sliding over each other, or where there is statical contact.

2. Where the resistance is accompanied by a sliding of the surfaces, or where there is contact of motion.

These two classes of applications may be subdivided. The first includes (i) the case where friction appliances merely act to fasten or lock two surfaces of appreciable extent, and so prevent their relative motion; and (ii) that in which the motion is transmitted from one surface to another by means of a point or line of contact. The second may be subdivided according to the objects in view. These may be:

(i.) To produce the molecular effects of heat and electricity.

(ii.) To obtain vibrations, such as occur in musical instruments, fog horns, etc.

(iii.) To effect a change of the surfaces in contact, as in the case of grinding and polishing.

(iv.) To absorb energy, such as takes place in the action of brakes, regulators, and appliances for measuring power.

The applications may, therefore, be stated thus:

(1.) Resistance to friction (statical contact):
- (i.) The prevention of motion.
- (ii.) The transmission of motion.

(2.) Resistance with friction (sliding contact):
- (i.) Production of heat or electricity.
- (ii.) Production of vibrations.
- (iii.) Abrasion of surfaces.
- (iv.) Absorption of energy.

(1.) STATICAL CONTACT.

(i.) The prevention of motion by means of frictional resistance is effected in a very large number of appliances used in every day life. This is the case not only in the ingenious contrivances which mark the progress of the mechanical arts, and upon which we now depend is a variety of ways, but in the clothes we wear and the dwellings we inhabit.

It might seem that in the numberless applications of statical friction there were a variety of principles involved, which admitted of classifications, such, for instance, as used by Professor Willis, who made a distinction between butting and jamming or twisting friction. In reality, the only conditions which have to be fulfilled are that the surfaces in contact are sufficiently rough, and the normal reaction between them sufficiently great, so that the relations expressed in the equation—

$$F = \mu R$$

shall be satisfied.

It is true that the normal reaction between the surfaces in contact may be obtained in a variety of ways. I shall not, however, attempt to make any arbitrary subdivisions, but proceed to consider such applications as are of novelty and importance.

The utility of nails and screws depends upon the frictional resistance which is due to the elastic nature of the materials, and without which no nail or screw would retain its hold. Where the screw is employed in contact with metal surfaces, as, for instance, in the case of a bolt and nut, the elastic reaction is frequently not sufficient to cause the hold to be retained when jarring action or vibrations occur. The vast quantity of bolts and nuts employed under such circumstances, where human life and property depend upon their retaining their relative positions, as, for instance, in the permanent way of a railroad, has led to a large number of ingenious devices for increasing the frictional resistance of the nut upon the bolt. It will be sufficient to explain one of these. Fig. 42 represents the gripper lock nut, in which the nut, N, is turned to fit a conical recess in a washer, WW (shown in section). When the nut is screwed home upon the bolt, B, the saw cut in

* Lecture recently delivered before the Society of Arts, London.

the nut allows the sides of the conical portion to close together upon the bolt, and grip it with a force depending upon the tension brought to bear upon it. In some devices a spring is interposed between the bottom of the nut and the surface against which it is screwed, so as to always cause a pressure against the sides of the screw thread, and thus obviate the injurious tendency of any jarring action, which is specially felt when the

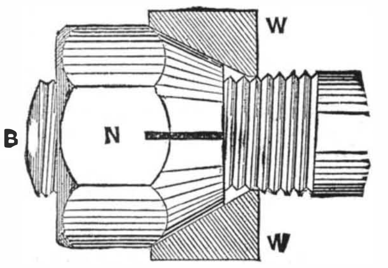


FIG. 42.—GRIPPER NUT LOCK.

nut and bolt do not fit each other in a proper manner.

In a large number of contrivances, the requisite normal reaction of the surfaces is brought to bear by the very tendency of the external forces to overcome the frictional resistance of those surfaces, the resistance increasing with the increase of the external force. An example of this kind is the invention known as the "Jockey" rein holder. This ingenious contrivance (shown in Fig. 43) enables the reins, DD, to be held by

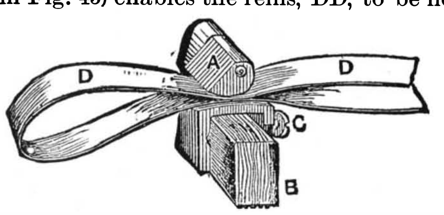


FIG. 43.—THE "JOCKEY" REIN HOLDER.

the frictional resistance resulting from the pressure between the eccentric block, A, and the frame. The action is easily understood, for it is only necessary to insert the reins sidewise under the block, A, which is previously lifted. When the block falls, it grips the upper surface of the rein in such a manner that, the harder the horse pulls, the more firmly the reins are held. The whole contrivance is fixed to the dashboard, B, by simply screwing up the set screw, C.

Another device of this kind is the valuable clip drum of Fowler (Fig. 44), which is much used in towing and

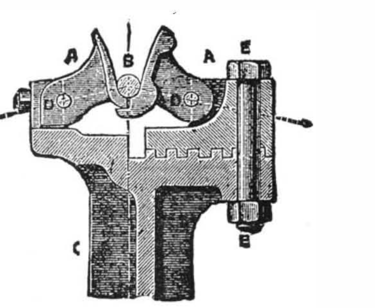


FIG. 44.—FOWLER'S CLIP DRUM.

agricultural operations. In this appliance, of which a section through the rim of the drum is shown, the wire rope, B, is pressed between two clips, AA, pivoted at DD, the surfaces of which are eccentric with the pivots. The greater the tension in the rope, the greater will be the downward force pressing it between the clips, and consequently the greater will be the frictional resistance which acts to prevent it from slipping.

There are a great number of contrivances in which "jamming" friction, as it is called, is employed; such is the case in tying of "knots" in rope. The only difference between the efficient "reef knot," which I now make, and the inefficient "granny" is, as you see, simply relative position of the coils, which in the former case "jam," and in the latter do not. A number of jamming friction contrivances were long ago described by Willis in his "Principles of Mechanism." He there mentions and gives an illustration of the "scheme" of Dr. Hooke, proposed 200 years ago, to "stop great weights falling," and which was the forerunner of numerous "safety" appliances now in use. Time does not permit an account to be given of the modern devices of this kind, or of the many other contrivances, such as the "silent feed" for replacing ratchet wheels, in which jamming friction is adopted.

One of the most important features in the use of statical friction must now be pointed out. In a large number of cases it is required to lock together surfaces which have initially a motion relatively to each other. A certain amount of energy of motion must be absorbed before this can take place, and the required uniform condition of rest or motion must be brought about gradually. By means of frictional contact, this can take place with the only injurious result of a certain amount of abrasion and heating of the surfaces. Thus there is a class of contrivances in which this important property is taken advantage of.

A simple and well-known application is in the case of coil friction. A rope which takes half a turn round a post will enable a force on one side to resist or sustain another force three times as great on the other. For every half turn the resisting power is multiplied three times. Thus a man pulling with a force of only 30 lb. could, with five complete turns round a post, oppose a resistance of no less than 657 tons. But although this large force is available, it is clear that, by reducing the number of turns, or diminishing the pull, the resistance may be reduced to any required extent, and may be brought to bear as gradually as required. Thus it is clear why a large ship can be brought to rest by one man, or a luggage train set in motion by a small revolving steam or hydraulic capstan, without involving any sudden shocks.

Brakes act upon the foregoing principle, but these will be alluded to later on, and we must also pass over other contrivances, such as the injector, which really acts on this principle, and conclude the first subdivision of statical friction with the consideration of one kind of application of great importance, viz., friction clutches.

Friction clutches serve to connect revolving shafts either with other lengths of shafting or with machines, and offer the great advantage of enabling the shaft or machine at rest to be connected with the revolving shaft without previously bringing the latter to rest, as must in many cases be done when clutch couplings or similar modes of connection are employed. Well-known examples of this kind of appliance are the friction clutches of Brown, Addyman (American), and Stephenson.

It will be sufficient to show and explain illustrations of these and other clutches, but through the courtesy of Messrs. Mather & Platt I am able to exhibit to you a model of their friction clutch, which is extremely simple, and at the same time most efficient in its action.

Accounts of the foregoing clutches have appeared in various papers and journals, but I will now describe to you a friction clutch invented by my brother, Mr. Edward Shaw, of Bristol, of which a published description has not hitherto appeared, and which is in many respects a very beautiful invention. Fig. 45 shows this

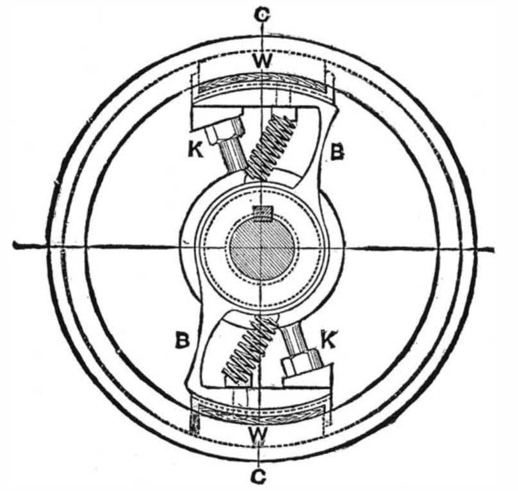


FIG. 45.

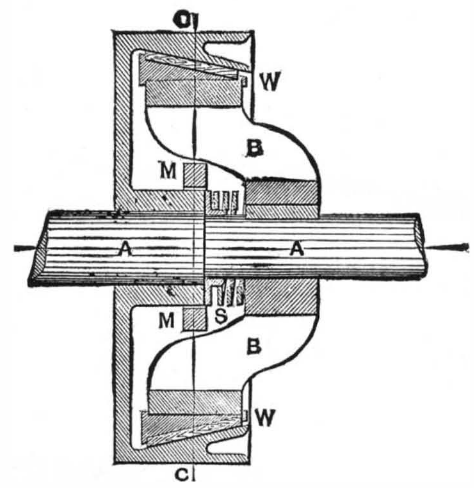


FIG. 46.

FRICTION CLUTCH INVENTED BY MR. EDWARD SHAW.

clutch in sectional elevation and Fig. 46 in side elevation. The frame, BB, is attached, by means of a feather, to the shaft, and thus turns with it. The outside shell, C, carries the driving belt, and is free to revolve on the shaft. Between the bosses of B and C is a spiral spring whose action is to force them apart. The inside of the pulley, C, is conical the arms, BB (see Fig. 46), carry sliding surfaces which, before being turned up concentric with the shaft, are sprung out at the free ends by means of the nuts, KK, the pressure being transmitted from one side to the other by means of a cylindrical frame, M, with screwed parts carrying the nuts. After being turned, the nuts are screwed back, and thus the blocks, WW, which work on these faces must move outward or inward as they slide in one direction or the other. The small spiral springs tend to pull them in such a direction as to move them inward. On the outer faces of WW are fixed oak blocks, which fit the inside face of C. When the clutch is not required, a lever forces B along the shaft toward C, thus separating the conical faces on C and WW. When the lever is released, the spring, S, separates B and C, bringing the conical surfaces into contact, the frictional resistance between them causing a grip between WW and C, and thus the revolving frame, BB, moves on, leaving WW behind. Thus the pressure between the conical surfaces is increased to any desired amount. The action of the clutch may briefly be described thus: A small pressure along the shaft is sufficient to make the conical surfaces touch. Directly they do so, the driving power causes the blocks, WW, to slide on B, so as to increase the grip. The resolved pressure between the conical surfaces is rather less than the angle of friction, hence there is little resistance to throwing the clutch out of gear.

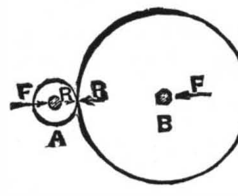
(ii.) The transmission of motion by statical contact occurs in the case of rolling friction, but (as we have seen in Lecture I.) actual statical contact, even with the smallest forces, in reality never occurs. For practical purposes, however, we may usually neglect the amount of slipping which occurs when the surfaces in contact are hard, and consider that they simply roll upon each other. When this is the case, although the points of each surface in actual contact have no relative motion, yet every other point in one surface is moving relatively to all points in the other.

The primary object in the use of two rolling surfaces may be either the transmission of force or the transmission of a definite motion, and we will consider these two applications in succession.

I have already mentioned the transmission of power by belt and rope gearing, which are examples of rolling friction; in these cases the contact occurs over an appreciable area, but in the large class of what is specially called "friction gearing," the contact occurs over a very much smaller area of surface.

Friction gearing has the great advantage, already pointed out, of obviating sudden and injurious shocks by a momentary slipping of the surfaces, and for this reason is largely and increasingly employed in cranes and hoists. It has also the advantage of being nearly noiseless in action, and has thus been adopted for driving dynamo-electric machines. The disadvantage which attends its use, but which, as I shall show, has been considerably exaggerated, is due to the fact that, in order to obtain the necessary normal reaction of the surfaces, the pressure on the bearings has to be correspondingly increased. Attempts have been made from time to time to obviate this objection. The late Professor Fleeming Jenkin invented what he termed "nest gearing" for this purpose, the principle of which will be made clear by means of the annexed figures (Figs. 47 and 48).

Fig. 47 shows that the reactions, RR, at the point of contact cause equal reactions on journals at FF of the shafts A and B. Fig. 48 shows the principle of "nest gearing." Three idle wheels, CCC, are interposed be-



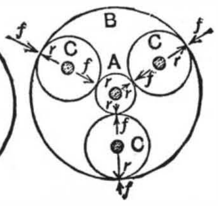


FIG. 47. FIG. 48.

ROLLING FRICTION AND JOURNAL PRESSURE.

tween the inside of the driving wheel, B, and the driven wheel, A. It will be seen that not only is the necessary friction at the points of contact (and consequently the normal reactions *r*, *r*, *r*) reduced to one-third of the former amount, but, what is more important still, the three reactions balance each other, and consequently there is no journal pressure at all. This idea was not, however, new, and Professor Jenkin mentions in his paper on the subject before the British Association * that Mr. Foster had, in 1882, patented one form of nest gearing, and Mr. Tibbits another one earlier still. The idea is, I have found, much older than any of these inventors seemed to have been aware, for in 1842 Mr. Elijah Galloway proposed an arrangement somewhat similar to one form described by Professor Jenkin in his paper as having been applied to a telpherage locomotive. Galloway's contrivance was designed for the purpose of driving a screw propeller shaft, in the days when high speed engines were not considered possible, and intermediate gearing was always used between the engine and the screw shaft. He proposed to fix a double coned cast iron drum upon the engine shaft, the cones being formed upon the inner edges of the flanges of the drum. Between these flanges were placed two much smaller cones, one being keyed to the screw shaft, and the other to an idle shaft. The idle shaft was pushed toward the drum by a spring, and so the cones were always kept in contact with each other and with the drum. The drum, upon being turned, actuated the cones, and thus gave motion to the screw shaft by frictional contact, the necessary normal pressure for which was obtained without causing any pressure upon the bearings of the shaft.

It is clear that, with the arrangement shown in Fig. 48, some device is necessary to keep all the wheels in frictional contact; and the idea that Professor Jenkin had for doing this was to place the center wheel, A, eccentrically to the driving wheel, B, and to have one of the idle wheels, C, smaller than the two others, the necessary tightening being effected by forcing one of the larger idle wheels into the narrower portion of the space between A and B. This had been previously suggested, he afterward found, by Mechwart, though not for friction gearing. A large winch was made on this principle, which was not altogether well designed; and although it was said to have an efficiency of 80 per cent., it did not, so far as could be seen, do justice to the nest gearing of Professor Jenkin. Perhaps it was from this cause that he was led to express an opinion that the eccentric method of tightening would prove less convenient than certain other plans. As far, however, as I am aware, the eccentric method is the only one now in successful operation, and is employed in the combined Armington-Sims engine and dynamo. Figs. 49 and 50 (for which I am indebted to the courtesy of Messrs. Greenwood & Batley) give view respectively in side and front sectional elevation.

From these views it is seen that the engine shaft, S, has attached to it the large wheel, A, upon the inner surface of which roll the three idle wheels, C C C, all of different sizes, which are driven by frictional contact, and in turn drive the wheel, B, which is attached to the spindle, T, of the dynamo, D—carried upon the framing, F F.

The adjustment is effected by three curved slots, G, G, G, in ribbed plate supported on the frame. Fig. 50 shows how the spindles, D, of the idle wheels are constructed and fixed, and also the ingenious device by which a constant supply of lubricant is insured, the spindle, Q, being attached to a heavy weight which rests upon the lubricating material, and forces it along the hollow spindle to the bearing in the boss of the wheel, C.

Although the advantages of nest gearing are undeniable, there are certain objections which are likely to be overlooked, the chief of these being that there *is* such a thing as rolling friction. Thus, by comparing Figs. 47 and 48, it is evident that the number of points of contact, and consequently of points of rolling fric-

* Report of British Association, 1883, p. 387.

tion, is six times as great in the case of nest gearing. This does not, since the pressures are much reduced, involve a corresponding increase in rolling friction, but still there is a decided increase. Secondly, the frictional resistance of the bearings under heavy pressures is much exaggerated, and arises, as we have seen, from a misapplication of Coulomb's laws. In a properly constructed and lubricated bearing, the friction does not increase directly with the pressure, or in anything like that proportion. Thus, considering the extra complication entailed with nest gearing, there are evident reasons why it has not yet been very widely adopted.

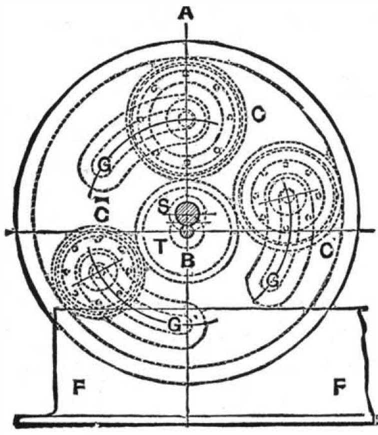


FIG. 49.

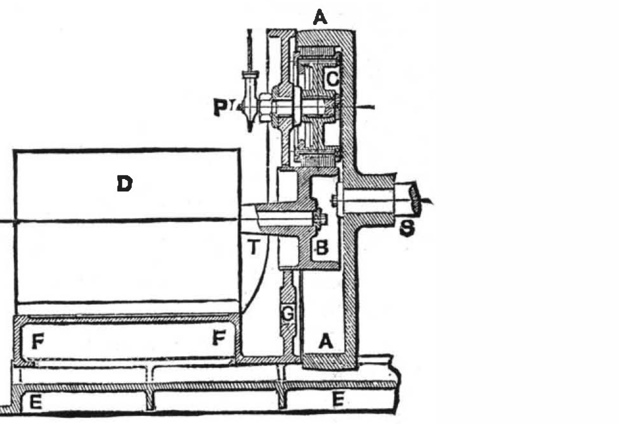
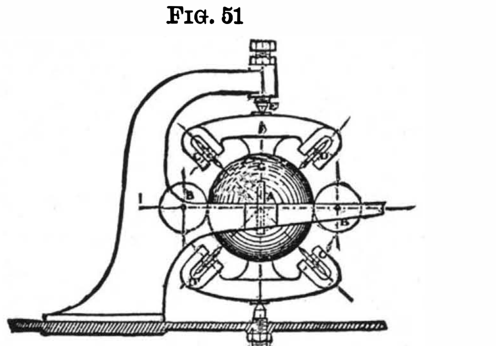


FIG. 50.

FRICTION GEARING WITH ECCENTRIC ADJUSTMENT.

We now come to an important advantage which the method of transmitting motion by the frictional contact of surfaces has over any other. This advantage is the possibility of varying in any way the relative speeds of rotation of the driving and the driven bodies. In the case of belts, this is done by employing a pair of conical frusta, the larger ends of which are turned in opposite directions. The frusta are keyed upon two parallel shafts, and by causing the belt to move along them, the relative speeds or velocity ratio can obviously be varied in any required manner. In the well-known disk and roller, the roller is caused to slide sideways across the disk, which drives it by frictional contact, and thus velocity of rotation is varied relatively to the disk. In both these cases, however, the surfaces in frictional contact are made to slide over each other, and this it requires considerable force to effect, and causes no little wear of the surfaces. About two years ago, I was led to attempt to solve the problem of varying the velocity ratio without introducing any sliding action at all. The solution at which I arrived is fully described elsewhere,* and I will only briefly describe the general principle of action. Figs. 51 and 52

FIG. 51



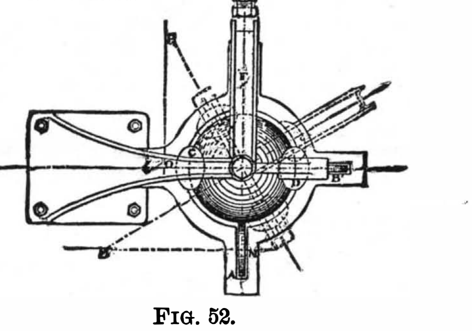


FIG. 52.

VARIABLE VELOCITY RATIO BY FRICTION OF SPHERE AND ROLLERS.

represent the plan and elevation of a sphere supported by two sets of rollers. One of these sets, A A', B B', is in horizontal contact round the horizontal great circle or equator. The other, C C', D D', is in contact round a circle made by the intersection of some vertical plane. The latter set are carried in a movable frame, F F, which can turn about a pivot, E E. The former set are carried in a fixed frame, I I. Suppose the wheel or roller, A, be turned, then the sphere must also turn; but as it can only roll about an axis in the plane of the axis of A (*i. e.*, in the horizontal plane), and as it also can only roll in the plane of the axes of C C', D D', it is clear there is only one axis about which it can roll, viz., the intersection of these two planes. Thus, by turning the movable frame, the axis of rotation can be made to take any position, and the relative velocity of the roller, A, to that of the roller, B, can be varied in any required manner by an action which involves merely the rolling of the wheels upon the surface of the sphere, *without any sliding friction.* My brother, Mr. Edward Shaw, has since developed and applied this mechanism for transmitting as much as two H. P., and, although the practical difficulties were very considerable, they have, to a great extent, been successfully overcome.

So far we have merely considered the transmission of appreciable forces, but there is a class of instruments in which the forces are not appreciable, the only object in view being to transmit a definite motion. Friction is sometimes used to transmit simple rolling, but it is for variable velocity ratios that the application is specially valuable. An example of the former class is the odometer, which appears to be a very ancient instrument, having been mentioned by Vitruvius as applied to carriages. This instrument merely consists of a wheel which is rolled along a curve or line whose length is required. The periphery of the wheel being known, and the number of revolutions of the wheel recorded by a suitable train of wheels, the calculation is easily made, or, as is more usually the case, the result is at once recorded upon a dial.

The most important instruments in which the velocity ratio or relative speed of the rolling surfaces is varied are called "mechanical integrators." These instruments multiply together two variable quantities, such as the length and breadth of an irregular figure, or the pressure of steam and corresponding distance moved by the piston in a steam engine, and perform operations which would be scarcely possible if the frictional contact of two surfaces rolling upon each other were not employed. All mechanical integrators may be divided into two classes, in which either :

I. *Both* slipping and rolling of the surfaces take place.

II. The correct action depends upon the surfaces rolling *without* slipping each other.

I. The former class has only been successfully employed where the motion is not continuous, and not very rapid. This is the case in the use of "planimeters," by which the area of a figure drawn upon paper can be obtained by merely passing round the perimeter a pointer connected in a suitable manner with one or more wheels rolling over the surface. The only planimeter which can be said to have come into general practice is that of Professor Amsler, invented in 1856. Other instruments of this kind had previously been suggested, as, for instance, in 1814 by Hermann, of Munich; by Oppikofer, of Berne, in 1827; and by Gonella, of Florence, in 1828. The planimeter of Oppikofer obtained a prize at Paris, in 1836; but Wettli, of Zurich, in 1849, seems to have been the first to produce an instrument of practical importance. The planimeter of Amsler is, however, so beautifully simple, and so marvelously exact in its operation, that it is little to be wondered at that it has practically superseded all others, since its invention no less than 12,400 having been made and sent out from the works at Schaffhausen. All the previous planimeters had been "linear," that is, the motion which must be possible in every direction over the surface was obtained by compounding two motions at right angles to each other, whereas that of Amsler was "polar," the motion being obtained by two arms, one turning about a fixed center, and the other jointed to it.

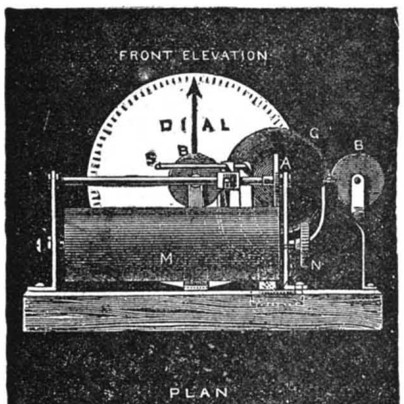
Planimeters have a variety of forms, and have been the subject of many inventions, but it is a curious fact that in all planimeters of the class we are now considering, that is, in which both sliding and rolling take place, the principle of action is the same. I have elsewhere proved this point, and given an account of different kinds of planimeters.*

It is clear that any relations of the nature of a product between two varying quantities may be represented by a drawing. This is so, not merely in the case of the superficial contents of an area, such as a field or tract of land, but also in a case such as that of an indicator diagram representing the work done in the cylinder of a steam engine or other prime mover. It is in many cases much more convenient to obtain the required product directly, without previously making a diagram or drawing; and to do this several integrators have been invented, in which the roller or measuring wheel slides as well as rolls, such as the integrators of Poncelet, Moseley, Ashton and Storey, and others. Since, however, the accuracy of the instrument depends upon the rim of the roller being a circle of an exact size, and since some appreciable pressure is necessary to obtain sufficient frictional contact, the unavoidable wearing of surfaces in contact which takes place has hitherto proved one insuperable objection to their permanent employment. Other integrators of the slipping class might be considered, did time permit, such as the beautiful "precision planimeters" of Coradi and Hohmann, and the "Moment" integrators of Amsler; but we must pass on to those of the purely rolling class.

(II.) Integrators in which there is no slipping have not been introduced to any extent for merely finding the area of a surface, that is as planimeters. They have even for this purpose certain advantages over those of the previous class which do slip, but these are not sufficiently marked to counterbalance the fact that they are not so simple in construction, and consequently cost more. Examples of these are the integrators of Abdank-Abakanowicz and Mr. C. V. Boys.

It was in the endeavor to invent a non-slipping integrator that I devised the sphere and roller mechanism which I have previously explained. Fig. 53 shows in elevation, and Fig. 54 in plan, the first model of an integrator made on this principle, which can be more easily explained than some of the later forms of instruments. A sphere of boxwood, G, is held in a frame simply formed by bending round suitably shaped sheet brass, which thus caused the rollers to grip the sphere. The rollers, A A, B B, were disks of boxwood, and merely had common red elastic bands cemented upon their peripheries. The paper on which is the area to be integrated is folded round a cylinder, M, and held there by two India rubber

FIG. 53.



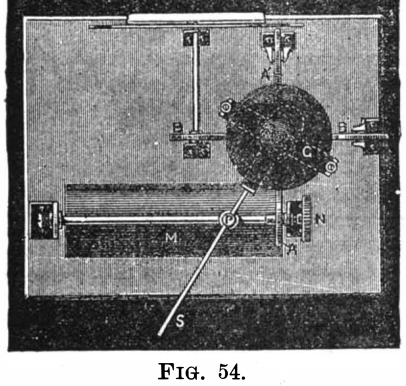


FIG. 54.

SPHERE AND ROLLER INTEGRATOR.

bands. The cylinder is turned by means of a milled wheel, N, with one hand, and the pointer, P, which is connected with the movable frame of centers, is kept on the curve with the other. The roller, A, works in contact with the surface of the paper, and communicates its motion by frictional contact of the India rubber to the sphere. The motion of the pointer connected with the axis of B is registered on a suitable dial. The reading of the dial gives the required area of the figures.

Though the results with the early forms of the sphere and roller integrator were as accurate as could be expected, yet there was always a certain mysterious error in these instruments, even when made by the very ablest mechanicians, the cause of which I could not discover for a long time, but which I have at last traced to a certain property of surfaces which roll upon each other, and are at the same time subjected to a force not in the plane of rotation. I will not now, however, say more upon this point.

Although not much employed as planimeters, integrators of this class have advantages which those of the slipping class cannot possibly possess. One of these advantages is the possibility of their being employed to trace curves representing the result of integration. Instruments which do this are called "integraphs," and both Mr. Boys and Mr. Abdank-Abakanowicz have devised instruments of this kind.* Fig. 55 represents the latest form of integraph devised by the latter gentleman. The iron straight edge at the lower end of the figure serves as a guide upon which run certain rollers in the movable frame of the instrument. This frame carries a pointer, A, which is passed round the curve the area of which is required. Another pointer, B, between two other rollers at the same time traces the integral curve (a portion of which is shown, though not very clearly, on the shaded portion of the sheet of paper). The area of the first curve is measured by the height to which pointer, B, rises in drawing the second curve.† Another advantage possessed by this class of integrators is that they can be employed where continuous motion is required, as, for instance, in steam engine integrators; for since the measuring wheel only rolls and does not slide, it is not liable to lose its initial form. In spite of this obvious advantage of non-slipping integrators, they have not yet been successfully introduced for such purposes, though it would not perhaps be a rash thing to predict an important future for them in this direction.

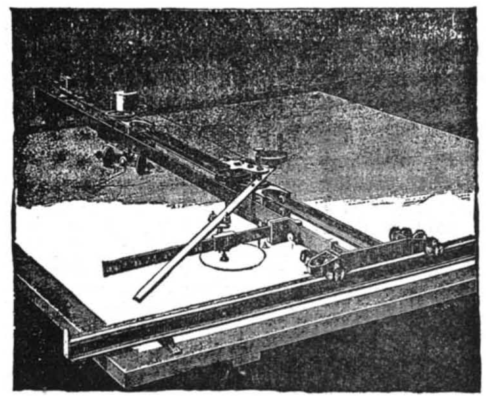


FIG. 55.—INTEGRAPH FOR TRACING INTEGRAL CURVES.

* "Phil. Trans. Royal Society," Part ii., 1885, p. 367.

* "Mechanical Integrators," Minutes of Proceedings of Inst. Civil Engineers, vol. lxxxii., p. 75, to which paper the reader is referred for further information on the subject.

* Integraphs trace the curve $y = \int f(x)\,dx + c$ from any given curve of the form $y = \varphi(x)$.

† This instrument is fully described in the "Comptes rendus de l'Academie des Sciences," vol. ci., 1885, p. 592.

(2.) SLIDING CONTACT.

(i.) The production of heat for the purpose of obtaining fire was probably one of the earliest mechanical applications of friction, and it has been conjectured that the fire drill for doing this was the earliest case of machinal motion. At the present day, every lucifer match testifies to the fact that we are dependent for fire upon the same source. The conversion of mechanical energy into molecular motion is not, however, a very profitable mode of obtaining heat upon any large scale, since 1 lb. of water can only be raised 1° in temperature by the expenditure of energy sufficient to raise 772 lb. one foot high, so that to boil a pint (initially at the average temperature of 62° Fah.) would require an amount of work capable of raising no less than 144,000 lb. to the same height; and heat when produced by friction generally takes place as a loss of energy which, as we shall see in the next lecture, has specially to be guarded against. A recent invention which employs the conversion of work into heat has, however, been made which is of considerable interest, and must be mentioned.

The "friction still" of Mr. Lionel Pearce is an invention for converting sea water into fresh, by means of a machine so simply constructed that to pour in sea water and to turn a handle are all that are necessary in order to obtain a supply of pure, drinkable water. The invention was recently described in the *Engineer* somewhat as follows:

Fig. 56 shows a friction still, fixed to and let through

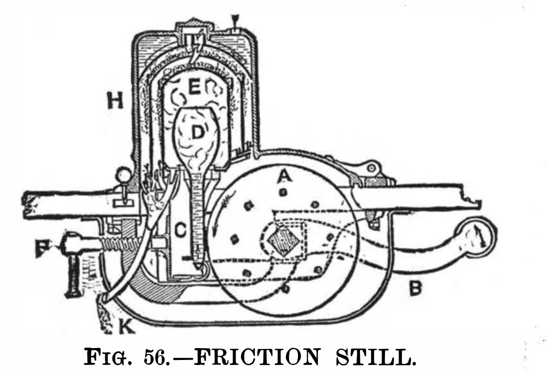


FIG. 56.—FRICTION STILL.

the seat or after thwart of a ship's boat; above that seat is the condensing or domed part, and below is the malleable iron framing. The machine may, of course, be fixed to the most convenient place in a boat. The framing may be said to consist of two parts, one fixed and the other movable; the fixed frame being bolted through the seat fixes the part above the seat to that below. The metal supporting the boiler must be understood to be part of this fixed frame, though the section does not clearly show it. The movable frame is capable of a sliding motion in three bearings, one above the pressure screw, F, and another to each side of friction wheel, A. It is single where shown in section, and branches off to each side of the wheel to form bearings for the spindle. This frame brings the friction wheel, A, in contact with the boiler, C, with any desired pressure, regulated by the pressure screw, F. The inequalities which may occur in the periphery of the friction wheel are compensated for in the elasticity of the packing. Either side of the spindle may be fitted with a handle, B, and the same still can be worked effectively within the range of power from that of a lad of fourteen years of age to four man power. The boiler, C, is held in a hardwood block, to prevent heat being readily conducted to the metal frame supporting it. The upper part of the machine is hinged, and may be thrown open, leaving the boiler and friction wheel exposed: the inner domes also hinge open or take out for any attention that might be required. The overflow tank is pivoted so as to be easily released from the boiler. The manner in which it is fed and the action is as follows:

It will be seen that the upper tank, H, is full of sea water. From this tank the water is made to pass at intervals down small pipes shown in the center, and feeds or saturates the flannel with which the two domes are covered. The sea water, after it has left the coverings, as it is collected by its trough, runs through a pipe into the overflow tank, which tank is connected with boilers in keeping that fed with sea water to the height allowed by overflow tank; the overflow from the middle dome is allowed to run away as cooling water, because that from the inner dome is sufficient feed for the boiler, and being hotter than that from the other dome is preferred. The water enters the boiler at the bottom, as shown by the arrow. The heat result of the friction of the wooden wheel, A, against the steel on the boiler causes the sea water to boil in about half a minute. The steam then rising is trapped in the dome, E, and condensing upon its inner surface, drains away into its trough, then from that to outlet pipe, K. The condensed steam or distilled water may be traced throughout the engraving indicated as drops. The heat given up by the steam condensed upon the inner surface, E, will be imparted to the sea water held in the saturated flannel covering the dome; this water is freely vaporized at a lower temperature than that required for the boiler, its vapor being condensed upon the inner surface of dome inclosing it. The action of vaporizing and condensing goes on in the next compartment, as just described, but at a lower temperature; the product from the three condensing surfaces can be traced as drops all flowing into and out of outlet pipe, K. The feed water in the tank will, when the machine is in full work, reach a temperature that a delicate hand cannot bear by heat imparted to it from the vapor which condenses upon the domed bottom of the tank.

It was known to the ancients that on rubbing amber, light bodies in the vicinity were attracted to it. This effect was ascribed by Thales of Miletus to an inherent soul or essence, which, being aroused by friction, went forth and brought back these substances to the excited amber. We do not know much more at present about the nature of electricity, although we do not quite believe that the attraction is due to this cause. We have, however, gone far beyond rubbing pieces of amber by hand, and there have been a variety of machines invented during the last 150 years, culminating in the large Wimshurst machine for the production of electricity on a large scale by friction. We are not certain that the so-called current electricity produced by the dynamo-electric machine is not produced by some action of the nature of friction, or whether friction is not the cause of the resistance in a wire to the passage of an electric current, which resistance results in the production of heat, just as obtained by the expenditure of mechanical energy in friction. But I am afraid others, far more competent to discuss this question than I, are yet unable to throw much light upon it.

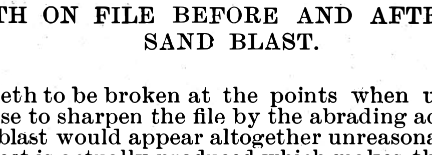
(ii.) Concerning the production of sound by friction, I need only point out that to this effect we owe the action of most of our stringed and wind musical instruments. In wind instruments, such as organs, the friction of the air in passing over the edge of the orifice in the pipes sets the column of air in vibration, and so produces a musical note. In stringed instruments, such as the violin, the bow being drawn across the string draws it to one side, its elasticity bringing it back, and thus setting up musical vibrations, resin being applied to increase the frictional resistance. Other sounds are produced in this manner by friction, which, though useful, are not always musical, such as those of the fog horn and steam siren, and it must be remembered that all sound is more or less modified by the friction of the air, without which the aerial waves could scarcely either be generated or dissipated.

(iii.) The grinding and polishing of surfaces by means of friction, as performed by the forces of nature, is a well-known effect. Buildings and monuments which have resisted all other forces have been defaced and changed in appearance by sand carried by the wind, and it is well known that the windows of houses exposed to the action of wind carrying sand become dull from this cause. I cannot attempt even to enumerate all the applications of this kind in the mechanical arts. To produce effects upon the hardest bodies friction has been employed from the earliest times, and is still used with the most astonishing results, by some savage tribes. Thus Mr. Wallace, in his "Travels in America and Rio Negro," tells of holes four to eight inches bored through hard quartz ornaments by the agency of the friction of sand with water, applied by means of a flexible leaf shoot, one hole being probably the work of years, and, in some cases, possibly of generations.

Mechanical science has found a way to expedite the process of cutting hard materials by frictional effects, and I will allude to one such process, which is the application of a sand-blast by Mr. Tilghman, for an account of whose work I am indebted to the columns of the *Engineer*. Mr. Tilghman has applied the capability of fast-moving sand to cut the hardest materials. The process was matured by him, and first used to cut stone for building and other purposes, the sand being impelled by steam at a pressure varying from 60 lb. to 325 lb. per square inch. The process consists in projecting sand at a great velocity by a jet or jets of air or steam against any hard surface, by which means the hard substance is slowly or rapidly worn away, according to the velocity of the current or blast of sand. With quartz sand, driven with high-pressure steam, granite crumbles away like a pile of sand under a falling stream of water, and even corundum can be drilled or grooved with ease. Diamonds, the hardest of all substances, cannot withstand its action. With the steam blast, cast iron stencils, ¼ in. to ½ in. in thickness, are used to protect the surface which is not required to be cut away. The blast is then directed at right angles to the surface, and moved by suitable mechanism regularly over the whole surface. With a jet using 6 horse power of steam, at 60 lb. to 70 lb. pressure per square inch, and 1½ cubic feet of sand per hour, 1½ to 10 cubic inches, according to the hardness of the stone, may be cut away per minute.

This process has many interesting applications, such as the ornamenting (by frosting) of glass, the cleaning of castings, ornamenting buttons, and marking glue, but one of considerable importance must be described. Files, when newly cut, have a burr or ridge, as at *a a a*, Fig. 57. This burr is a considerable evil, as it causes

FIG. 57.



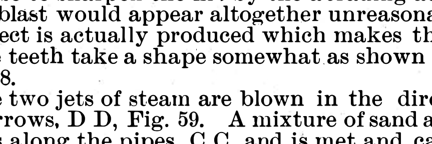


FIG. 58.

TEETH ON FILE BEFORE AND AFTER THE SAND BLAST.

the teeth to be broken at the points when used. To propose to sharpen the file by the abrading action of a sand blast would appear altogether unreasonable; yet an effect is actually produced which makes the points of the teeth take a shape somewhat as shown at 3 3 3, Fig. 58.

The two jets of steam are blown in the direction of the arrows, D D, Fig. 59. A mixture of sand and water comes along the pipes, C C, and is met and carried by the steam upon the file, B, in the manner shown at S S; the jets are regulated by the screws, E E. A rest (not shown) serves the double purpose of holding the file in position and enabling the operator to tell, by moving the file to and fro upon it, when the teeth have reached a good cutting edge. The kind of sand used is exceedingly fine, and is the waste material obtained in the process of grinding plate glass. The Tilghman Company have recently made further improvement in the sand blast process.

In practice, the most simple and inexpensive way of giving the necessary velocity to the sand has been by steam. Notwithstanding these advantages, the difficulty of manipulating the articles to be frosted, engraved, perforated, etc., in a chamber full of steam or vapor, the difficulty of finding a suitable resisting material which will not be affected by either heat or moisture, the danger of breaking in the case of glass by the heat of the steam, the danger of the stencil getting clogged with sand, have precluded its use in many manufactures. In consequence of these objections, an air blast was used instead of steam. In the new arrangement, steam is used to give velocity to the sand, which passes along after being freed from steam and cooled. This new sand blast has, therefore, the advantage of the steam blast without its objections. The force of the blast can be easily regulated, from the low blast required to engrave table glass to the strong blast required to perforate sheet glass.

(iv.) The last application which we must consider is the absorption of energy, and this alone might form

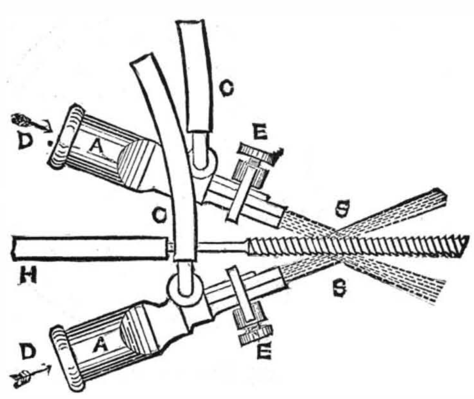


FIG. 59.—SHARPENING FILES BY FRICTION OF SAND.

the subject of a lecture. The use of brakes makes ordinary conveyances safe and railway traveling possible. In the revolving fly of striking clocks and musical boxes we have an application of frictional resistance for regulating speeds which finds its development in some of the most beautiful devices of governors for marine engines, such as those of Silver, Huntoon, Thomson, Siemens, and others, while the principle of the cataract of the old Cornish engine, which regulates speed by varying the size of an orifice through which liquid is made to flow, has been applied in the well known service buffer, and has its latest application in regulating the number of shots fired in a given time by the Maxim gun. Again, the use of friction is employed to absorb the energy, and thereby measure the power, of prime movers in machines, as in the dynamometers of Prony, Armstrong, Egen, Cadiat, and others, where the friction of solid surfaces is used, and in that of Froude, where liquid friction is employed.

The above are a few cases in which the friction of solids, liquids, and gases is employed to absorb energy for useful purposes, and these examples must suffice.

I have endeavored, in the brief space of a lecture, to give some account of the useful applications of friction, but it is not by these applications that the important part it plays in the economy of the world is most strikingly seen. It is, indeed, scarcely possible to picture the results that would follow the cessation of the action of friction. The whole face of nature would be at once changed, rivers and winds would flow with incredible velocity, though their effect would be very different from what it is at present; the latter, for instance, would raise no ocean waves, and no tides would flow up estuaries and channels; much of the dry land, and, even more rapidly, most of our buildings, would disappear beneath the sea. Such inhabitants as remained for a short time alive would not only be unable to provide themselves with fire or warmth, but would find their very clothes falling back to the original fiber from which they were made, and if not destroyed in one of the many possible ways, such as by falling meteors, no longer dissipated by friction through the air, or by falling masses of water, no longer retarded by the atmosphere and descending as rain, would be unable to obtain food from inability to move themselves by an ordinary method of locomotion, or, what would be equally serious, having once started into motion, from being unable to stop except when they came into collision with other unhappy beings or moving bodies. Before long they, with all heavier substances, would disappear for ever beneath the waters which would now cover the face of a lifeless world.

UNSUSPECTED DANGERS WITH FRICTIONAL ELECTRICITY IN BLASTING.

By W. E. IRISH.

SOME years ago, when I was engaged in assisting to carry out a series of experiments in the firing of torpedoes and mines by means of electricity, an incident occurred which nearly resulted in a most serious calamity through the want of knowledge regarding the power of induction.

About a week after the commencement of a long series of experiments, several charges of gunpowder, guncotton, and dynamite were submerged in a river about one hundred feet apart, the object being to learn what the effect of each would be when fired under the same conditions. The firing station and position of the charges in the river were on this occasion totally obscured from each other, and about one mile apart. The cable employed to connect the charges with the firing apparatus consisted of a stranded copper conductor well insulated with "Hooper's compound." Two lines were used for firing the charges, and a third or special cable of the same description was laid for communicating between the two points by telegraph. The three cables were laid on the grassy land parallel to but separated from each other by a space of a few inches throughout the greater part of their length. Electricity for firing the charges was obtained from Baron Von Ebner's ebonite-disk frictional machine, which is too well known to need description.

The two ends of the cables at the river were each connected to a charge, while at the firing station one end was carefully sealed and suspended in the center of the firing room as a precaution and guard against the possibility of its coming in contact with the firing battery or machine. The other end was connected to the electric generator in connection with the charge to be fired first.

Final arrangements having been completed and all made ready, instructions were telegraphed to fire No.

1 charge, which was carefully and correctly done. Scarcely, however, had the firing key been depressed when word was wired from the river "to stop further operations, and leave everything at the firing station in the exact position it then occupied, as two charges had been fired instead of one only, as directed, and that in consequence a boat and party of men engaged near the charge which ought not to have been fired had most miraculously escaped being blown to pieces." This was declared by the operators at the firing station to be impossible through any action or neglect on their part.

The matter, however, was too serious to be left without a thorough and searching investigation. There was no question as to the second charge having been fired, and a careful examination of the cables between the points, immediately after the occurrence, failed to show the slightest sign of their having been tampered with. The evidence tended to locate the cause at the firing station, but how or by what means the charge was fired was quite unaccountable to all, and remained a matter of conjecture for several days, as the spare end of the cable had remained securely sealed and suspended, and was at the time of firing many feet away from the electric generator. A very careful examination and insulation test of the end of this cable in the firing station proved that it had not been injured or tampered with in any way.

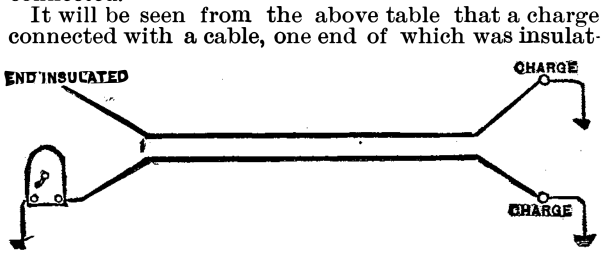
It was determined to unravel the mystery, if possible, and we set resolutely to work, and were not long in discovering that under precisely the same conditions the same result was always obtained. One gentleman ascribed the cause to be the detonation of the charge fired, but we had satisfied ourselves from the outset that such was, under the circumstances, very unlikely indeed.

Experiments and investigation led us eventually to discover the fact that the firing of the second charge was due to induction. This, at first, we found some difficulty in proving to the entire satisfaction of the gentleman who stood up so stoutly for the detonating theory. To remove all further doubt, and for the information of all concerned, two half miles of the same description of cable were placed one foot apart throughout their entire length, fuses being connected to the cables at one end to represent the charges, and the wire being then grounded as before, as shown in the accompanying diagram. To one of the cables at the firing station the frictional machine was connected, while the other end was carefully sealed and suspended in the same room as before and at least ten feet away from the electric generator. The disks of the machine were given twenty revolutions, and the condenser was discharged, when both fuses fired. Other tests were then made, as given in the following table, to discover the greatest distance through which this inductive action would fire a charge, the wires being arranged as described above:

Distance of cable apart in feet.	No. of revolutions of the disk.	No. of charges fired.	Distance of cable apart in feet.	No. of revolutions of the disk.	No. of charges fired.
6	20	2	20	30	2
3	4	2	30	30	2
3	4	1	40	30	1
9	20	2	40	30	1
12	20	2	40	40	1
15	10	1	40	50	1
15	20	1	40	50	1
15	30	2	35	50	1
20	30	2	30	50	2
25	30	2	30	50	2

It would be dangerous on cables running parallel, and within forty or fifty feet of each other, to employ the frictional machine where more than one charge is connected.

It will be seen from the above table that a charge connected with a cable, one end of which was insulat-



CHARGES FIRED BY INDUCTION.

ed, could be fired by the inductive action of another cable running parallel to and separated from it by a space of thirty feet when one class of electric generator was employed, whereas with a different generator the second fuse was not fired, even when the cables were tied or twisted together, as will be shown by the following tests.

The frictional machine was now removed, and tests were made with dynamic machines and voltaic batteries, but in no instance did we succeed in firing more than the one charge, and then it was the one connected in circuit with the machine or battery, even when the wires were as close together as it was possible to get them.

These experiments clearly prove that the detonation from the primary charge fired was not the cause of the second one exploding, and that the action was alone due to induction. Had it been due to the detonation, both charges would have been fired as readily by a dynamic machine or voltaic battery as with the static machine.

The writer is well aware that one charge is frequently fired by the detonation of another when the two are within a limited distance of each other.

This power of induction could be put to good use, particularly in naval warfare, in firing and destroying the enemy's mines. It may also be interesting to know that, with a thirty-cell Grove battery and similar cable to the above, we succeeded in firing through a fault made by stripping off twenty-four inches of the insulation and submerging the bare wire in the sea. With an induction coil, we failed to fire through a fault in the insulation only sufficient to expose the conductor to the eye. Wheatstone's magneto-exploder fired the charge through a leak $\frac{1}{24}$ of an inch long, but failed through a fault exposing ⅛ inch of the conductor. Siemens' dynamo machine fired the charge through a leak exposing a surface of $\frac{1}{16}$ inch, but failed to do so with a larger fault.

Von Ebner's frictional machine fired through a leak of 4½ inches of bare conductor. It also fired the charge through a perfect break in the conductor. A four-cell Grove battery fired through ⅜ inch leak, but failed to do so through ¾ inch.

These rough and ready tests and experiments were made to show as simply and quickly as possible, to men having little electrical knowledge, the most suitable firing apparatus to use under certain circumstances and conditions.

I have not seen any published information relating to this subject, and as the facts as here stated do not appear to be generally known, I think them of sufficient interest to record, in order that accidents may be avoided by the use of such apparatus in the hands of the inexperienced.—*Electrical World.*

PURE ICE AND SNOW.

SOME experiments have been made by T. Andrews in regard to the relative conductivity of ice and snow, the dilatation of pure ice, and its relative penetrability at various temperatures. In experimenting in regard to the first point, a mass of water about 2 feet square and 1 foot high was converted into ice by a freezing mixture, and a uniform temperature of 0° F. obtained. In place of the freezing mixture, fresh snow was then supplied and the gradual increase of temperature noted by a series of thermometers until the whole mass was at 32° F. This required 73½ hours. The experiment was then repeated with pure snow lightly pressed together; 165½ hours were required to bring it up from 0° F. to 32° F. The relative conductivities obtained are expressed in a diagram, the conclusion being that the conductivity of the ice was about 122 per cent. greater than the snow under the conditions of the experiment.

The dilatation of ice was measured between —35° F. and + 32° F. The linear coefficients obtained are as follows:

Linear coefficient	for 1°	between	+ 16° F.	and	+32° F.	=0·000040876.
"	"	"	0	"	+16 "	=0·000028042.
"	"	"	—21	"	0 "	=0·000020484.
"	"	"	—30	"	—21 "	=0·000019744.

The hardness of ice at different temperatures between —35° F. and + 32° F. was measured by the relative depths to which a blunt-pointed steel rod with a weight of 181½ lb. on its top penetrated. It was found that between —35° F. and + 10° or 20° F. the ice was nearly impenetrable, the depth of penetration being only ¼ inch at 10° and ⅔ inch at 20°; after which the power of resistance decreased rapidly with the temperature.—*Proc. Roy. Soc.*

SOLUTION.*

OPENING OF THE DISCUSSION BY PROF. TILDEN.

FOR want of time, the consideration of various phenomena connected with the subject was necessarily omitted. Thus no reference could be made to the various formulæ relating to expansion or density of solutions, nor their optical properties, magnetic rotation, nor to the subject of electrolysis. In what follows, a review is presented of the principal phenomena observed in the act of solution of solids (especially metallic salts and other comparatively simple compounds) in liquids, and the chief properties of the resulting solutions, with the object of arriving (if possible) at some conclusion as to the physical explanation of the facts. The question must at once arise whether these phenomena are to be considered as chemical or mechanical, and all the theories which have been put forward to explain the nature of solution are roughly divisible into two classes, according as, on the one hand, they represent the process as a kind of chemical combination, or, on the other, explain the phenomena by reference to the mechanical intermixture of molecules, or by the influence of the rival attractions of cohesion in the solid and liquid, and of adhesion of the solid to the liquid.

The former hypothesis seems to have been universally adopted by the older writers, such as Henry and Turner, and it seems pretty clear that Berthollet also regarded solution as an act of chemical combination. Among modern chemists, Prof. Josiah P. Cooke takes a similar view, but M. Berthelot is the most consistent and powerful supporter of the same hypothesis. In his "Mecanique Chimique," tome ii., p. 160, will be found a very clear and formal statement of the views upon this subject which, it is interesting to know, are retained by M. Berthelot without modification in any essential particular.

On the other hand, there are a number of writers who, while referring the phenomena of solution to a molecular attraction of some kind, do not attribute solubility to the formation of chemical compounds of definite composition. Graham distinctly ranges himself on this side. Brande also appears to have taken a similar view; Daniell, Miller, Nicol, and Dossios may be more or less ranked with them. A theory differing in some important respects from those of the above writers was briefly enunciated in a paper communicated to the Royal Society by Tilden and Shenstone in 1883. In discussing the connection between fusibility and solubility of salts, the authors point out that the facts tend to "support a kinetic theory of solution, based on the mechanical theory of heat. The solution of a solid in a liquid would accordingly be analogous to the sublimation of a solid into a gas, and proceeds from the intermixture of molecules detached from the solid with those of the surrounding liquid. Such a process is promoted by rise of temperature, partly because the molecules of the still solid substance make longer excursions from their normal center when heated, partly because they are subjected to more violent encounter with the moving molecules of liquid." This theory, however, only relates to the initial stage of the process of solution, and does not sufficiently explain saturation or the influence of dissolved substances upon vapor pressure, specific heat, specific volume, etc. How far is it true that evolution of heat indicates chemical combination. Does the evolution of heat which often takes place on dissolving a solid in water, or on adding more water to its solution, indicate the formation of hydrates, *i. e.*, compounds of the dissolved body with water in definite proportions? Thomsen answers this question in the negative ("Thermochemische Untersuch.," tome iii., p. 20).

Take the case of sulphuric anhydride (SO_3). It is evident from the diagram exhibited that more than half the total evolution of heat occurs on addition of the first molecule of water to the solid substance; yet the succeeding molecules give quite an appreciable thermal change. At what point in such a curve should we be justified in setting up a distinction between the effect due to chemical combination and that due to other causes, such as the change of volume consequent on dilution or the possible loss of energy from the adjustment of the motion of the molecules of the constituents to the conditions requisite for the formation of a homogeneous liquid, or (though not in the present case) the decomposition of the compound by the water? In the act of solution of the solids, and especially of anhydrous salts in water, the volume of the solution is always less than the sum of the volumes of the solid and its solvent, with the exception of some ammonium salts, in which expansion occurs. Similarly, the addition of water to a solution is followed by contraction. This contraction may be due to mere mechanical fitting of the molecules of the one liquid into the interspaces between the molecules of the other (see Mendelejeff's abstract in *Journ. Chem. Soc.*, Feb., 1885, p. 114). This would probably not be attended by loss of energy. Or the contraction may arise from the readjustment of molecular motion already referred to.

If we know the coefficient of expansion of the liquid and its specific heat, we can calculate the amount of heat evolved for a given contraction. If this is done for sulphuric acid, and many other cases, it is found that, after accounting for the thermal change due to alteration of volume alone, there is a surplus of heat evolved which may really indicate some kind or some amount of chemical combination.

Thomsen has found that, as a rule, the heat of solution and of dilution are both either positive or negative. Of thirty-five salts examined, only four supply well-marked exceptions. However we may ultimately explain the anomaly exhibited by these salts, the fact remains that the heat evolved or absorbed during the admixture of any substance with water is in every case a continuous function of the quantity of water added. Similarly, the contraction which ensues on diluting an aqueous solution proceeds continuously, and the molecular volume of a salt in solutions of different strengths is continuously greater, the larger the amount of salt present. So that in none of these thermal or volumetric phenomena is any discontinuity observed, or any indication of the formation of compounds of definite composition, distinguishable by characteristic properties.

The question we are now considering, as to whether in a solution the solvent and the substance dissolved in it—or any portion thereof—exist independently of each other, is in some degree answered by the facts known as to the specific heats and vapor pressures. For instance, when water is added to a solution of sodium nitrate, the molecular heat of the resulting liquid seems to show that all the water added is influenced at least until a very large quantity is present. In this case one molecule of sodium nitrate can affect the movements of a hundred molecules of water, and probably more. It is also well known that the vapor pressures of water holding in solution almost any dissolved solid is less than the vapor pressure of pure water, and that the boiling point of a liquid is raised by the addition to it of any soluble, non-volatile substance. This fact of reduction of pressure can only be explained upon the hypothesis that there is no free water present at all; that is, that there is no water present which is not more or less under the influence of the dissolved substance.

What becomes of water of crystallization forms a part of the same question as to the relation of solvent to solvent. Observed facts lead us to infer that white copper sulphate, blue anhydrous cobalt chloride—and by analogy other salts which are colorless—retain their hold upon water of crystallization when they are dissolved in water. A very important observation has been made by Dr. Nicol, which bears directly upon this question. In his study of the molecular volumes of salt solutions, he finds that, when a salt containing water of crystallization is dissolved, this water is indistinguishable by its volume from the rest of the water of the solution. In the report presented to the British Association last year, the following passage occurs: "These results point to the presence in solution of what may be termed the anhydrous salt in contradistinction to the view that a hydrate, definite or indefinite, results from solution; or, in other words, no part of the water in a solution is in a position relatively to the salt different from the remainder."

These two statements, however, are not strictly consequent upon each other. The view seems preferable that (save, perhaps, in excessively dilute solutions) the dissolved substance is attached in some mysterious way—it matters not whether it be supposed to be chemical or physical—to the *whole* of the water. We cannot otherwise get over the difficulty presented by the hydrated salts, which give colored solutions, by the control of the vapor-pressure of the dissolved salt, and by the altered specific heat. With regard to water of crystallization, E. Wiedemann has shown that hydrated salts in general expand enormously at the melting-point; and the observations of Thorpe and Watts on the specific volume of water of crystallization in the sulphates of the so-called magnesium group show that, while the constitutional water occupies less space than the remaining molecules, each successive additional molecule occupies a gradually increasing volume. So that when a salt, with its water of crystallization, passes into the liquid state (either by melting or by solution in water), it requires a very slight relaxation of the bonds which hold the water to the salt for it to acquire the full volume of liquid water, while the water of constitution is not so easily released. And this conclusion accords with Nicol's observations on the molecular volumes of the salts when in solution

Now comes the question as to what determines the solubility of a substance. Why, for example, is magnesium sulphate very soluble in water, while barium sulphate is almost totally insoluble? With regard to salts, the following propositions seem to be true: 1. nearly all salts which contain water of crystallization

* Report of a discussion at the Birmingham meeting of the British Association.—*Nature.*

are soluble in water, and for the most part are easily soluble; 2, insoluble salts are almost always destitute of water of crystallization, and rarely contain the elements of water; 3, in a series of salts containing nearly allied metals, the solubility and capacity for uniting with water of crystallization generally diminish as the atomic weight increases.

The fusibility of a substance has also much to do with its solubility. Neither fusibility alone nor chemical constitution alone seems to be sufficient to determine whether a solid shall be soluble or not. But it may be taken as a rule to which there are no exceptions that when there is a close connection in chemical constitution between a liquid and a solid, and the solid is at the same time easily fusible, it will also be easily soluble in that liquid.

Salts containing water of crystallization may be considered as closely resembling water itself, and these are for the most part both easily fusible and easily soluble in water. But space is wanting for the discussion of the details of these matters, as well as of the relation of molecular volume to fusibility of solids

The fascinating character of the phenomena of supersaturation has attracted a host of experimenters, but no definite explanation has been generally accepted. In the opinion of the speaker, supersaturation is identical with superfusion. Supersaturated solution of, say, alum, thiosulphate of sodium melted in its water of crystallization, and fused sulphur at 100°, exhibit phenomena of exactly the same kind.

Finally, we are led to the consideration of what is meant by chemical combination. From the phenomena under discussion, and others, the conclusion seems inevitable that chemical combination is not to be distinguished by any absolute criterion from mere physical or mechanical aggregation; and it will probably turn out ultimately that chemical combination differs from mechanical combination, called cohesion or adhesion, chiefly in the fact that the atoms or molecules of the bodies concerned come relatively closer together, and the consequent loss of energy is greater.

FIFTY YEARS OF SANITATION.

ALTHOUGH Her Majesty did not commence her reign in the "good old times when George the Third was king," yet only seventeen years elapsed between his death and her accession, and thus her jubilee, which is to be celebrated next year, carries us a long way back toward the days which it is sometimes the fashion to praise to the disparagement of our own. During the next few months we shall be overwhelmed with comparisons between our own days and those of half a century ago, and every point of difference will be brought into high relief. But, as regards the comfort and happiness of the masses, no sharper contrast can be drawn than that presented by Captain Douglas Galton in his opening address to the Society of Arts.

Sanitation may not show a progress equal to that achieved in locomotion or metallurgy, but it is of far more general interest, as it comes home to immensely greater numbers. It matters only to a few that the journey can now be made from London to Edinburgh in nine hours instead of ninety, but every one is interested in the fact that immunity can be obtained from smallpox, which formerly was as common as measles. Health is the basis of happiness, and the healthier a people become, the happier they are, and thus every step gained in sanitary science distributes benefits to the entire community.

In order to understand how much we have gained during the present reign, we will go back to the commencement, and see how matters then stood, according to the picture drawn by Captain Galton. The long wars had ceased, and had been followed by a period of very severe depression, during which great social changes had taken place. Machinery had displaced much hand labor, and the workers, bred under the old system, were unable to adapt themselves to the new order of things. Food also was dear, and fevers were rife, the result being that, one person out of every eleven was a pauper, and one out of every 500 was committed for trial. Disease was as common among the laboring population in the country villages as it was in the most crowded and filthy districts in towns. In the latter the people were congregated in courts and alleys, and swarmed in cellars which were neither ventilated nor drained. In 1837 it was calculated that one-tenth of the population of Manchester, and one-seventh of the population of Liverpool, lived in cellars. Many of these were in unpaved courts filled with holes which formed receptacles for all the household slops of the neighboring tenements. The ground was sodden with filth, and the damp oozed through the reeking walls into the underground dwellings, where the children lay on the floor breathing a fetid atmosphere.

In the country the half-starved families crowded into miserable cottages, around which was piled the refuse of years, tainting the air, and almost obscuring the little light which could gain admittance at the small windows. In very few places was there a public water supply, and all that was required had to be fetched in pails. Often this came from polluted sources, and not unfrequently it was disgusting both in taste and smell. Water closets were unknown, and the privies discharged into cesspools, which from motives of economy were made leaky, in order that the liquid contents might escape, and thus save the expense of their removal. The vagrant population crowded into common lodging houses, which were under no kind of control, and were the centers from which epidemic disease was disseminated.

It was not only the poor who suffered from these evils, although, of course, they pressed most heavily upon them. The middle classes had to fetch their water from the common well, unless they happened to have one in their own garden, and even then it was probably contaminated with sewage, for the universal cesspool was never tight, and its contents saturated the adjacent ground. The fetching of water was looked upon as a matter of course years later than the commencement of Her Majesty's reign, even by persons of education.

As an example, we may point out the house to which George Stephenson retired to spend the evening of his life. This originally had a deep well, but the mining operations in the neighborhood and the constant pumping at the coal pits drained it, and when he occupied the premises, all the drinking water for a very large mansion had to be fetched from a spring a quarter of a mile distant, at the foot of the hill upon which the house was built. There was very extensive storage for rain water, but it was undrinkable, and all that was required for culinary purposes was carried by hand. Even in London, which had a water supply very early, matters were far from satisfactory, for up till 1852 the tidal part of the Thames was drawn upon, to some extent, and it needed only a glance at the banks to convince the most ignorant of the fearful contamination to which it was subject. Light, a most important factor in health, was excluded to a great extent, for every window was taxed until the year 1851. Vaccination was not known, while inoculation, which was being extensively tried, was believed to give rise to some of the epidemics of smallpox which periodically appeared in all parts.

We have not space to trace at length the steps by which the evils have been abated. The progress has been slow and difficult, and was rendered more so at first by the pernicious theories of political economy which were so diligently preached by the Manchester school. Free competition and non-interference with individual liberty are doctrines which cannot safely be applied to sanitary matters. No doubt in the long run these would lead to a survival of the fittest, but the process is fearfully wasteful of life. One of the most important steps in discovering the cause of disease was the civil registration of births, deaths, and marriages, including the causes of death. This was commenced on the 1st of July, 1837, just eleven days after the Queen's accession, and thus the jubilee year of this reign is the jubilee of the registration of disease. Registration not only forms the basis of scientific sanitary investigation, but acts as a powerful spur to its prosecution, and, accordingly, we find that it had not long been established before hygienic measures were vigorously recommended. Dr. Farr immediately proclaimed that it was possible to reduce the annual death rate by 30,000, and two years later the House of Lords instituted an inquiry into the cause of the great prevalence of disease. The Poor Law Commissioners were ordered to report, and a little later (1844) private associations were formed in all the large towns to encourage cleanliness among the working classes, by establishing public wash houses, and providing means for domestic cleansing. All the reports and recommendations, however, produced but little result, as there was no legal machinery for putting them expeditiously into action. But a force more powerful than either press or Parliament appeared in the land. The cholera, after devastating every country between ourselves and Northwest Hindostan, appeared in London on September 22, 1848. Everybody knew what it was, for in 1832–33 it had visited us, and snatched 16,437 victims, and it was not long before it demonstrated what were the conditions most favorable for its spread, for it followed the track of its previous progress.

It commenced in Bermondsey, close to the same ditch where the earliest fatal cases occurred in 1832. The first case which appeared in Leith took place in the same house and within a few feet of the very spot where the previous epidemic of 1832 commenced its course. In Pollockshaws the disease snatched its first victim from the same room and in the very bed in which it broke out in 1832. In fact, it confirmed most unmistakably the evidence already gathered regarding the unhealthy effect of filth, bad water, overcrowding, and polluted subsoil. Parliament applied itself to the test, and erected boards of health, armed with powers which can be best learned from the series of articles we are now publishing concerning them. This general act has since been supplemented by a large number of local bills, under which immense sums have been spent, and at present there is a liability of over 130,000,000*l.* sterling on this account, in addition to the debts which have been gradually liquidated.

Let us now turn to the results which have been attained by this work and expenditure. The death rate of London in 1838–42 was 25·57 per 1,000. In the five years of 1880–84 it was 21·01 per 1,000; and the deaths from zymotic diseases, which in the decade 1841–50 had averaged annually 5·29 per 1,000, were reduced in the years 1880–84 to 3·4 per 1,000. That is, a saving of 5·61 per 1,000 had been effected by sanitary measures. In other words, the sanitary improvements of the metropolis effected an annual saving of 4,604 lives during 1860–70; of 13,929 lives annually during 1870–80; and of 21,847 lives annually between 1880–84. In England and Wales the death rate from 1838–42 was 22·07 per 1,000; from 1880–84 it was 19 62 per 1,000, and the deaths from zymotic diseases, which averaged 4·52 per 1,000 in 1841–50, were reduced to 2·71 per 1,000 in 1880–84. In the decade of 1840–50 the average annual saving of lives in England and Wales from sanitary improvements was 7,789; in 1860–70 it rose to 10,481; in 1870–80 to 48,443; and in the five years 1880–84, the average annual number of lives saved by sanitary improvements has been 102,240.

This is a splendid result, but it comes far short of what it should be, and quite as much remains to be accomplished as has already been done. The community have provided good water and main drainage, and by doing so zymotic disease has been decreased one-half. But the other half yet remains to be extirpated, partly by keener scientific investigation of its more remote sources, but more particularly by a higher standard of cleanliness among the people. In spite of all that has been written and taught, the presence of unsatisfactory house drains is widely tolerated, and water is drunk out of cisterns which are loathsome both to sight and smell.

Overcrowding is almost as bad as ever, and will continue as long as the poor are thriftless and the middleman is greedy. More legislation is needed to repress those property owners who exact the last farthing of their rights and ignore their responsibilities. It is wonderful how these men thrive among a community possessed of a household suffrage. One would think that they would be the object of a popular agitation which would be irresistible. But misery always seems to vent its discontent in the wrong direction. When the people lived in damp cellars, immeasurably worse than the pigsties on a well-managed farm, they did not ask for cleanliness, water, or ventilation, but for the charter, and to gain this they raised riots and faced the troops, though it is difficult to see how it could have lessened the ills they endured. And now, when matters are changed, when good water is supplied to all and food is cheap, when the social condition of the working classes is immensely above that of their fathers, and even above that of the lower middle classes of fifty years ago, the murmur of misery, which might be a most potent factor for progress, is heard denouncing the capitalist and crying for State aid. The school board is opposed, the sanitary inspector is cheated, the free libraries act is shelved, and all such forms of a beneficent socialism are scouted, while a spurious, impossible variety, which can bring good to no one, finds many followers, and converts a popular pageant, like the lord mayor's show, into an armed demonstration on the part of the authorities.

The constant craving of the human mind for something better than it has is the engine for the regeneration of the world. During the last fifty years it has accomplished much, but not a tithe of what it might have done if it could only have been directed into more useful channels. If a popular leader could arise, and could gather the masses behind a banner inscribed with "*Sanitas sanitatum, omnia sanitas*," he would do more for the happiness and comfort of his fellow men than a dozen cabinets of party tacticians.—*Engineering.*

THE

Scientific American Supplement.

PUBLISHED WEEKLY.

Terms of Subscription, $5 a year.

Sent by mail, postage prepaid, to subscribers in any part of the United States or Canada. Six dollars a year, sent, prepaid, to any foreign country.

All the back numbers of THE SUPPLEMENT, from the commencement, January 1, 1876, can be had. Price, 10 cents each.

All the back volumes of THE SUPPLEMENT can likewise be supplied. Two volumes are issued yearly. Price of each volume, $2.50 stitched in paper, or $3.50 bound in stiff covers.

COMBINED RATES.—One copy of SCIENTIFIC AMERICAN and one copy of SCIENTIFIC AMERICAN SUPPLEMENT, one year, postpaid, $7.00.

A liberal discount to booksellers, news agents, and canvassers.

MUNN & CO., Publishers,
361 Broadway, New York, N. Y.

TABLE OF CONTENTS.