MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. CII.

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15, 22 and 29 *April*, 1890.

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CORRIGENDA.

Vol. xcix. p. 305. The footnote was inserted under a misapprehension and should be expunged.

Vol. c. p. 403, line 5, *for* "24th of May" *read* "26th of May."

„ ci. p. 39, line 2, *for* "1866" *read* "1886."

„ „ p. 211, line 24, *for* "1887" *read* "February, 1888."

„ „ p. 212, line 22, *for* "pthutukawa" *read* "pohutukawa (*Metrosideros tomentosum*)."

Vol. ci. p. 213, lines 23 and 24, *for* "6 feet by 3 feet" *read* "6 inches by 3 inches."

„ „ p. 214, line 33, *for* "chambers" *read* "chamber."

„ „ p. 215, line 1, *for* "float" *read* "floor."

„ „ „ line 23, *for* "culvert" *read* "penstock."

„ „ p. 216, line 29, *for* "12 feet by 8 feet" *read* "12 inches by 8 inches."

„ cii. p. 102. The numeral "·3" on the cut (scale of pitch-ratios) should be "·8."

„ „ p. 104, line 6 from bottom, *for* Figs. 1 and 2 *read* Figs. 3 and 4.

„ „ p. 105, line 2, *for* "Fig. 3" *read* "Fig. 4."

THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1889-90.—PART IV.

SECT. I.—MINUTES OF PROCEEDINGS.

15 April, 1890.

SIR JOHN COODE, K.C.M.G., President, in the Chair.

(*Paper No. 2460.*)

"The Application of Electricity to Welding, Stamping, and other Cognate Purposes."

By Sir FREDERICK BRAMWELL, Bart., D.C.L., F.R.S., Past President Inst. C.E.

IN speaking of the constructive part of Civil Engineering, it is a mere truism to say that nothing is of more importance than the efficient union of the materials of which a structure is composed; especially is this true of those parts of a structure which have to bear tensile stresses; and having regard to the important and gradually increasing part which iron or its ally (or alloy) mild steel is taking in engineering construction, any process which embodies a reasonable hope of improving the means of uniting pieces of these metals, is well worthy of the attention of the members of the Institution of Civil Engineers.

Although large structures of wrought-iron and of mild steel commonly have their parts united by bolting, or by riveting, and although much ingenuity has been expended in so arranging and proportioning riveted joints, as to obtain in the joint the greatest percentage of the strength of the material, nevertheless cases occur in all large structures where the union of these metals by welding becomes almost a necessity, or if not a necessity, a matter of convenience and economy. There is very little doubt that structures would be so designed as to go together by means of bored eyes, fitted with turned pins, rather than by riveting, if welding could be effected with greater ease, but above all, with greater certainty of a good result.

Wrought-iron, in addition to its many other merits, has that of being, *par excellence*, the weldable metal; mild steel also possesses this merit, but there is always a feeling of doubt about a weld. It may be fair to the eye; it may pass the few tests to which it can be put, without injury in the very act of testing, and yet it may have such serious latent defects as could not exist in the case of a riveted joint. Nevertheless welds are of necessity largely trusted. No better illustration of this can be given than that of a common chain, each one of its manifold links having a separate weld.

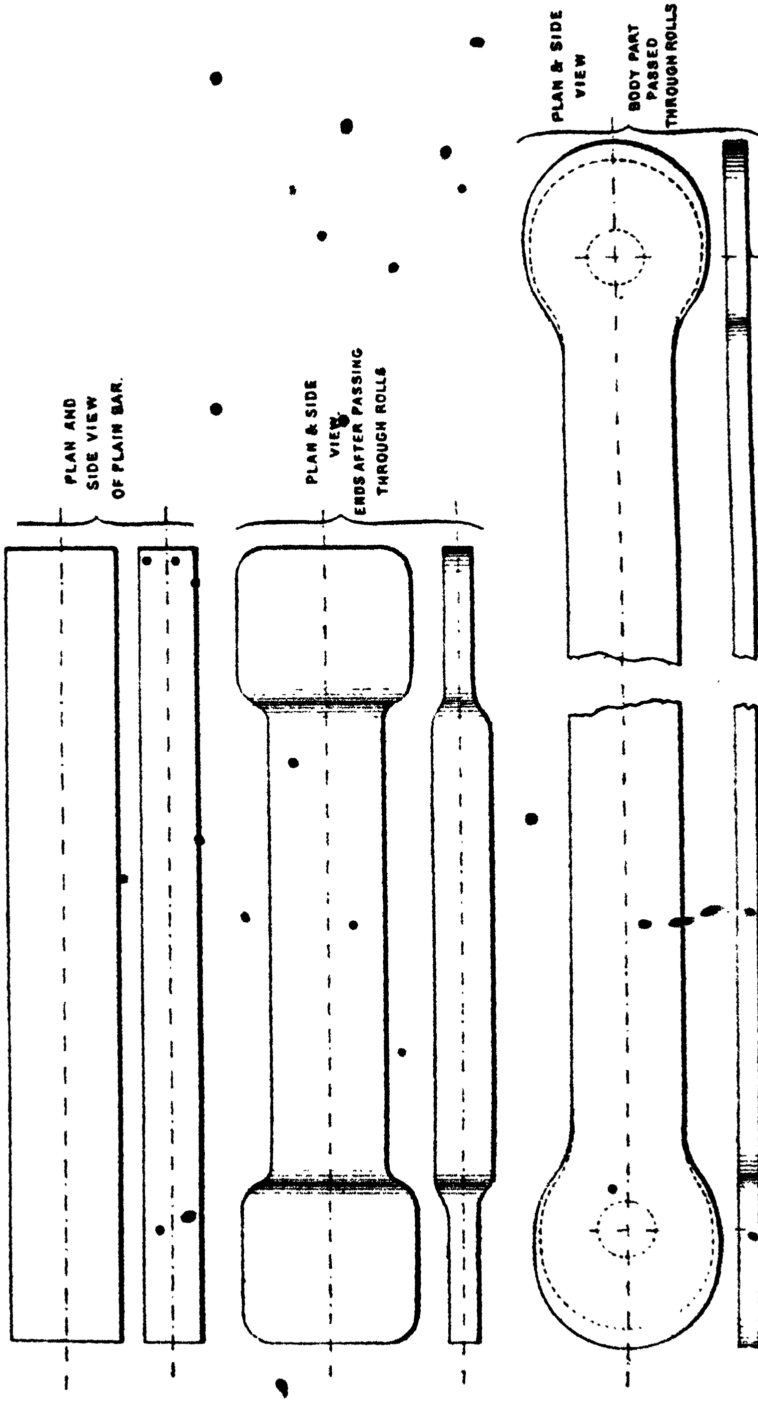
In the early days of building suspension-bridges, the links—unless the wasteful process of cutting away a large portion of the bar was resorted to—were made by forming the eyes separate from the bar, and by welding them on. To obviate these difficulties, as long ago as 1845, Mr. Howard, of the firm of Howard and Ravenhill, of the King and Queen Ironworks, Rotherhithe (who was, be it said in passing, the inventor of the quicksilver engine), devised a plan which, while avoiding the necessity of welding on the eyes, avoided also the waste of material before alluded to. This plan is illustrated in *Figs. 1* and *2*. It will be seen from *Fig. 1* (which shows the various stages of the manufacture, from the plain bar to the finished link), to have consisted in taking a bar much thicker, and, therefore, very much shorter than the finished dimensions of the intended link, and in passing this short, thick bar, sideways through a pair of rolls. These rolls (*Fig. 2*) had their operative parts at the two ends only, these parts being made of any desired diameter, but the remainder of the rolls, *i.e.*, all their middle portions, were of a diameter so much smaller than that of the ends that when the bar was fed through between the rolls sideways, its extremities only were subjected to the rolling pressure, and by this pressure were reduced in thickness to one slightly greater than that of the finished eye, and were widened out to a breadth somewhat in excess of the diameter of that eye, while the middle part of the bar was left of the original width and thickness. In this condition the bar was passed lengthways in the ordinary manner through a pair of plain rolls, and was thus brought to the proper length, thickness, and width to form the completed link, the excess of metal around the eyes at the ends, as shown by the dotted lines, being afterwards slotted off.

Large numbers of links for important bridges, notably the bridge over the Dnieper at Kieff, in Russia, by the late Mr. Vignoles, were made in this manner.[1]

Within the last few years a plan of "upsetting" the ends of the bars by mechanical means so as to obtain the requisite material for

[1] Minutes of Proceedings Inst. C.E., vol. viii. p. 275.

Fig. 1.



Suspension-Bridge Links in various Stages of Manufacture on Howard's Principle.

the formation of the eye has been introduced in the United States. The Author saw this plan in operation when over there, either on

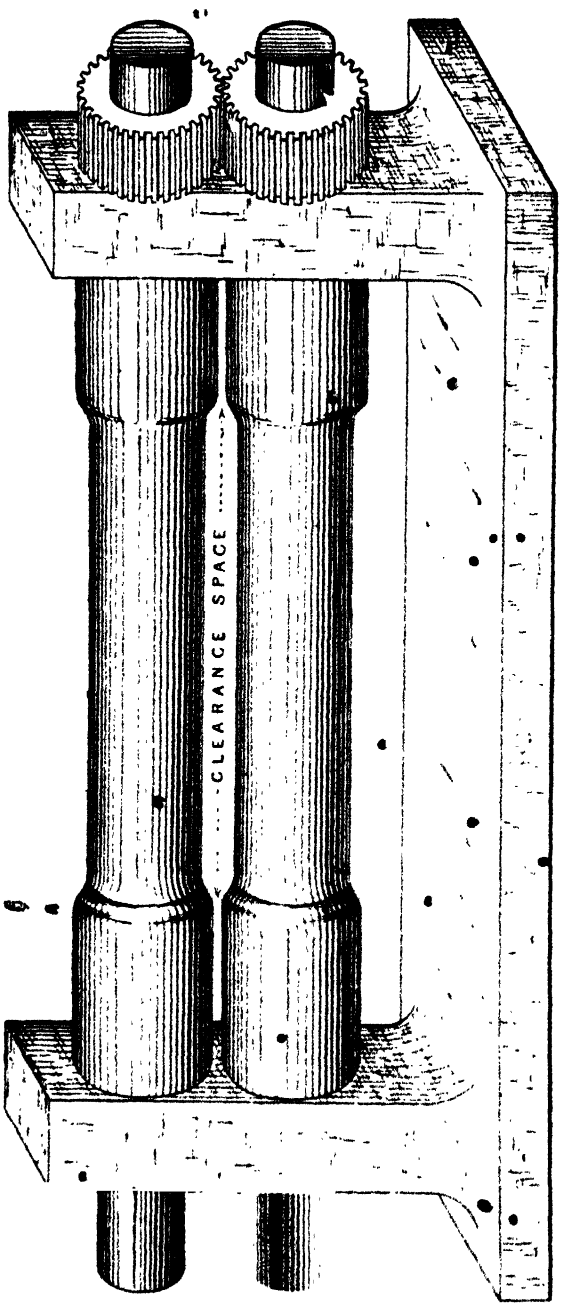


Fig. 2.

DIAGRAM SKETCH OF HOWARD'S ROLLS FOR ROLLING THE EYES OF SUSPENSION-BRIDGE LINKS.

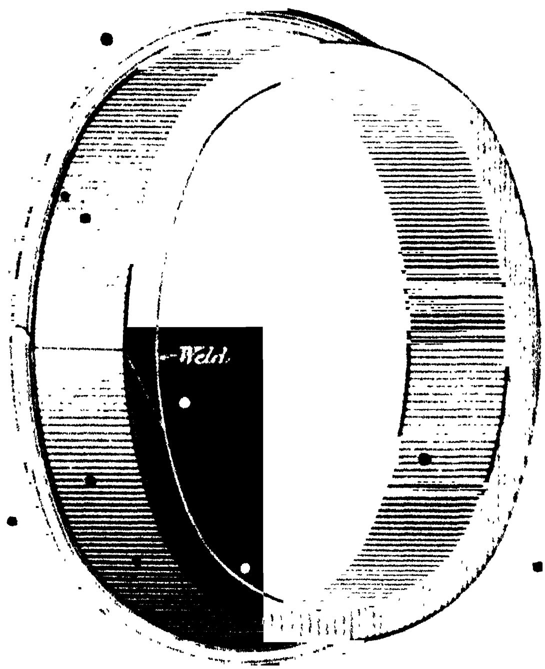
the occasion of his visit in 1882 or on that of his following visit in 1884.

References to the various modes which have been suggested or adopted for making such links as these, will be found in the Paper by Mr. T. C. Clarke, M. Inst. C.E.[1]

The foregoing modes of making links with enlarged ends for suspension bridges, without the use of welds, are brought forward as evidences of the amount of suspicion that attaches to a union by welding, and as instances of the efforts that have been made to obviate the necessity for this process.

Although imperfection in a weld may arise from insufficient heat, or indeed from an excess of heat, or from the application of inadequate power (either in the form of hammering or of pressure)

Fig. 3.



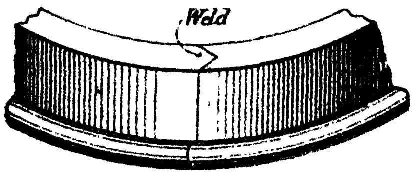
Ordinary Scarf-Weld.

to bring the heated surfaces together, it is probable that by far the greater proportion of defective welds arises from the presence of some foreign body between the surfaces to be welded—the oxidation of the metal; the formation of slag, by reason of the use of sand or other means employed to prevent oxidation; the union of sulphur in the coal with the iron surfaces; absolute particles of the fuel—in a word, as it is expressively called, "dirt" of some kind or another.

[1] Minutes of Proceedings Inst. C.E., vol. liv. p.

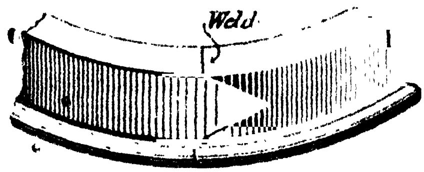
Attempts have been made to obviate these difficulties, by employing gaseous, or liquid fuels, and, in rare cases, by the removal

Fig. 4.



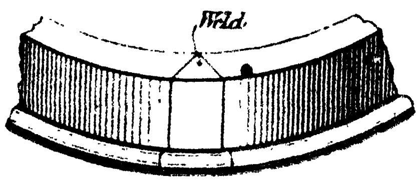
Bird's-mouth Weld.

Fig. 5.



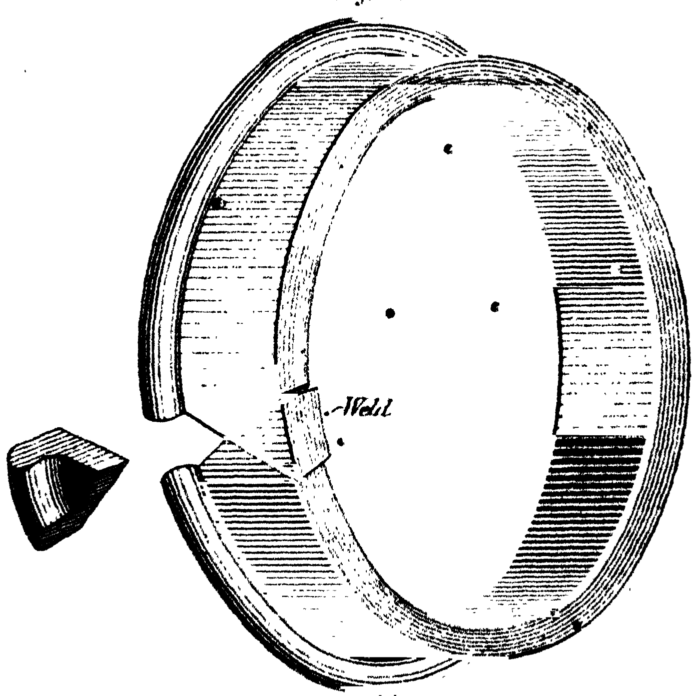
Bird's-mouth Weld.

Fig. 6.



Single-Wedge Weld.

Fig. 7.



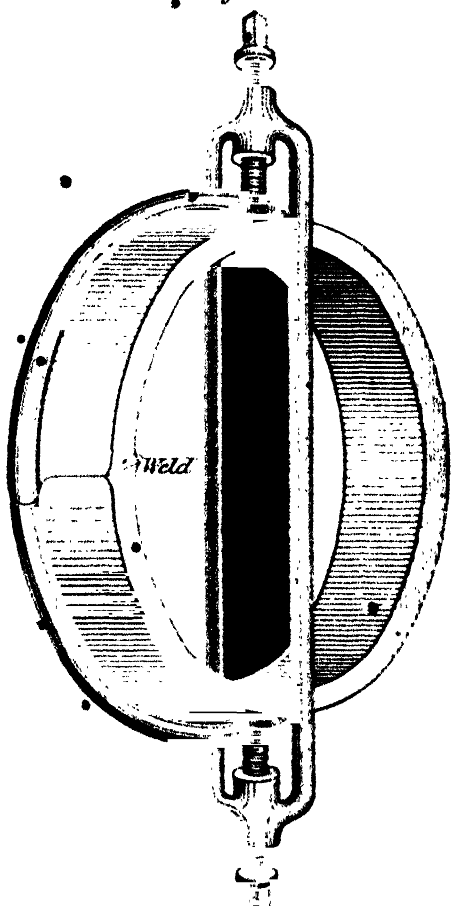
Double-Wedge Weld.

of the oxide of the metal from the surfaces, by turning or planing, and the formation of the surfaces so that the one part is "housed" within the other, thus preventing the introduction of any foreign matter between them.

Commonly the mode of making a weld is by hammering the parts which are to be joined; but that mode is occasionally departed from, and steady pressure, produced by a screw—or, in these days, hydraulically—is applied.

Allusion may be permitted to the welds that were succes-

Fig. 8.



BUTT-WELD.

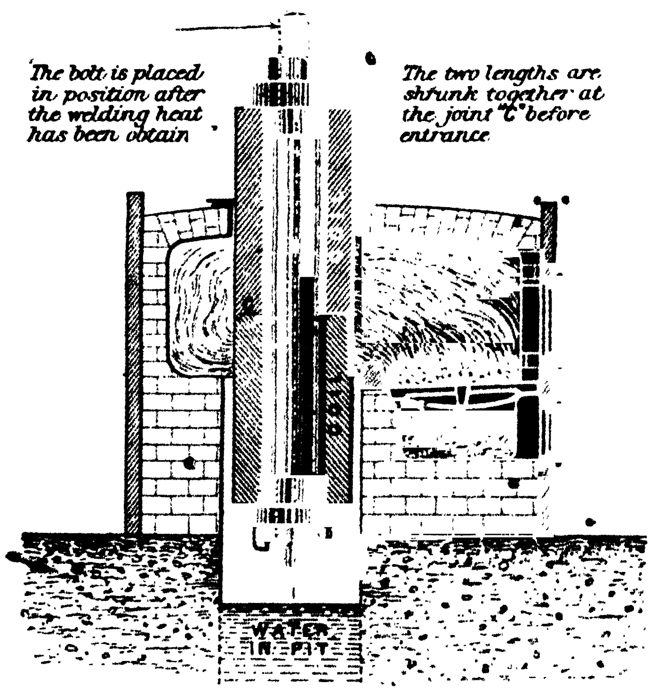
sively employed for the welding of railway tires in the days prior to the present system of making these tires by continuous rolling, and in the hoop form. These comprised an ordinary scarf weld (*Fig. 3*), where the two ends of the bar, having been previously "upset," were scarfed and brought together, heated and hammered; bird's-mouth welds in both directions (*Figs. 4* and *5*); single-wedge welds (*Fig. 6*); and the double-wedge welds

(*Fig.* 7). The last was a weld very much used for engine tires.

In all these cases hammering was employed; but for carriage-tires, at all events, the butt-weld (*Fig.* 8) was used, and pains were taken to draw the edge of one portion over and around the other portion, so as to "house" the surfaces to be brought into contact, and thus to prevent the introduction of "dirt."

The latest weld therefore was of the "butt" character, and pressure was applied, in this case by means of a screw, to bring the surfaces together, and was so applied while the parts

Fig. 9.



SKETCH SHOWING MODE OF WELDING BIG GUN TUBES.

remained in the fire, resulting in a considerable upsetting and enlargement at the joint, which was afterwards brought to shape by hammering.

Many years ago, in the early days of wrought-iron ordnance, where it was desirable to have in one piece a wrought-iron tube so long in relation to its diameter that it would have been difficult to have welded it up as a single coil, it was made by welding two coils together, each of about half the length of the desired tube. One end of one coil was faced in the lathe and was left with a slight projection, or spigot, and one end of the other coil was also faced, but was made with a shallow recess to receive the spigot; the two coils were put end to end with the spigot in the recess and then the tube was placed in a furnace properly constructed to bring it, at the faced parts, to a welding heat. Screw pressure was then applied to force the two coils together, and thus a butt weld was effected, the surfaces of which, having first been rendered clean, metal and metal, were so arranged as to prevent the access of any deleterious matter from the fire in the act of heating.

A diagram of this arrangement is shown in *Fig. 9.*

It need hardly be said that every one of the modes of heating that were employed, involved that the heat should proceed from the outside, inwards, with the result that, as is occasionally said of joints of meat, the outside might be "burnt," whilst the inside was "raw." There were also the chances of inadequate heat, of an excess of heat, and, as has already been stated, of the presence of "dirt" in the weld.

Moreover, there was the difficulty of ascertaining to what state the heat had attained; commonly in small welds the pieces were withdrawn from the fire, with the consequent risk of picking up "dirt" during re-introduction.

Among the desiderata for heating for welding purposes are, that the mode adopted shall be one admitting of uniform heating throughout the sectional area to be welded; that shall admit of absolute regulation of the heat; that shall be free from the possibility of introducing either particles of fuel or gases between the welding surfaces, and shall admit also of complete inspection during the time the heating is going on. All these desiderata are afforded by electrical heating.

As regards the power of an electric current in passing through substances to develop heat, the most familiar instance is probably that of the carbon filament of a glow lamp, such as are now so largely used in theatres, in clubs, and in private houses.

It seems but a very short time, since Mr. Henry Wilde, of Manchester, first showed by the use of one of his dynamos, having its field magnets excited by a separate dynamo, how he was able to heat up pieces of iron wire of as great a length as 15 inches, and of $\frac{1}{4}$ inch in diameter.[1] Now, as will be shown to the meeting, it is possible to electrically heat up to the welding-point, and, indeed, beyond it, sections of iron having eighty times as great an area

[1] Phil. Trans. 1867, vol. 157, p. 106.

as those with which Mr. Wilde dealt, and, were sufficient power at hand, these sections could be almost indefinitely enlarged.

It is common knowledge that electrical energy is compounded of electromotive force or potential, or preferentially "pressure," multiplied into the amount of the current—or (as with water, when used for power purposes), the pressure multiplied into the quantity.

Whenever this electrical energy has to pass through a conductor, the resistance of that conductor to its passage destroys a certain portion of the electrical energy, which energy so destroyed reappears in the form of heat, and must appear in the very conductor which has been the cause of the destruction of the electrical energy. Therefore the amount of heat produced must be that which is the thermal equivalent of the electrical energy destroyed. What the temperature will be—and in most cases it is the temperature reached by the conductor, as the result of the passage of a given quantity of current, which is of importance—depends not only upon the heat-units produced, but upon other considerations. This question will be dealt with hereafter.

Although electrical energy is represented by the multiplication of the pressure into the current—it will be found that the heating effect of any given current is independent of the pressure.

Take for example three glow lamps in series, and assume each of them to be a 33-volt lamp, needing say 99 volts to pass the current through the three lamps; then it is obvious that, after passing through the first lamp, 33 of the volts will have disappeared, and the pressure at the point of entrance of the current, into the second lamp, will be 66 volts, and similarly at the point of entrance to the third lamp will be 33 volts. The lamps being in series, the current will be the same in all, and the illuminating power (the index of the temperature, and, in this case, of the heat) will be the same in all three lamps, because the same amount of electrical energy has been absorbed by the third lamp in the fall of the electrical pressure from 33 volts to zero, as was absorbed in the first lamp, in the fall of the pressure from 99 volts to 66 volts. Again, take the case of a piece of wire, say 3 feet long, heated by an electric current, and suppose the current enters at 99 volts pressure and leaves at zero, obviously at the end of 1 foot of the wire the pressure will have dropped to 66 volts, at the end of 2 feet to 33 volts; but the same current goes through and therefore the heating effect is uniform from end to end.

To pass to another subject—the heat produced in relation to the current employed—take the following instances. Assume a wire of a length of 1, and of such material that 100 volts will send through it 12 amperes, 100 × 12 = 1,200 of electrical energy (*i.e.*, 1,200 watts); then assume this 1,200 of electrical energy will be destroyed and will be converted into heat in the length of 1. Assume next that the wire be reduced to a length of ½; then the resistance being halved, and the initial electrical pressure remaining the same, the amperes which pass through will be doubled, = 24, and the watts will be 100 × 24 = 2,400: this loss of electrical energy will be reproduced as heat in a wire of only ½ length, and therefore the effect per unit of length will be fourfold. Again, let the wire be made of a length of 2; then the resistance being doubled, the amperes (if the initial electrical pressure remains the same) will be halved, and the watts will be reduced to 100 × 6 = 600 distributed over a length of 2, and therefore the heating effect per unit of length will only be one-fourth of that which obtained when the wire was of a length of 1, *i.e.*, the heat per unit of length varies as the square of the current.

Although it will have to be reverted to, it will be well here to point out that, bearing in mind the foregoing considerations, it is clear that in any apparatus intended to utilize heat produced by electricity, the construction to be sought, is one wherein the electrical energy in its passage through the metal to be heated, exists in the state of low pressure and of large current, and not in the condition of large pressure and small current.

As regards the heating effect of any given current upon different materials: if there were an absolutely perfect conductor, which offered no resistance to the passage of an electric current, no amount of electrical energy could heat it, because no extent of conductor could destroy any part of that electrical energy. On the other hand, in the case of a material absolutely impermeable to an electric current, it need hardly be said that no heating could result, as no current could pass.

Leaving the consideration of these two impossible or practically impossible, materials, and going to the domain of the practically possible, it is found that a piece of ordinary iron, 1 foot long and 1⅛ inch diameter, or having 1 square inch of sectional area, will at usual atmospheric temperatures of, say, 60° Fahrenheit, offer so much resistance to the passage of 10,000 amperes of current as to reduce the electric pressure in passing through by some half volt = 5,000 watts, or, in other words, to destroy in every second of time 3,700 foot-lbs. of electrical energy demanding in substitution 4·5 units of heat to be developed per second.

A similar bar of German silver would destroy say 7,700 foot-lbs., involving the production of about 10 units of heat per second; while a similar bar of silver would destroy only 515 foot-lbs. of electrical energy, involving the production of 0·66 of a unit.

Fortunately the materials commonly needed to weld—iron and steel—hold a very happy position in the scale of metals, for the purposes of being electrically heated.

The temperature is imported as a condition in the foregoing

Fig. 10.

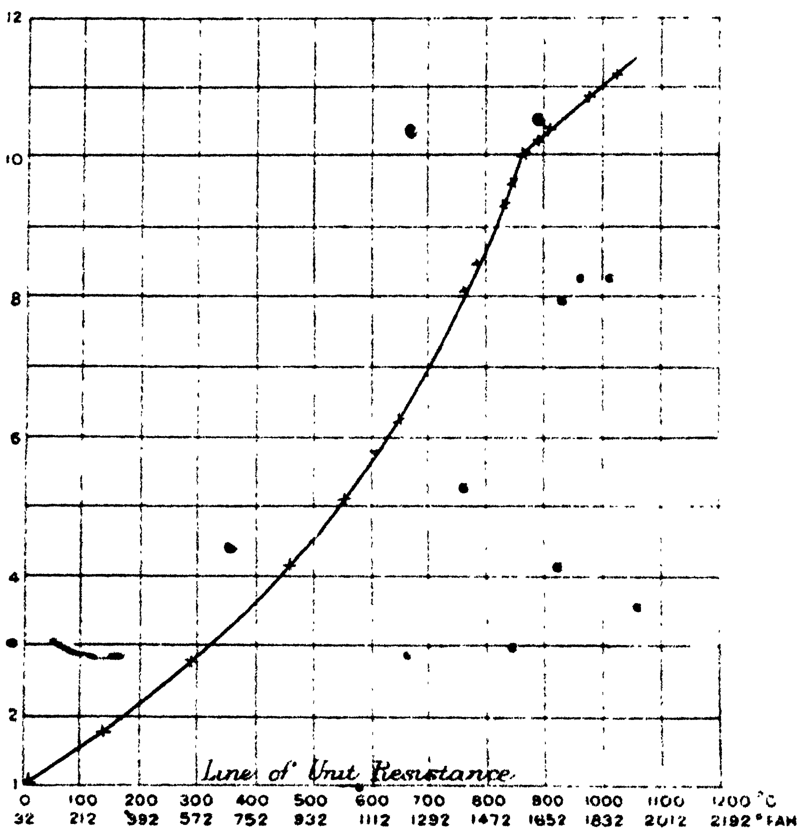


Diagram of Increase of Resistance due to Increase of Temperature in Soft Iron Wire (Hopkinson, Phil. Trans., 1889, p. 462, Plate 19).

statements, and necessarily so, as the resistance increases with the rise of temperature.

Among those who have studied the subject of the influence of temperature on the resistance of conductors is Dr. Hopkinson, and the results he has obtained are published in the Philosophical Transactions for the year 1889. On page 462 Dr. Hopkinson says, in reference to the experiments relating to Curves XXXV., XXXVI., and XXXVII., shown on Plate 19 (reproduced in *Figs. 10, 11,* and *12*):—

"These experiments were made in a perfectly simple way. Coils of very soft iron wire, pianoforte wire, manganese steel wire, and copper wire were

Fig. 11.

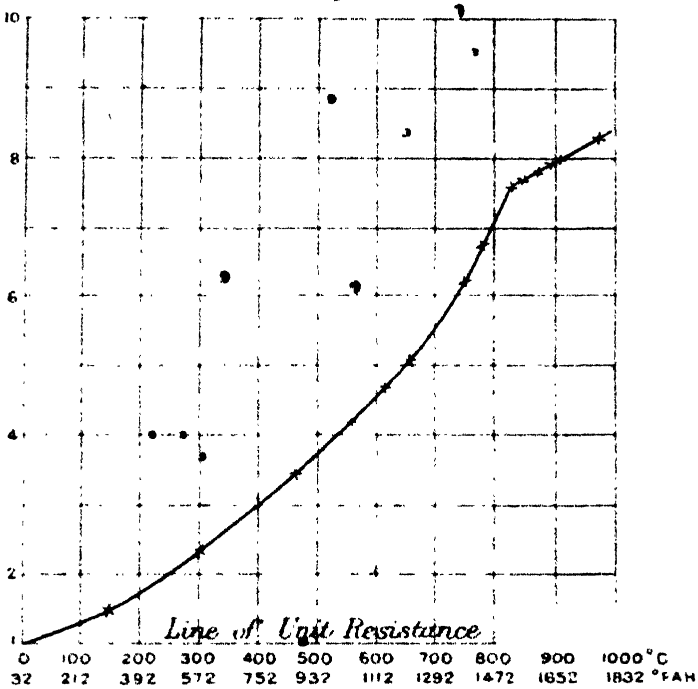


DIAGRAM OF INCREASE OF RESISTANCE DUE TO INCREASE OF TEMPERATURE IN PIANOFORTE WIRE (Hopkinson, Phil. Trans., 1889, p. 462, Plate 19).

Fig. 12.

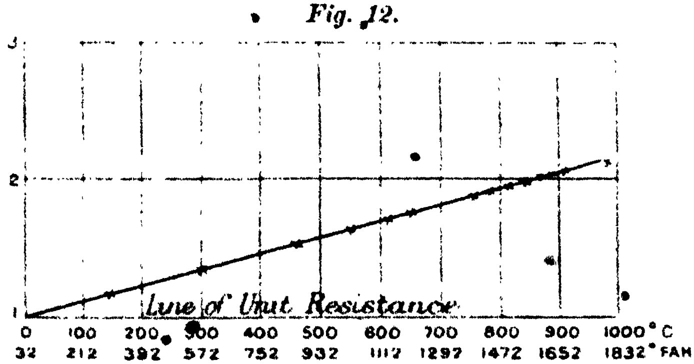


DIAGRAM OF INCREASE OF RESISTANCE DUE TO INCREASE OF TEMPERATURE IN MANGANESE STEEL WIRE (Hopkinson, Phil. Trans., 1889, p. 462, Plate 19).

insulated with asbestos, were bound together with copper wire so placed as to tend by its conductivity for heat to bring them to the same temperature, and were placed in an iron cylindrical box for heating in a furnace. They were heated with a slowly rising temperature, and the resistance of the wires was successively observed, and the time of each observation noted. By interpolation the resistance of any sample at any time intermediate between the actual observations could be very approximately determined. The points shown in Curves XXXV., XXXVI., XXXVII., were thus determined. In these curves the abscissæ represent the temperatures, and the ordinates the resistance of a wire having unit resistance at 0° C."

The limit of the temperature, therefore, to which a metal can be raised by the passage of a current through it, will depend primarily upon this, that the heating of the metal will so increase its resistance as the temperature is increased, that the quantity of current flowing through it—the initial pressure being constant—will be reduced until a point is reached at which equilibrium is obtained, the temperature attaining its maximum when the losses by radiation, conduction, and convection, equal, in a given time, the increment of heat arising from the destruction of electrical energy in that time, a maximum which can only be increased by an augmentation of the initial pressure.

This increase of resistance to the passage of the current, as the temperature increases, is of great utility in electrical welding. Consider the two ends of bars to be welded, mere ordinary rough surfaces, the first contact is made upon numerous points, through these the current passes, and they become rapidly heated, and offer more resistance. As endway pressure is applied, the surfaces in contact become of larger and larger area. The greater current seeks those parts which, although in contact, are at a lower temperature, and this goes on until contact, and uniform temperature, are obtained all over.

Having regard to the foregoing considerations, it is impossible to say, as an abstract proposition, what number of amperes are required to be sent through a given section of iron, say 1 inch square, in order to raise it to a welding temperature, the fact being that the heat is cumulative, and thus "time," has to be taken into account. Assuming that there were no losses by radiation, &c., and leaving out of account the increase of resistance due to the rise of temperature, a current of 1 flowing through 1 inch section of iron would, at the end of four minutes raise it to the same temperature as that to which it would be raised by a current of 2 flowing through it for one minute. This will be shown by passing a comparatively small current through a piece of iron, and observing for a considerable time the gradual increase of temperature; then, when a maximum appears to have been obtained and the increase to have ceased, from the accession of heat being no more than sufficient to supply the dissipation, the iron will be surrounded by a casing of asbestos, which is not a very good conductor of heat, and this very same current will then go on adding and adding to the temperature until again the dissipation under the new circumstances at the higher temperature will balance the increment of heat.

As the particular form of electrical energy needed to produce heat, is that of large current and low pressure, it is clear there must be very great difficulty, amounting almost to a commercial impossibility, of transmitting electrical energy in such a form over any but very short distances, for, unless the conductors were of enormous size, they themselves would be injuriously heated by the passage of the current; and, moreover, the pressure to drive these large currents, through any considerable length of conductor, would be so large a percentage of the working pressure, as to add very greatly to the power required.

For these reasons it is desirable that the electrical energy should only take the form of large current and low pressure, in the very neighbourhood of the welding-machine itself. A mode of accomplishing this is to bring the dynamo and the welding-machine into one structure. Photographs of such machines are on the table. But probably for general purposes, and for use at many separate points in a factory, it will be more convenient to adopt the plan wherein the electric energy is developed by the dynamo in the form of considerable pressure and of small current, admitting of ready transmission by conductors to the various welding-machines throughout the factory, and then the conversion, by means of transformers, of this condition of electrical energy into the needed condition of low pressure and of large current.

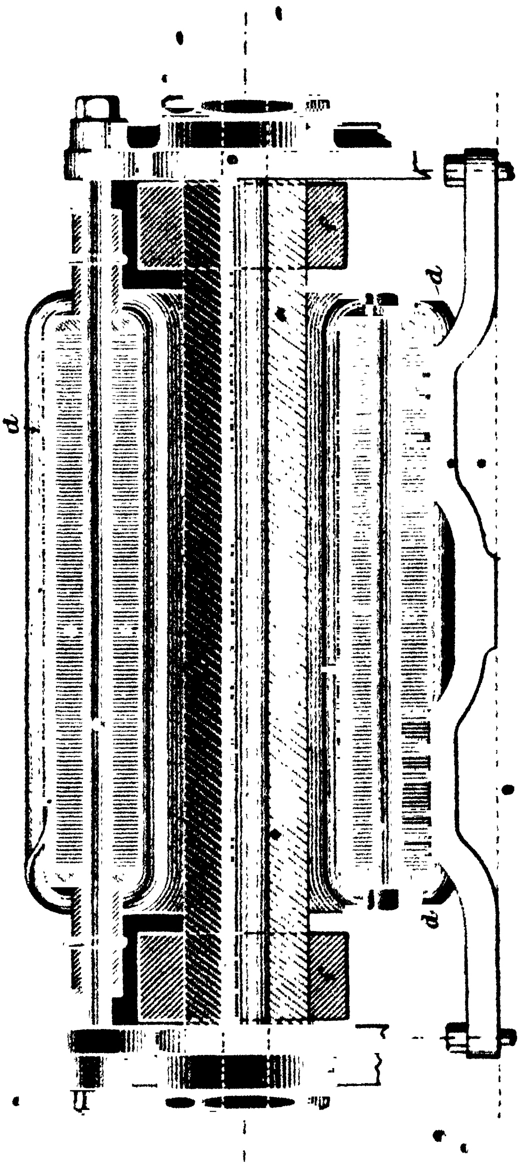
A machine for welding, thus constructed, is shown in front and end elevation in *Figs. 15* and *16.*

This machine—and others having modifications to suit them for different classes of work—embody the results of the labours of Elihu Thomson, who is so well known for his scientific attainments and for the many improvements he has made in connection with electricity.

A suitable framework supports the various parts, and maintains the objects under operation at a convenient working height. The high-pressure current ("alternating") arrives and departs by leads (as shown on *Fig. 16*), embracing in its course the transformer. This transformer is seen in longitudinal and cross-section in *Figs. 13* and *14.*

The transformer consists of a hollow cylinder or sleeve, *c c*, built up of disks of wrought iron, insulated by paper, round about the walls of which cylinder is wound longitudinally the insulated copper wire conductor *d d d*. In the particular machine under consideration (that which is now before the meeting) the wire makes in all seventy-two convolutions lengthways around the cylinder. In the space left in the interior of the inner

Fig. 13.

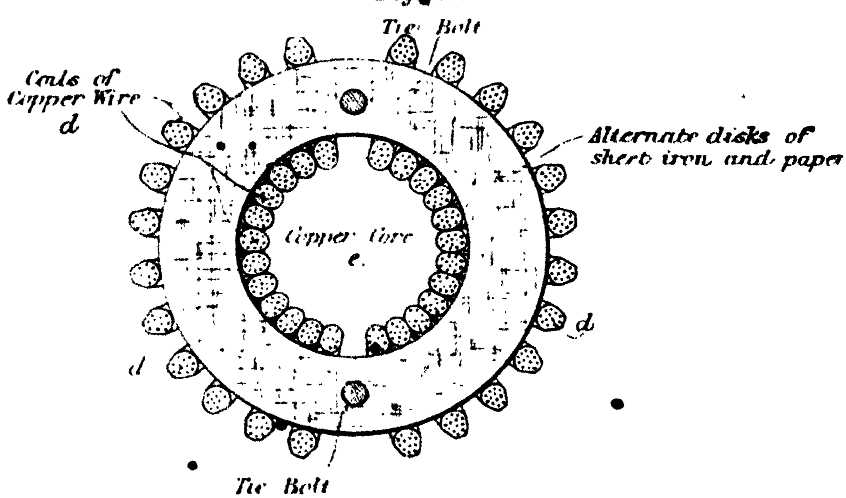


Longitudinal Section through Transformer.

parts of the convolutions, there is placed a central longitudinal hollow copper core *e*, to the ends of which are attached the main copper conductors *f f*. It is by this arrangement that the high-pressure current is caused to set up an induced low-pressure current, *i.e.*, is in effect "transformed" into the needed low-pressure current of large quantity, and is conveyed to the material to be heated. This conveyance is effected by the contact between the copper conductors *f f* and the gun-metal jaws *g g*, each provided with a binding screw to grasp the object to be welded or heated.

Reverting to the diagrams of the machine, *Figs. 15* and *16*, it will be seen that one of the holding jaws *g g*, in addition to sliding on the prolongation of the conductors *f f*, is guided on a bar *h*, along which it can slide, the other jaw being fixed so as to prevent its endway movement. The operative jaw, which gives the endway pressure, has its position controlled by the screw *j* in the hand-wheel *k*, by which the rapid setting up, and also the withdrawal

Fig. 14.

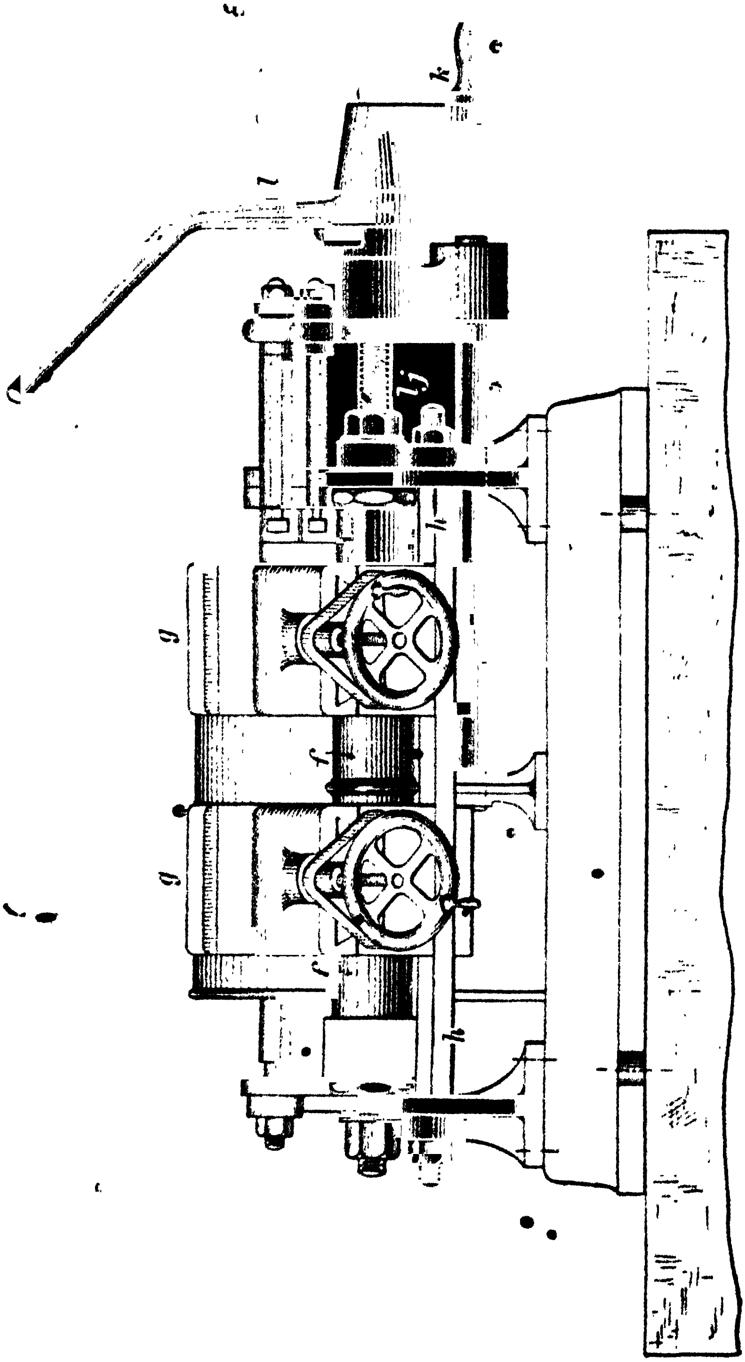


CROSS-SECTION THROUGH TRANSFORMER.

of the pieces from contact, the one with the other, can be effected, while the final pressure is given by the ratchet lever arrangement *l* operating upon the same screw *j*. The jaws are bored up, to admit of the passage of water through them, and the flow is maintained by means of india-rubber pipes, but this provision is only necessary in case of long-continued working.

With this arrangement of machine the electric current is conveyed by conductors of large area, and of admirable conducting power, to the pieces to be heated, and very near to the ends of those pieces; that is to say, the distance the current has to travel is short, and thus the effective head or pressure needed to drive the current through is low; some 3 inches only, or even less, of the pieces to be welded are heated up, 6 inches could, of course, be equally well heated up by the same current, but if there no other resistance than the metal being heated, then the operative

Fig. 15.



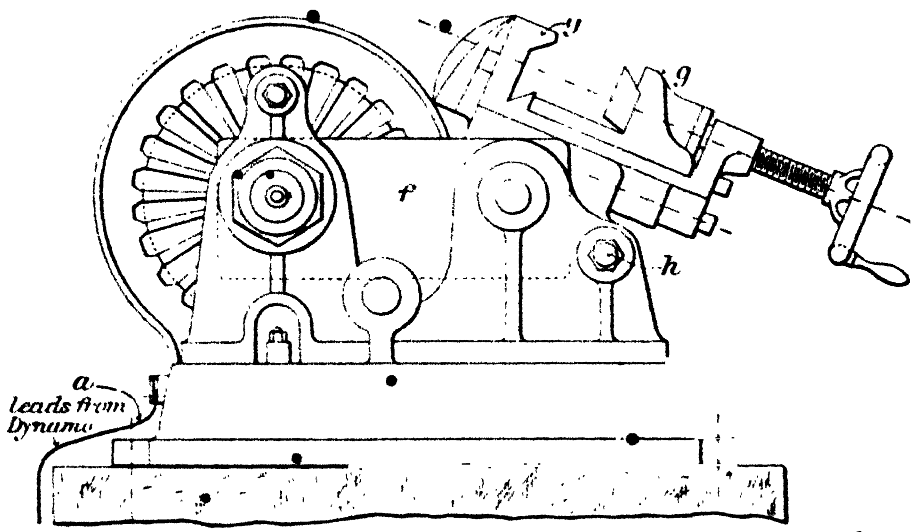
FRONT ELEVATION OF LARGE WELDER.

electric pressure would have to be doubled and the HP. would be doubled.

The dynamo used in conjunction with this particular machine is an alternating-current dynamo, of the Thomson Welding Company, and is called a 40,000 watt machine. This is shown in front and end elevation in *Figs. 17* and *18*. Its field-magnets are excited by a small Thomson-Houston dynamo.

To regulate the current which is needed for the particular work under operation, there are provided:—First, an arrangement shown in sectional elevation and plan in *Fig. 19* and *20*, and in the detail section, *Fig. 21*, by which a variable resistance can be put into the circuit between the exciting dynamo and the field-

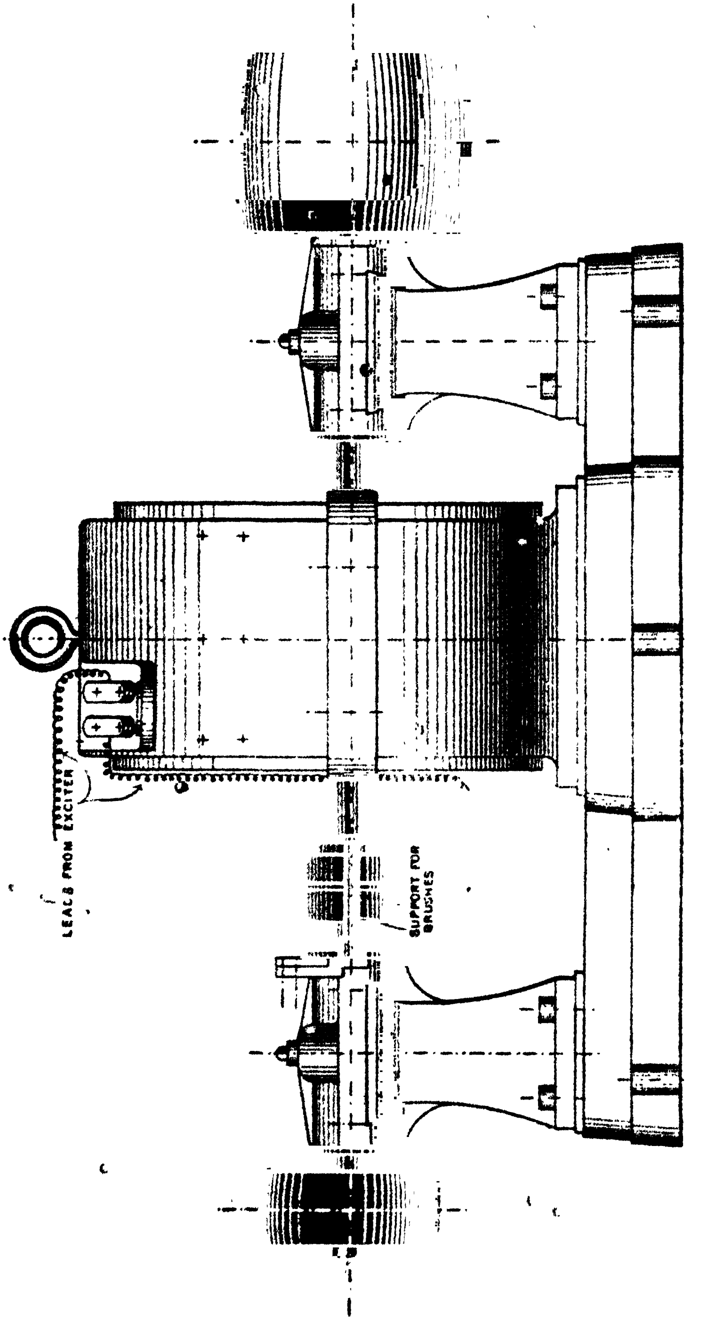
Fig. 16.



END ELEVATION OF LARGE WELDER.

magnets of the principal dynamo; second, a switch placed close to the machine by which the current can be cut off altogether. The resistance consists of a light vertical cylindrical case, having slate ends, and containing a number of German silver wire coils running from top to bottom of the case, and at the top passing through the slate insulation and terminating in metallic blocks insulated in a ring. A central non-conducting spindle carries a handle and an arm which bears on this top ring, and is in contact with the underside of a metallic ring above, and according to the position of the arm, any number of these vertical wires can be put into the circuit to add to its resistance. Both the handle which deals with the exciter currents, and the switch by which the current can be cut off altogether, are brought within easy grasp of the operator.

Fig. 17.

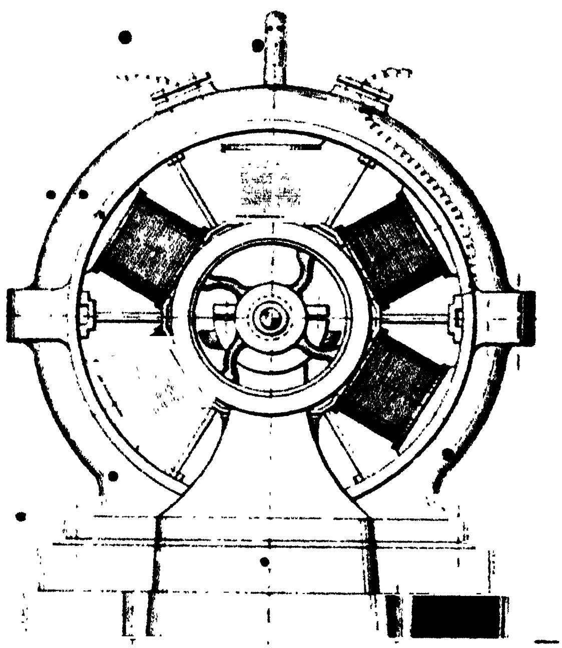


FRONT ELEVATION OF THOMSON-HOUSTON ALTERNATING-CURRENT DYNAMO USED WITH LARGE WELDER.

Within the limits of the power of the machine, any desired current can at the will of the operator be passed through the pieces being heated, and this current can be maintained with absolute steadiness, can be increased, or can be diminished, thus giving a control of the temperature which probably could not be obtained from any other source of heating. Furnished with this mode of regulation, the operator can vary the electric pressure so as to cope with the augmented resistance arising from increase of temperature.

Although in all probability the great use of these machines will be for uniting pieces of special and of difficult form, and for dealing with refractory metals (refractory in the sense that they do not

Fig. 18.

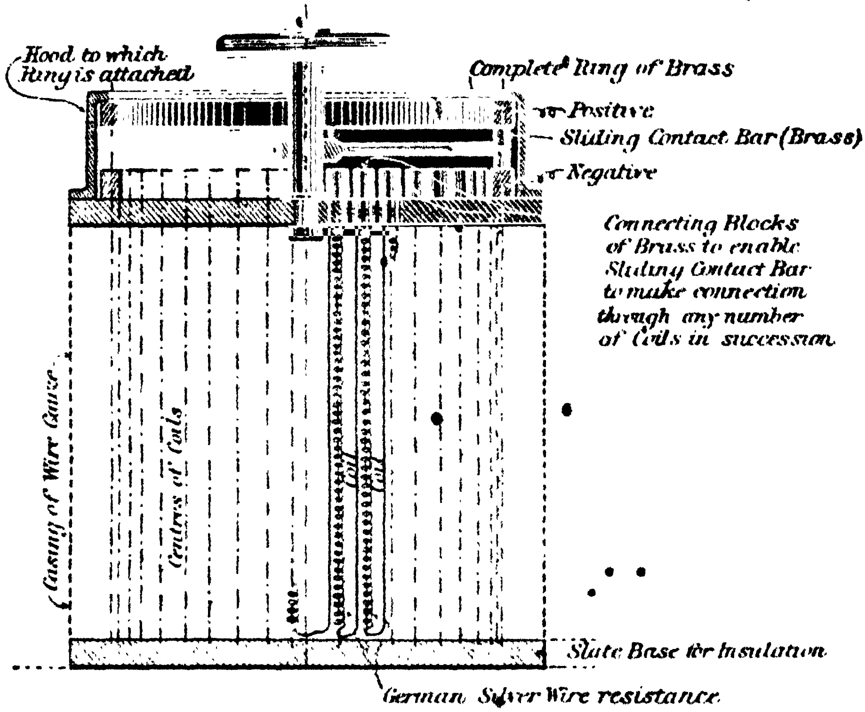


END ELEVATION OF THOMSON-HOUSTON ALTERNATING-CURRENT DYNAMO USED WITH LARGE WELDER.

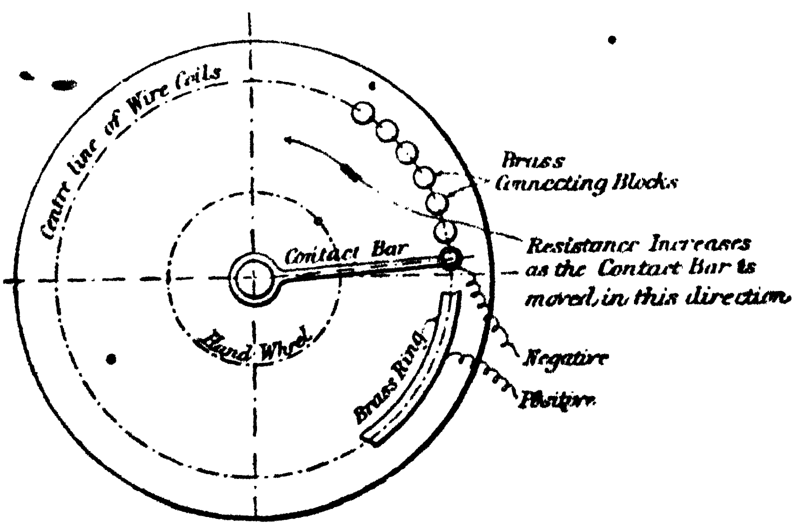
lend themselves to successful welding by any of the ordinary processes) it was nevertheless judged expedient by the Author to try the capabilities of the machine in performing an ordinary run of work, and to ascertain as far as practicable the HP. needed for this purpose, comparing the results thus obtained with those attendant upon hand-welding.

The machine that has been described, with others of a smaller size, and having modifications to suit them for different classes of work, was temporarily erected in Fanshaw Street, in the manner shown in the plan-diagram, *Fig. 22*. The power was derived from

Fig. 19.

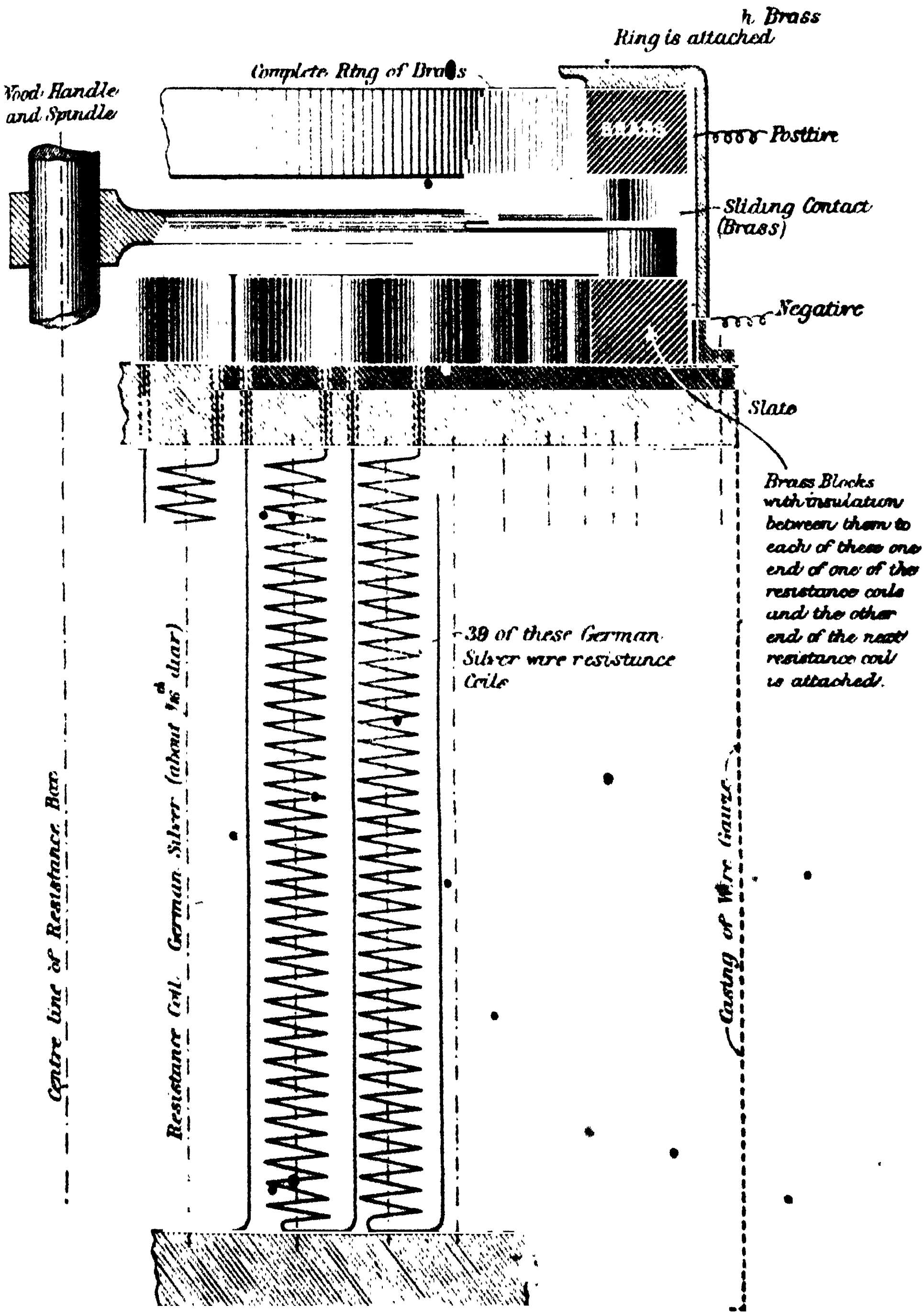


SECTIONAL ELEVATION THROUGH RESISTANCE-BOX.



PLAN OF

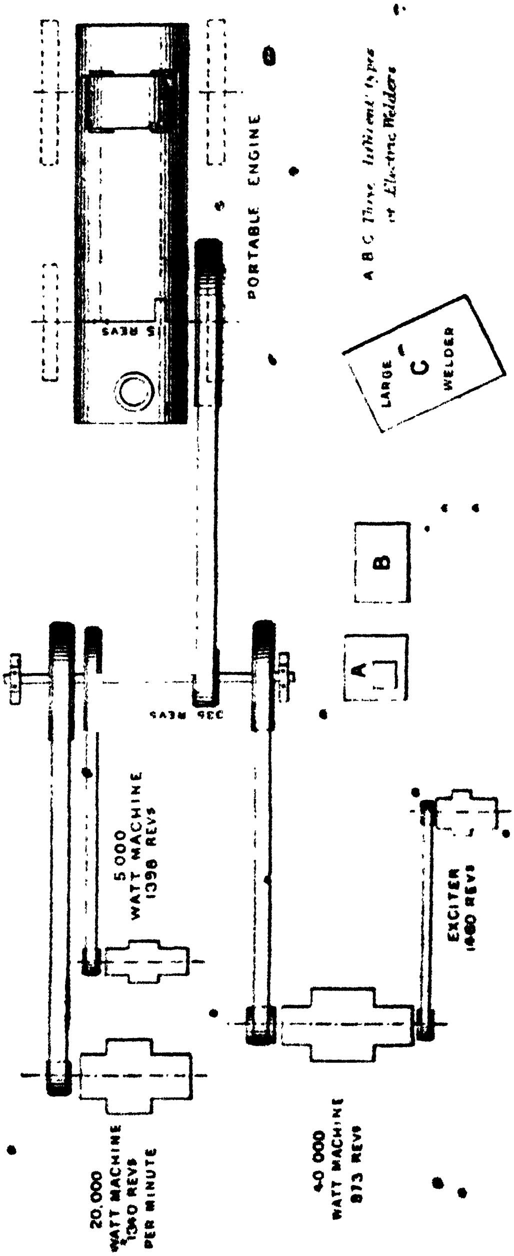
Fig. 21.



DETAIL OF RESISTANCE-BOX.

one of Marshall's two-cylinder portable engines, the diameter of bore of the steam cylinders being 9½ inches × 14 inches stroke, the revolutions, when the current was partly on, averaging 115 per

Fig. 22.



Plan of Installation at Fanshaw Street, Hoxton.

minute, and the steam-pressure being 80 lbs. A strap from the band fly-wheel drove the countershaft at 335 revolutions. Three pulleys on this shaft drove the three dynamos of, respectively, 5,000 watts, 20,000 watts, and 40,000 watts. The 5,000 and

20,000 dynamos could be coupled up as desired to the two smaller welding machines, A and B, the 40,000-watt dynamo working the largest of the three electric welding machines, that which is now before the meeting. The separate exciting dynamo was driven by a strap off the spindle of the 40,000-watt dynamo.

This being the arrangement of the apparatus, it was determined to make an experiment with the large dynamo and large welder only, and to do this, as has been said, with a continuous run of ordinary work. The straps of the two smaller dynamos were thrown off. Tanks for measuring the feedwater were provided, and indicators were applied to the engine. A large number of pieces of Farnley round iron, 1¼ inch in diameter, and 1 foot 2 inches long, were sent to the works, and the operation of welding these was commenced at 11.45 A.M., and was continued until eighty welds had been made. This was effected by 3.24 P.M., being three hours thirty-nine minutes, out of which there was a rest of half an hour, leaving three hours and nine minutes as the net time occupied in work, or an average of a little under two and a quarter minutes per weld. During this time many indicator diagrams were taken, some with the engine running light when no current was being used, others when the current was in full operation, and others showing the progressive increase in HP. as the current came on. From these it appears that the average gross indicated HP. throughout the time of trial was 33·1; that the mean gross indicated HP. when the engine was running light was 9·6, giving as the mean gross indicated HP. consumed in welding throughout the experiment 23·5. The maximum gross indicated HP. observed at any time during a weld was 50·7, the minimum 10·98. The feed-water evaporated during the experiment was 3,130 lbs., giving about 31½ lbs. per gross indicated HP. per hour evaporated from a mean temperature of 48°, no feed-heater being used. Such a consumption agrees very well with the indicator results before stated. Observations taken on individual welds show that the two and a quarter minutes may practically be divided as follows:—

	Seconds.
Fixing the iron into the jaws, and heating up to full heat at one operation	26
Full heat to taking out of jaws	11
Work on the anvil	15
Re-putting in, to full hot	21
Full hot to re-taking out	10
Re-taking out to completion	32
Completion to putting in new piece	20
	135

It should be stated that those who acted as smith and hammerman were two electricians, and not smiths, and were thus labouring under a very considerable disadvantage.

With the object of making a direct comparison, portions of the same lot of iron were welded in the ordinary manner by the smith and hammerman now present to use the machine. In this case also the work was continued for three hours, with the result that 44 welds were made in that time, and 1½ cwt. of "coke-breeze" was used in the fire.

It may interest the meeting to know that after the smith had made these welds in the ordinary manner, he was taken to practise on the electric machine, and at the fourth weld made perfectly satisfactory work.

Reverting to the indicator diagrams; *Fig. 23* shows by the successive curves upon it, the increase in the needed horse-power as increased use was made of the current. *Fig. 24* shows a diagram taken when the engine was running light, that is to say, with no current passing, and *Fig. 25* shows a diagram taken when the power employed was at its maximum.

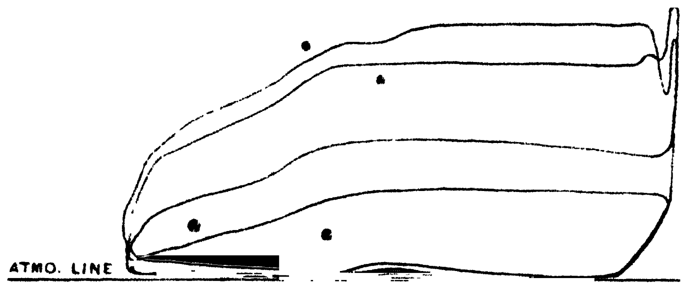
The pieces which had been welded electrically at Fanshaw Street were numbered with consecutive numbers, as were also those which had been hand-welded. The whole were sent to Mr. Kirkaldy's Testing Works, and, in order to leave samples for bending stress, he took for the tensile tests those which bore the even numbers. These testings are given in Appendix I to this Paper.

From this it appears that the strength of the metal in the solid being 52,646 lbs. per square inch of original sectional area, the strength of the electric welds—in the case of those that broke at the welds—was 48,215 lbs. also per square inch of original sectional area, or 91·9 per cent. of the strength of the solid; and, in the case of the hand-welds, the strength of those bars which broke at the welds was 46,899 lbs. per square inch of original sectional area, or 89·3 per cent. of the strength of the solid.

Bending tests were applied to some of the remaining bars, with the result that in the electric welds cracks or breakages occurred when the bars were bent cold, to an angle of 66° from the straight on the average, while in the hand-welds 138° were attained as an average (*Fig. 26*). When bent hot, however, the electrically-welded gave a mean of 144°, while the hand-welded gave a mean of 147°. The full particulars of these tests will be found in Appendix II.

Having stated the results of using the electric machine for the plainest of welds, it will be well to mention what was done with unusual sections and unusual material. A channel-iron $1\frac{3}{4}$ inch by 1 inch by $\frac{1}{4}$ inch was welded; a sample of this, with the others next to be enumerated, is on the table. A tee-iron $1\frac{1}{4}$ inch by $1\frac{1}{4}$ inch by $\frac{1}{4}$ inch, two angle-irons $1\frac{1}{16}$ inch by $1\frac{1}{16}$ inch by $\frac{1}{4}$ inch,

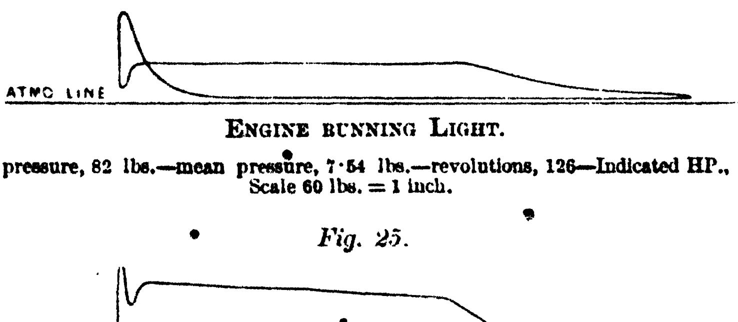
Fig. 23.



SERIES OF FOUR DIAGRAMS TAKEN DURING THE PROGRESS OF A WELD.

Boiler pressure, 83 lbs.—mean pressure, 30·59 lbs.—revolutions, 122—mean Indicated HP., 37·16. Scale 60 lbs. = 1 inch.

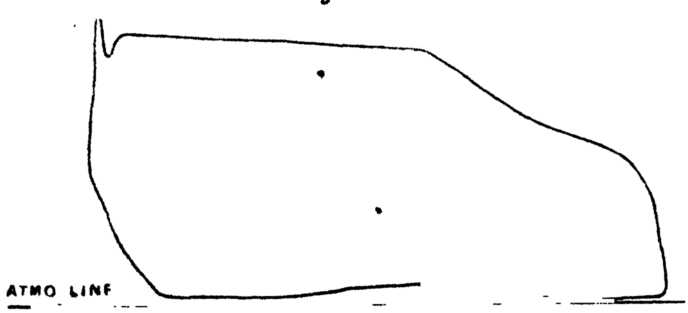
Fig. 24.



ENGINE RUNNING LIGHT.

Boiler pressure, 82 lbs.—mean pressure, 7·54 lbs.—revolutions, 126—Indicated HP., 9·69. Scale 60 lbs. = 1 inch.

Fig. 25.



MAXIMUM INDICATED HP. DURING A

Boiler-pressure, 79 lbs.—mean pressure, 53·45 lbs.—revolutions, 119—Indicated HP., 50·78. Scale 60 lbs. = 1 inch.

a wrought-iron tube $1\frac{1}{2}$ inch diameter by $\frac{3}{8}$ inch thick was welded to a bar $1\frac{1}{2}$ inch diameter. Another wrought-iron tube $1\frac{1}{2}$ inch diameter by $\frac{3}{8}$ inch thick was welded to a similar tube. A piece of $\frac{5}{8}$ inch square tool steel was welded, this being what is known as Pfeils' unweldable steel.

There is on the table a board of samples (not, however, produced under the inspection of the Author), where it will be seen various forms and sections are welded together, or are brazed together, and some of these have been cut open to show the weld. Probably

Figs. 23.

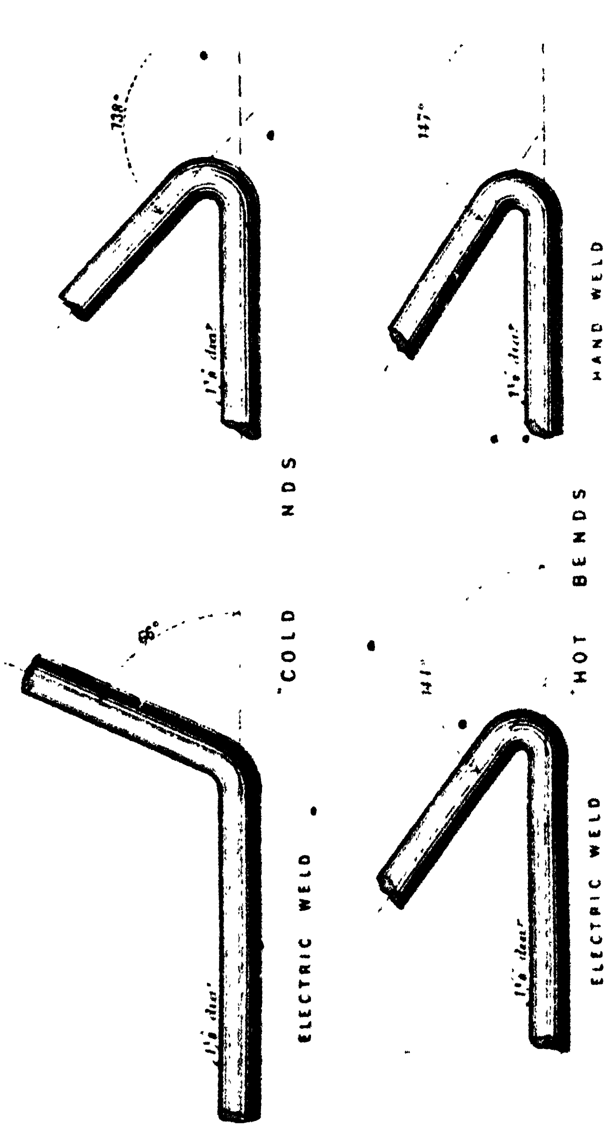


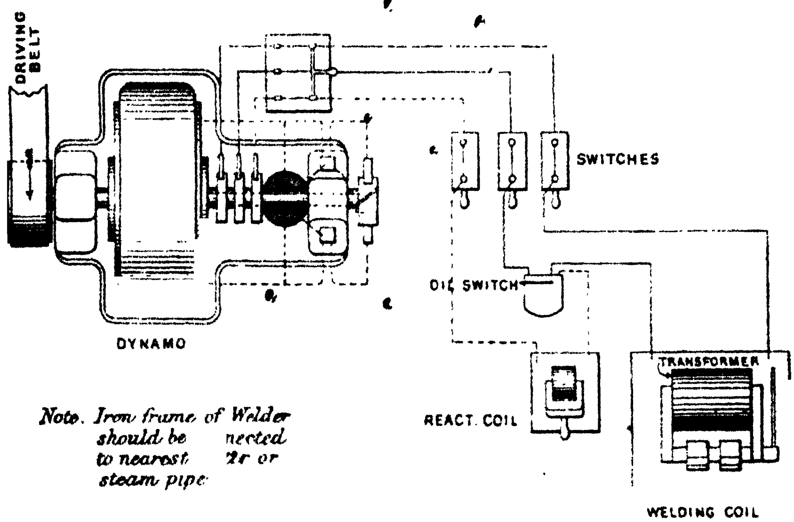
DIAGRAM SHOWING ANGLE OF BEND IN KIRKALDY'S TESTS.

the most singular of all these is the welding together of the two sections of a wire-rope. A similar sample of wire-rope has been welded and has been afterwards cut open, and it will be seen that the portion which is rendered solid, *i.e.*, has been converted from a rope into a bar, is very short indeed.

Two different modes of connection of the dynamo to the machines and resistances, each adapted for a different class of work, are shown in diagrams, *Figs.* 27 and 28.

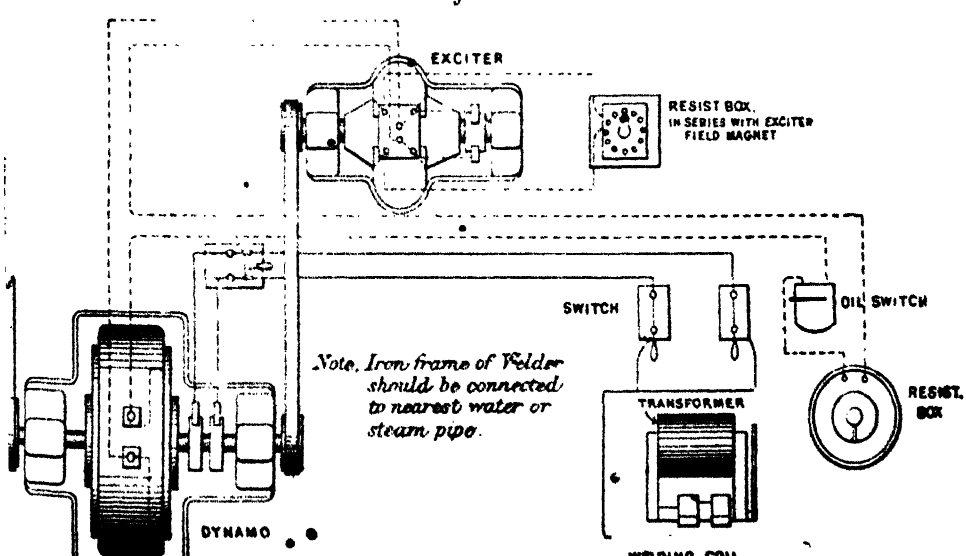
With ordinary processes of heating and of giving the pressure

Fig. 27.



Connections for Type C Dynamo and Indirect Welder.

Fig. 28.



Connections for Type D Dynamo and Indirect

there is extreme difficulty (not to say impossibility) in welding other metals than iron, steel, and platinum, but with the electric current it is possible to make a junction by that which probably looked upon as a fusing together rather than as a welding, as this is commonly understood. Metals which have been dealt with in this way comprise among others:—

Steel:—Every variety seems to be weldable.
Iron:—Cast, wrought, malleable, case-hardened, ferro-aluminium.
Copper:—Cast, rolled, drawn.
Brass:—Cast, rolled, drawn.
Delta metal: Muntz metal.

Aluminium.	Tin.	Cobalt.
Silver.	Lead.	Manganese.
Gold.	Zinc.	Bismuth.
Platinum.	Nickel.	Iridium.

Bronze:—Aluminium, phosphor, silicon, etc. Gun metal.

Gold to platinum.	Bronze to iron.
Iron to steel.	German-silver to iron.
Brass to iron.	German-silver to brass.
Copper to iron.	Copper to brass.

Specimens of most of these are on the table.

Another instance in which electrical heating may be of great value is that of the power of performing this operation in places where it might be difficult to erect a forge even of the simplest and most portable character.

For example, the heating of the rivets for a girder high up in the air, and numerous other cases that are constantly occurring in practice.

At the Crewe works, Mr. Webb has one of these welding machines at work. The Author has had the opportunity afforded him of seeing it in operation. He found it at work shutting on eyes to screwed rods of some $\frac{7}{8}$ inch in diameter; the weld was made close up to the screw which was in no way injured in the process. It has also been employed to weld ends to tubes, to weld together the parts of twist drills which have been broken, and to weld best steel for tools on to commoner materials.

It is obvious that a machine that gives the power of heating any material with an absolutely controllable heat, and that enables that heat to be inspected and to be communicated without the advent of impurities, must have many uses in the arts, in preparing pieces for brazing, for stamping, and in a variety of other ways; in fact there can be no doubt that the existence of such a machine will itself give rise to a large number of new uses.

It has been said that the maximum HP. developed during the working of the machine was 50. Say, that out of this 50 HP., 35 HP. reached the dynamo, of which probably some 70 to 75 per cent. came to the welding machine itself, or say 25 HP. of electrical energy are turned into heat, equivalent to, in round numbers, 1,070 heat-units per minute.

Taking the specific heat of iron at ordinary atmospheric temperatures to be between one-eighth and one-ninth that of water, this should suffice (were there no loss going on by radiation, &c.,) to heat 9 lbs. of iron about 1,000° in a minute. The portion of the $1\frac{1}{8}$-inch round bars actually heated was about $2\frac{1}{4}$ inches long, being equal to about $\frac{3}{4}$ of a lb. The temperature that was attained was presumably about 3,000°, and this temperature should under the above conditions be reached in such a sized piece of iron in fifteen seconds. Out of the average of twenty-six seconds, which, as already stated, were needed for putting pieces into the jaws and the heating up to full heat, some twenty seconds were employed in raising the bars from the temperature of the air to the welding temperature. This is a sufficiently near agreement with the fifteen seconds shown by calculation to be necessary when it is remembered that losses are going on, that the power is developed gradually, and is at its maximum when the bar is at its hottest.

The Author trusts that the importance of this new application of electricity to the uses of the engineer may be looked upon as a sufficient justification for directing the attention of the Institution to the subject.

The Paper is accompanied by diagrams from which the *Figs.* in the text have been engraved.

APPEN

APPENDIX I.—RESULTS OF EXPERIMENTS TO ASCERTAIN THE TENSILE

NOMINAL SIZE, 1⅛ inch DIAMETER.

Broke in Solid.

Test No.	Description.	Original.		Ultimate Stress.			Contraction of Area at Fracture.	Extention in 10 Inches.	Appearance of Fracture.
		Diameter.	Area.	Total.	Per Square Inch of Original Area.				
Y		Inch.	Sq. In.	Lbs.	Lbs.	Tons.	Per cent.	Per cent.	
405	F B 2	1·11	0·968	52,875	54,623		53·1	24·2	Fibrous
407	,, 4	1·11	0·968	50,890	52,572		53·1	28·1	,,
409	,, 6	1·11	0·968	50,480	52,149		50·6	24·2	,,
411	B 8	1·11							
413	,, 10	1·11	0·968	52,410	54,143		49·4	22·7	,,
415	,, 12	1·11	0·968	49,840	51,488		50·6	20·6	,,
417	,, 14	1·11							
419	,, 16	1·11							
421	,, 18	1·11	0·968	50,910	52,592		51·8	23·9	,,
423	,, 20	1·11							
425	,, 22	1·11							
427	,, 24	1·11							
429	,, 26	1·11							
431	,, 28	1·11	0·968	51,335	53,032		51·8	20·8	,,
433	,, 30	1·11	0·968	50,260	51,921		49·4	19·1	,,
435	,, 32	1·11	0·968	50,060	51,715		49·4	20·6	,,
437	,, 34	1·11	0·968	50,745	52,423		51·8	21·2	,,
439	,, 36	1·13	1·003	51,710	51,555		52·3	23·9	,,
441	,, 38	1·11	0·968	51,645	53,352		49·4	21·1	,,
443	,, 40 (Electric Welded.)	1·13							
445	,, 42	1·11	0·968	50,665	52,340		49·4	20·9	,,
447	,, 44	1·11	0·968	52,260	53,988		50·6	22·2	,,
449	,, 46	1·11	0·968	50,195	51,854		49·4	22·0	,,
451	,, 48	1·11							
453	,, 50	1·11	0·968	51,280	52,975		49·4	20·6	,,
455	,, 52	1·12	0·985	52,555	53,355		50·3	21·8	,,
457	,, 54	1·11	0·968	51,480	53,182		48·0	20·4	,,
459	,, 56	1·11	0·968	50,385	52,051		50·6	22·1	,,
461	,, 58	1·11	0·968	51,320	53,017		49·4	21·7	,,
463	,, 60	1·11							
465	,, 62	1·11	0·968	50,065	51,720		49·4	21·2	,,
467	,, 64	1·11							
469	,, 66	1·11							
471	,, 68	1·11	0·968	51,355	53,053		53·1	21·6	,,
473	,, 70	1·12							
475	,, 72	1·11							
477	,, 74	1·12	0·985	51,310	52,091		48·9	22·6	,,
479	,, 76	1·12	0·985	51,155	51,934		51·5	23·4	,,
481	,, 78	1·12							
483	,, 80	1·12	0·985	52,245	53,041		52·7	23·6	,,
				Mean	52,646	=23·5	50·6	22·2	

DIXES.

STRENGTH, ETC., OF SIXTY-EIGHT ROUND-IRON BARS, WELDED.

BRAND, FARNLEY.

Broke in Weld.					
Original.		Ultimate Stress.			Ratio of Weld to Solid.
Diameter.	Area.	Total.	Per Square Inch of Original Area.		
Inch.	Square Inch.	Lbs.	Lbs.	Tons.	Per cent.
1·12					
1·13					
1·11					
1·12	0·985	49,775	50,533		96·3
1·13					
1·15					
1·14	1·021	50,065	49,035		93·4
1·16	1·057	49,740	47,058		89·7
1·14					
1·13	1·003	42,485	42,358		80·7
1·13	1·003	49,315	49,167		93·7
1·13	1·003	44,740	44,606		85·0
1·13	1·003	49,705	49,556		94·4
1·15					
1·14					
1·16					
1·15					
1·14					
1·14					
1·14	1·021	49,185	48,173		91·8
1·14					
1·12					
1·15					
1·13	1·003	52,240	52,084		99·2
1·14					
1·15					
1·13					
1·14					
1·14					
1·14	1·021	48,045	47,057		89·7
1·12					
1·11	0·968	43,570	45,010		85·8
1·13	1·003	48,215	48,071		91·6
1·12					
1·12	0·985	48,380	49,117		93·6
1·12	0·985	48,745	49,487		94·3
1·14					
1·13					
1·13	1·003	52,070	51,914		98·9
1·13					
		Mean	48,215	= 21·5	91·9

APPENDIX I.—RESULT

Broke in Solid.

Test No.	Description.		Original.		Ultimate Stress.			Contraction of Area at Fracture.	Extension in 10 inches.	Appearance of Fracture.
			Diameter.	Area.	Total.	Per Square Inch of Original Area.				
Y			Inch.	Sq. In.	Lbs.	Lbs.	Tons.	Per cent.	Per cent.	
639	B 92	Hand welded.	1·11							
641	„ 94		1·11							
643	„ 96		1·11							
645	„ 98		1·11							
647	„ 100		1·11							
649	„ 102		1·11	0·968	50,360	52,025		50·6	20·1	Fibrous
651	„ 104		1·11							
653	„ 106		1·11	0·968	49,330	50,961		51·8	21·6	do.
655	„ 108		1·11							
657	„ 110		1·11							
659	„ 112		1·11							
661	„ 114		1·11							
663	„ 116		1·11							
665	„ 118		1·11							
667	„ 120		1·11							
669	„ 122		1·11							
671	„ 124		1·11							
673	„ 126		1·11							
675	„ 128		1·11							
677	„ 130		1·11							
679	„ 132		1·11	0·968	50,240	51,901		48·0	20·6	do.
681	„ 134		1·11							
720	„ 200	Electric welded.	1·11	0·968	50,245	51,906		50·6	23·1	do.
721	„ 201		1·11							
722	„ 202		1·11	0·968	49,090	50,713		46·8	20·8	do.
723	„ 203		1·12	0·985	53,310	54,122		52·7	25·6	do.
724	„ 204		1·11	0·968	50,055	51,710		49·4	25·1	do.
725	„ P		1·11							
			Total Mean of 32			52,484 =	23·4	50·5	22·2	

OF EXPERIMENTS—*continued.*

Broke in Weld.					
Original.		Ultimate Stress.			Ratio of Weld to Solid.
Diameter.	Area.	Total.	Per Square Inch of Original Area.		
Inch.	Square Inch.	Lbs.	Lbs.	Tons.	Per Cent.
1·12	0·985	41,765	42,401		80·8
1·11	0·968	45,340	46,839		89·2
1·11	0·968	39,245	40,542		77·2
1·11	0·968	48,860	50,475		96·2
1·13	1·003	47,420	47,278		90·1
1·11					
1·11	0·968	50,035	51,689		98·5
1·11					
1·11	0·968	49,860	51,508		98·1
1·10	0·950	46,635	49,089		93·5
1·11	0·968	44,835	46,317		88·2
1·11	0·968	47,340	48,905		93·2
1·09	0·933	39,915	42,781		81·5
1·12	0·985	47,205	47,924		91·3
1·10	0·950	43,880	46,189		88·0
1·11	0·968	38,810	40,093		76·4
1·11	0·968	48,240	49,835		95·0
1·12	0·985	47,255	47,974		91·4
1·12	0·985	48,510	49,249		93·8
1·11	0·968	45,090	46,581		88·8
1·11					
1·11	0·968	43,965	45,418		86·5
			Mean 46,899	= 20·9	89·3
1·14					
1·13	1·003	45,885	45,748		87·2
1·16					
1·16					
1·15					
1·11	0·968	43,720	45,165		86·1
			Mean 45,456	= 20·3	86·6

APPENDIX II.—Results of Experiments to ascertain the behaviour
Farnley. Electric Welds

Cold.

Test No.	Description.			Angle.	Effects.
Y				°	
404	Bar, 1⅛ inch diameter	F B 1	Electric Welded.	37	Broken.
406	„ „	„ 3		65	Cracked.
408	„ „	„ 5		65	Broken.
410	„ „	„ 7		34	Cracked.
412	„ „	B 9		58	Broken.
414	„ „	„ 11		115	„
416	„ „	„		65	Cracked.
418	„ „	„ 15		57	„
420	„ „	„ 17		37	Broken.
422	„ „	„ 19		58	„
424	„ „	„ 21		58	Cracked.
426	„ „	„ 23		50	„
428	„ „	„ 25		90	„
430	„ „	„ 27		150	Broken.
432	„ „	„ 29		95	„
434	„ „	„ 31		59	Cracked.
436	„ „	„ 33		70	„
438	„ „	„ 35		35	„
440	„ „	„ 37		55	Broken.
442	„ „	„ 39		64	Cracked.
	Mean			66	
640	Bar, 1¼ inch diameter	B 93	Hand Welded.	60	Cracked.
642	„ „	„ 95		180	Uncracked.
644	„ „	„ 97		90	Cracked.
646	„ „	„ 99		150	„
648	„ „	„ 101		170	„
650	„ „	„ 103		75	„
652	„ „	„ 105		180	„
654	„ „	„ 107		180	Uncracked.
656	„ „	„ 109		180	„
658	„ „	„ 111		180	„
660	„ „	„ 113		70	Cracked.
	Mean			138	
727	Channel, 1¾ by 1 by ¼ inch	B 82	Electric Welded.	28	Cracked.
728	Tee, 1¼ by 1¼ by 3/16 „	„ 83		10	Broken.
729	Bar, tool steel, ⅝ in. square	„ 84		2 45	Broken, at weld. „ in solid.
730	Angle, 1 by 1 by ¼ inch	„ 85		93	Cracked.
731	„ „	„ 86		35	„
732	„ „	„ 87		70	Buckled, removed.
733	„ „	„ 88		75	„ „
734	„ „	„ 89		75	„ „
735	Bar, 1⅛ inch diameter, welded to tube . .	„ 90		8	Broken, cone weld.
736	Tube, 1¼ inch diameter	„ 91		58	„ „

726 Ring 13 inches diameter B 81. Bar cracked, clear

UNDER BENDING OF SEVENTY-TWO PIECES OF IRON AND ONE OF STEEL, WELDED.
WERE BUTT; HAND WELDS WERE SCARF.

HOT.

Test No.	Description.			Angle.	Effects.
Y				°	
444	Bar, 1⅛ inch diameter	B 41	Electric Welded.	180	Very slightly cracked.
446	,, ,,	,, 43		180	Uncracked.
448	,, ,,	,, 45		160	Cracked.
450	,, ,,	,, 47		175	,,
452	,, ,,	,, 49		94	,,
454	,, ,,	,, 51		180	Uncracked.
456	,, ,,	,, 53		60	Cracked.
458	,, ,,	,, 55		180	Uncracked.
460	,, ,,	,, 57		96	Cracked.
462	,, ,,	,, 59		180	Uncracked.
464	,, ,,	,, 61		180	Slightly cracked.
466	,, ,,	,, 63		81	Cracked.
468	,, ,,	,, 65		163	,,
470	,, ,,	,, 67		98	,,
472	,, ,,	,, 69		180	,,
474	,, ,,	,, 71		90	,,
476	,, ,,	,, 73		120	,,
478	,, ,,	,, 75		180	Uncracked.
480	,, ,,	,, 77		180	Cracked.
482	,, ,,	,, 79		117	,,
	Mean			144	
662	Bar, 1⅛ inch diameter	B 115	Hand Welded.	100	Cracked.
664	,, ,,	,, 117		75	,,
666	,, ,,	,, 119		180	Slightly cracked.
668	,, ,,	,, 121		180	,,
670	,, ,,	,, 123		180	,,
672	,, ,,	,, 125		180	,,
674	,, ,,	,, 127		180	,,
676	,, ,,	,, 129		90	Cracked.
678	,, ,,	,, 131		180	Slightly cracked.
680	,, ,,	,, 133		180	Uncracked.
682	,, ,,	,, 135		95	Cracked.
	Mean			147	

of weld, when nearly straight. Bar 1 inch diameter.

[DISCUSSION.

Discussion.

Sir John Coode. Sir JOHN COODE, President, said that at the end of last year Professor Elihu Thomson, the inventor of the process, had been asked to communicate a description of the system of electric welding, but owing to numerous engagements he was unable to prepare a Paper for the Institution, and thereupon Sir Frederick Bramwell had kindly undertaken to do so; he had taken an immense amount of trouble in the fulfilment of his task, and deserved the hearty thanks of the members. He would now ask Sir Frederick to give some practical illustrations showing the process in operation; and he could not help thinking that the members would be as much struck as he himself had been with the marvellous simplicity of the process. The heating of the carbons of the arc lamp had been before the world about a quarter of a century; the two carbons had been brought close together in a state of fusion, and it was remarkable that no one had before thought of putting two metals together in the same way and giving them a squeeze; for that was what, put in the simplest terms, the process amounted to.

Sir Frederick Bramwell. Sir FREDERICK BRAMWELL observed that as the President had already explained, the Paper had been written at his invitation; if, therefore, the time of the Institution had been occupied by an uninteresting subject the President only was to blame.

The process of welding, as ordinarily understood, depended upon a property possessed by the so-called weldable metals, which was, that while their surfaces could be brought into a sufficient degree of plasticity to form a union, their bodies were nevertheless still left sufficiently tough to bear the stress of hammering or pressure. Dr. Percy had explained the matter in the clearest possible manner, with regard to the typical weldable metals, and in speaking of non-weldable metals, he had shown what was needed to enable them to be united by fusion.[1] It would be

[1] "Metallurgy." By JOHN PERCY. "Iron and Steel." Edition 1864, p. 5. *Action of heat. Welding.*—Iron requires a very high temperature for its fusion. Its melting point has not yet been determined with certainty, but has been estimated at 1550° C. by Pouillet, which, however, is questionable. We have no difficulty in fusing it perfectly in our assay-furnaces in which platinum remains infusible. Iron has one remarkable and very important property, namely, that of continuing soft and more or less pasty through a considerable range of

seen that as regarded the so-called non-weldable metals, Dr. Percy had pointed to the difficulty of hitting upon that which might be called the critical temperature of such metals; and also had alluded to the further difficulty that even if it could be hit upon, there was no certainty of maintaining it during the time needed for the operation. These two obstacles to the welding of the so-called non-weldable metals were, however, absolutely overcome by electric heating, because any temperature could be obtained within the power of the machine, and it could be maintained any length of time without change. He had placed upon the wall some illustrations of tire welding, which went back to a state of things long passed away. The mode in which railway tires were welded was shown, and there was also an illustration of the mode (not so well known) in which lengths of gun-tube were welded together. He had always looked upon this last as one of the best instances of welding, an instance where care was taken to make the surfaces clean at the outset and to prevent them from being injured by the access of dirt, and thus to obtain in a clean manner the welding heat and then to effect the union by endway-pressure. He had alluded to Mr. Wilde's Paper, which excited so much attention twenty-four years ago, when he showed how a dynamo excited by another dynamo could perform that which was then the marvellous feat of fusing a piece of wire 15 inches long and ¼ inch in diameter. Mr. Wilde was one of those whom the world did not sufficiently remember, as having done a very great deal towards the perfection of the electrical implements which were now so largely used. He did not know whether there was any need to enforce it, but he had said that for welding purposes the question of heating was in a sense irrespective of the electric pressure. No doubt it was the lowering of the pressure, the destruction of it, if it might be so called, which did away with energy in the electrical form and caused it to be reproduced in the form Sir Frederick Bramwell.

temperature below its melting point. It is sufficiently soft at a bright red-heat to admit of being forged with facility, as every one knows; and, at about a white-heat, it is so pasty that when two pieces at this temperature are pressed together they unite intimately and firmly. This is what occurs in the common process of *welding*. Generally metals seem to pass *quickly* from the solid to the liquid state, and so far from being pasty and cohesive at the temperature of incipient fusion, they are extremely brittle and in some cases easily pulverizable. But, admitting that there is a particular temperature at which a metal becomes pasty, its range is so limited in the case of the common metals, that it would scarcely be possible to hit upon it with any certainty in practice; or, if it were possible, its duration would be too short for the performance of the necessary manipulations in welding.

Sir Frederick Bramwell. of heat; but whether that lowering took place from 99 volts to 66, or from 66 to 33, or from 33 to zero, the effect was the same. Dr. Hopkinson, who was one of those who had devoted great attention to the subject of the change in the electrical conductivity of metals under variations in temperature, had been kind enough to allow him to put upon the wall enlargements of the diagrams of some of his experiments on this increase in resistance (*Fig. 11*). It would be observed that, whereas at 32° Fahrenheit, there was a resistance of 1, at 1823° Fahrenheit the resistance had increased to 8¼; and, no doubt, if the observation had been carried on to the temperature attained in the experiments just performed before the meeting, the resistance would have been much greater. The Paper to which he had referred was to be found in the Philosophical Transactions for 1889, and it contained a vast variety of most important matter which he recommended to the attention of members interested in these subjects. He had mentioned that it was impossible to state the exact number of amperes needed for a particular temperature. The fact was that the heat was cumulative. He was now about to show not a weld, but a heating up of a bar put in between the jaws, and heated by the passage of a comparatively low current, which would be continued until a temperature was reached at which there appeared to be a balance between the heat generated and the losses, so that the temperature was maintained. If round the heated bar there were then placed an incombustible envelope, and if it were kept there for some little time, and then withdrawn, it would be found that the temperature had enormously increased. He would instance such an experiment as proving that it was impossible to say that any particular number of amperes were needed to produce any particular temperature, and as establishing that the number of amperes depended upon other circumstances as well as on the desired temperature. With reference to the statement in his Paper that it was desirable that the large currents should be produced close to the machine, he wished to call attention to a piece of conductor of the same size as that which was bringing the electricity from the dynamo a few yards away. He would ask the members to compare its diminutive section with that of the conductors of the machine itself conveying the large current of low electromotive force. It would be seen that these were two bars of copper about 7 inches deep, and 2 inches or 2½ inches thick. They were the conductors which were needed for the transmission, without too much heating of this extremely large current; while the current from the dynamo, before it reached the transformer, was brought in by conductors, which were mere wires. The machine in which the large welding had been carried on had been so fully described in the Paper that he need not further refer to it; but there was on the table a machine which had not been so fully described. It was used for the welding of small wires, and matters of that sort. In the box, forming the stand, there was a transformer, and there were jaws to hold the piece under operation; the two jaws were urged to approach by a spring, and in this way was obtained the endway pressure which performed the welding. There was an implement for the purpose of insuring that according to the nature and dimensions of the metal it should have when fixed in the jaws a proper projection. When the switch with which the apparatus was provided was drawn into the position shown, the current was on; but as soon as the jaws had moved sufficiently near together to "upset" the softened material, they struck a detent, allowing the switch to move automatically, and to cut off the current. Reverting to the iron welds he wished to call attention to the results, shown on the table, of the bending cold of the bars that had been electrically welded. They were certainly below those of the hand-welded specimens to the extent of about one-half; while when bent hot the results of the two modes of welding were practically the same. He was referring to diagram, *Figs. 26*. He could only say that he wished he had had the wit to have the welds annealed, because he had no doubt that would have brought the cold bending to an equality. He would now show, with two pieces of Farnley iron, a weld of the character of those of which eighty had been made, as mentioned in the Paper. The next experiment would be with two pieces of wire cable. In order to obtain the results just shown, an engine of Marshall's which indicated 50 HP., a large dynamo and a small one, had been erected at the back of the meeting room. This had involved, of course, a great deal of preparation; but it would not be all bestowed on this single meeting, as he had the permission of the President to say that the apparatus would be allowed to remain during the week, and that on each day it would be in operation between the hours of two and four o'clock. Sir Frederick Bramwell.

Mr. W. H. Preece observed that during the past twelve years he devoted so much attention to the connection existing between passage of electricity through matter and the generation of heat therefrom, that he was sure the Institution would pardon his giving to some extent the substance of numerous papers on the subject which he had submitted to the Royal Society. It was desirable, in the first instance, to point out that the trans- Mr. Preece.

Mr. Preece. ference of what was called electricity through matter, whether gas, liquid or solid, was always accompanied by an expenditure of work. If a spark passed through a gas, the gas was dissociated into its constituent atoms; if a current passed through a liquid, the liquid also had its molecules broken up into their constituent atoms; and if electricity passed through a solid, inasmuch as there was nothing there to break up, the electricity generated a certain motion of the molecules which gave what was called heat. It was nearly half a century ago, in 1841, that Joule—one of the greatest experimenters and one of the most wonderful men that the century had produced—developed the law that determined the generation of heat, and that law had been proved ever since to be actually true, and it underlay the fundamental facts of the system of electric welding and of all practical applications of heat derived from electricity. But Joule's law, that the heat developed per second varied directly as the square of the current and as the resistance of the conductor, or $H = C^2R$, assumed that the conductor conveying the electricity was surrounded by something that was not itself a conductor of heat, and that all the heat generated in the conductor was utilized, or, as some said, wasted, in the conductor. Another great genius, happily still living, Sir William Thomson, about ten years afterwards said that the development of heat in a conductor could not possibly be taken into consideration without also considering the effect of the dissipation of heat from the surface of the conductor; that whenever a conductor conveyed a current of electricity there was not only the generation of heat in the conductor but a radiation and convection, or, as it was called by the more general term, the emissivity of heat from the surface; and that when the heat generated in the conductor was equivalent to the heat emitted from the surface, the temperature of the wire became constant. He wished to point that out because in every heat question it was essential to draw a broad distinction between the heat generated and the temperature of the body that conveyed the heat. His attention to the subject began with the improvement of lightning protectors to preserve sub-marine cables, which were based upon the notion that a very fine wire, say of platinum, would be fused by a lightning flash before it was possible that the strength of the current derived from the lightning flash could injure the cable; and therefore it was desirable to find the dimensions of the fusible conductor which could not under any circumstances be fused by such currents as were used for telegraphy, but would be fused the moment the current acquired such strength that it might injure the cable. This was

Mr. Preece.

the principle of "cut-out" so largely used in electric lighting. In carrying out that inquiry he showed that the law that determined the fusing of a wire bare and exposed in air (a condition assumed in all inquiries and in all papers written on the subject) simply depended upon the strength of the current that flowed, or rather the quantity of electricity that passed. It followed a distinct law based upon the diameter of the wire, which was expressed thus:—

$C = a\, d^{\frac{3}{2}}$; C being the current, a a constant called the fusing constant, and d the diameter. In fact, by determining by experiment the current that would fuse a wire of any material an inch in diameter, the current that would fuse any other wire could be determined by simply taking the square root of the cube of the diameter. An iron rod, an inch in diameter, through which a current flowed, would certainly be fused when the current reached 3,148 amperes. There was nothing in nature more certain than this; and to ascertain how much current would fuse a wire 2 inches in diameter it was only needful to take the cube of 2, and the square root of that, which was 2·8. That rule had been shown to be absolutely exact. Based on that rule he had made a series of very careful experiments from which had been determined what were called the fusing constants of metals. Assuming that a rod of iron 1 inch in diameter would fuse with 3,148 amperes, 1 inch of copper would fuse with 10,244 amperes, and the other metals in proportion.

FUSING CONSTANTS.

—	Diameter in Inches.	—	Diameter in Inches.
	Amperes.		Amperes.
Copper	10,244	Platinoid	4,750
Silver . . .	7,688	Iron	3,148
Aluminium .	7,585	Tin	1,642
German Silver	5,230	Lead	1,379
Platinum	5,172		

The point which he wished to urge was that those who argued on Joule's law alone argued on a false assumption, and that it was necessary to take into consideration the question of the surface exposed to radiation and convection, and the environment of the conductor. Mr. J. T. Bottomley, Professor Dewar and others had

Mr. Preece. lately worked in that field, and they were now getting clearly to understand the relation existing between surface temperature, and emissivity. But the curious fact had come out in his enquiries, that in some circumstances the question of time might be altogether neglected. A wire conveying a current took time to acquire a constant temperature, and the time it required depended upon its dimensions. A wire so small that it might be called hair-like cooled and heated with such rapidity, that it actually emitted sounds; and a thermo-telephone, which he had submitted to the Royal Society in 1878, reproduced the voice by the rapid heating and cooling of a fine platinum wire. The law was so exact, and it gave such concordant and satisfactory results, that there was now not the slightest difficulty in determining the temperature that any wire could attain from any current; and *vice versâ*, by measuring the temperature which a round cylinder acquired when carrying electricity, the current could be ascertained. But like all laws, that one was liable to be broken, and certain departures had to be taken into consideration. It was, of course, scarcely applicable to the apparatus exhibited. One of the most serious allowances that had to be made was the cooling effect of the ends. In the apparatus there were short lengths of iron bars, probably about 3 inches long, inserted between heavy jaws, the ends being attached to immense masses of metal. The result was that those masses of metal had to acquire heat, and they reduced the temperature of the end, so that instead of a bar of iron taking about 3,000 amperes to fuse it, the probability was that it would take nearer 10,000. On the other hand, if instead of being 3 inches the bar of iron were 3 feet long, it would probably be found that in the centre of that bar fusion would be effected by about 3,000 amperes. It would be noticed, in watching any experiments that might be made, that the bright heat was in the centre, and the black part of the bar was at the end. Again, allowance had to be made for the influence of the environment of the wire. Many engineers were apt to consider the effect of lagging in steam-pipes, and there were certain forms of lagging that maintained the temperature of the steam pretty constant, and reduced the waste heat very greatly. On the other hand, certain forms of lagging had exactly the opposite effect. It was a curious thing that if the environment of the wire had a deleterious influence on conductors, heating would be seriously felt in submarine telegraphs. Submarine telegraphs conveyed currents for a long time, while heavy street mains conveyed powerful currents for electric lighting purposes, and if heat had an accumulative effect in conductors surrounded by insulators, sooner or later damage might be occasioned; but as a matter of fact, the presence of gutta-percha, india-rubber, asphalt, and nearly all materials used for insulating conductors had the reverse effect, for they tended to cool the wire. In 1882 he was engaged with Mr. Robert Sabine in some interesting experiments, which were unfortunately brought to an end by that gentleman's untimely death. It was found that the emissivity of an asphalt surface was seven times that of a copper surface, and india-rubber and gutta-percha were greatly in excess of bright copper. The result was that, with most of the materials that were used to insulate the current, the wire was cooled. There were some things in which the reverse effect occurred, one of them being asbestos, the emissivity of which was very small. It was an insulator of heat; and one of the prettiest experiments that the Author had shown was that of covering a glowing wire with a sheet of asbestos, the result of which was that the emissivity was checked, the temperature rose, and the wire was fused. There was a departure from that law, and a curious one, with which electricians were not yet thoroughly acquainted, but they were becoming more familiar with it every day, namely, the practical effect of alternate currents of great frequency, such as were being used at Deptford to be transmitted to London for electric lighting purposes, and which formed the basis of nearly all the great systems of electric lighting, not only in America, but in England. It was a remarkable fact that when alternate currents of electricity were transmitted through iron wires, there was not only the heat due to the passage of the currents of electricity, but there was a kind of churning action in the iron itself due to the incessant rapid reversals of magnetism. It was a kind of viscous friction amongst the molecules of iron, and heat was generated, which varied almost directly with the number of the alternations of the current per second, and also with the strength of the current. The result was that with alternate currents the generation of heat was greater than with continuous currents. A careful experiment showed that an iron wire which fused with a steady current of 122 amperes was melted with 92 amperes when the current was alternating. That effect of alternate currents on wires had received the rather awkward, but now well-known, name of hysteresis. It represented the work done on iron molecules by the reversals of magnetization. So far as present knowledge was concerned, the practical application of these laws had been most charmingly shown by the experiments the meeting had witnessed. There were one or two Mr. Preece.

Mr. Preece. points which the Author had not made as much of as he might have done, and which were worthy of careful consideration. When iron was heated first for welding purposes, it was raised to a very high temperature indeed, probably 3,000° Fahrenheit or more, and was thus heated beyond the point where oxidation set in. In the case of steel, the blue, yellow, and orange points of oxidation were very fairly indicated, but he did not know that any one had absolutely measured the temperature of iron or steel at which scaling commenced. Whatever that temperature was, it was a point to be avoided; but in welding by hand it was not avoided. There was a fixed fiducial point in heating, the point where objects first became visible. The first appearance of red light was a marked fiducial point, like the freezing or boiling point of water, and it had been determined by many physicists to be 525° Centigrade, or 970° Fahrenheit for all substances. In welding by electricity the metal reached that point, and then gradually, as the current increased, became plastic; it got beyond the state of viscosity, it virtually became liquid, the molecules were mixed together, and before reaching the point of scaling the very temperature was reached which secured the weld. He might be permitted to give an illustration of a perfect weld. He would take a tube in which there was a cylinder of ice; if the cylinder were drawn out and broken, and he desired to weld it, he would put it back in the tube and melt the broken bar of ice; the molecules of water would then rush about amongst themselves, and become one homogeneous mass. Then, by freezing the bar again, an absolutely perfect weld would result. Very much the same thing happened in welding a rod of metal by a current of electricity. The metal was brought to a condition of fluidity, where all the molecules rushed together and became one homogeneous whole; it was then allowed to cool in air, and the result was an absolutely perfect weld. The subject of electric welding was not altogether novel. It had long been employed in the works of Messrs. Siemens, where he had seen it many years ago; indeed, one of the first to work in that direction was the late Sir William Siemens. Mr. Alexander Siemens was present, and perhaps he might be able to state something about the work which was carried on. Electricians were obliged to keep their eyes as well as their ears open since the advances in electricity were so great, and he hardly knew where they were going to stop. Electric welding had been introduced in Russia, and had attracted great attention there. He referred to the Bernardos system, in an account of which he had read that it was possible to weld iron-plates under water; that if a leak, or a crack, or an accident took place to a plate of an iron ship under water it was possible to fuse it even there. Mr. Preece.

Mr. ALEXANDER SIEMENS said that, as Mr. Preece had mentioned, there had been some practical applications of electric welding at the works with which he was connected. It was found that much time was lost in welding the wires in the ordinary way during the sheathing of cables, and in 1881 a special apparatus was constructed, in which the welding heat was produced by a continuous current of electricity. The machine used at that time was small, the current was 60 amperes and 20 volts, but occasionally during the welding it increased to 100 amperes. In the circuit of the machine a variable resistance was fitted. The firm did not weld butt-ends, but made scarf-joints, so as to be quite sure of making a strong joint. On testing afterwards it was found that the wire broke as often in another place as in the weld. The sizes of the wires were 0·073, 0·11, and 0·131 inch. About the same time —in April, 1881—a proposal was made by Mr. Atkinson, who wanted to tin the iron plates of ships as a protection against the action of sea-water. He employed a carbon handle, to which one pole of the dynamo was fastened, the other pole being attached to the iron body of the ship. Bringing a piece of tin into the arc, so to speak, he first fixed little patches of tin on the iron plate, and then he attached the tin plates. There was an application of the same sort of welding in the electric tramway on Ryde Pier. The rails on which the tramcars ran were used as conductors; the ordinary fish rails were not a good enough electrical connection, and therefore the neighbouring rails were attached to each other by a piece of iron bent in a U shape. Mr. Siemens.

Mr. R. E. CROMPTON remarked that those who had seen the apparatus shown at the Paris Exhibition must have been greatly struck with the way in which every detail had been worked out, and must have highly appreciated the mechanical skill and inventive power of Professor Thomson. The Paper and discussion so far as it had gone might convey the belief that only the alternating current could be used for attaining the great heat necessary for this mode of welding. Mr. Preece, in particular, seemed to think that the hysteresis of iron added to the heating effects, but Mr. Crompton did not agree with him. He had made such welds on the previous day, using continuous currents supplied from a few large accumulators; he took pains to measure the current and found it much higher, possibly tenfold the amount stated by Mr. Preece. As the heating was accomplished so very rapidly, the Mr. Crompton.

Mr. Crompton. question of emissivity did not much affect the matter. He believed it was of great importance that the intense heat commenced at the point where the cross-section of the circuit was smallest, namely, where the two rounded surfaces of the ends of the bars to be welded were forced into contact. The welding thus commenced at the centre of the bar, and then spread outwards. This conduced to making the welding sound; for as contact commenced in the centre and the welding commenced also in the centre, the scale which must always be formed whenever iron was heated to such a temperature was forced outwards as the weld took place. Those who had not attempted electric welding had little idea of the great difference in welding metals other than iron and steel. These two last were weldable metals in the true sense of the word, that was, they attained a pasty condition before fusing, whereas the non-weldable metals lost all cohesion just at the fusible point. Mr. Preece had made a mistake in comparing the regelation of the ends of two cylinders of ice with the welding of iron. The phenomenon of the freezing together of the two cylinders of ice was of the same class as the fusing together of two non-weldable metals; a broad distinction should be drawn between it and the phenomenon of welding.

Sir Frederick Abel. Sir FREDERICK ABEL wished to add a word in confirmation of what Mr. Crompton had stated. He thought the action was extremely simple. There was no doubt that a scaling or oxidation of the metal must take place. It was not a question of temperature; it began at a comparatively low temperature, but as the temperature increased the tendency to the fusion of the scale increased, and if welding began at the centre the fused scale would be squeezed from between the surfaces by the two first portions that came together, and as the pressure was continued, and the surfaces were brought together, the scale would be squeezed out, and a perfect weld obtained. When Mr. Preece referred to Joule, Sir Frederick Abel wondered whether he was going to remind the Institution of Civil Engineers that Joule actually predicted in detail many years ago the practical application of electricity to welding purposes. He had given an interesting description of the way in which electric welding ought to be carried out, and the way in which it had been carried out.[1]

Mr. Mordey. Mr. W. M. MORDEY said that he wished to be allowed to point

[1] Memoirs of the Literary and Philosophical Society of Manchester. 2nd Series. Vol. xiv. (1857), p. 49. "On the Fusion of Metals by Voltaic Electricity."

out some of the differences between direct currents and alternate currents for welding. When Professor Elihu Thomson first published his account of electric welding eighteen months or two years ago, his dynamo was a direct-current machine. It was interesting to note that he had abandoned the use of that class of machines and now employed an alternate-current machine to get the large currents that he required. The first apparatus that he used was a low-tension direct-current dynamo, and the welder was placed immediately over the machine. He now was able to adopt the much more convenient plan of having the engine and dynamo at a distance from the place where the welding was done. With low tension direct working that was not possible, even separation of a few feet being objectionable on account of the enormous conductors necessary. By using alternate currents quite a small conductor sufficed to convey the high-tension primary current to the welder, where, by means of a transformer, it was conveniently changed to a very low tension current. There were several advantages in connection with the use of alternate currents. He did not agree with Mr. Crompton as to the advantages of using a direct current for the purpose. Except for very small welds he thought that a direct current was not anything like as useful as an alternate current. Mr. Preece had said that magnetic hysteresis caused the heating of the iron, but he thought this was not exactly the case; in the case of welding copper and other non-magnetic metals, hysteresis had not to be considered at all, and even with iron the metal soon reached the temperature at which it was non-magnetic, and therefore not subject to hysteresis. Besides hysteresis, alternate currents set up an action which was absent with direct currents. Hysteresis was a magnetic molecular effect; it was molecular friction accompanying the change of magnetic condition. The other, or as it had been called, virtual resistance effect was due to the induction of the current on itself, and the result was a tendency to drive the current to the surface of the conductor, and to cause the conductor to oppose a higher resistance to alternating than to direct currents. Alternating currents in passing through conductors were denser near the surface than in the inner portion, and with large conductors and rapid alternations, the inner portions were scarcely traversed at all by the current. This effect, which was not understood a few years ago, was the explanation of some of the difficulties experienced in electric lighting, when it had been attempted to work with large alternating currents. He suggested that it would very probably have a bearing on electric welding and could be made use of to advantage, as a large conductor Mr. Mordey.

Mr. Howard. the end with a sledge-hammer, the result being that it broke through the solid material, and the weld was not affected. He had submitted one of the cylinders to Mr. Kirkaldy, who at the weld obtained a tensile strain within a fraction of 92 per cent. of that of the solid metal. He did not think that the two processes should be regarded as rivals. What one could not do the other could, and he believed there was ample room for both.

Professor Kennedy. Professor A. B. W. KENNEDY said that he had lately spent a few weeks in examining the working of the process in America, and would give a few particulars as to what he had seen. In most of his experiments a machine of the type shown in *Fig. 18* was used, a 60-unit machine having an electromotive force of 300 volts, its rate of alternation being 50 double alternations per second, and its speed about 1,000 revolutions per minute. The engineers who had charge of the works at Lynn, near Boston, where most of the machines were made, had fixed by experiment a standard time during which it was convenient that the operation should last, and also a standard projection beyond the edges of the copper clips for the pieces to be welded. The projection which they made in the case of a round bar was equal to the diameter, so that for a bar 1 inch in diameter there was a clear space of 2 inches between the clips. The standard time was forty seconds for a 1-inch bar, and otherwise in proportion to the diameter. Whatever the duration of the current and the diameter of the bar, within certain limits it might be expected that the actual energy expended would be reasonably proportional to the cube of the diameter, speaking only of round bars. He did not, in his own experiments, measure the indicated HP., but he measured directly the current going to the transformer (using a watt-meter which he had previously calibrated), and he obtained the following figures. For a 1-inch bar the weld took 328,000 foot-lbs. of energy, for a ¾-inch bar 143,000 foot-lbs., for a ½-inch bar 43,000. These quantities were very nearly in proportion to the cube of the diameter. With steel the figures were nearly the same. As the length of the part heated was made to vary as the diameter, and as the time was also made to vary as the diameter, the HP. ought to vary as the square of the diameter, and the HP. per square inch ought to be constant. He found that the HP. per square inch for a 1-inch bar was 20·0, ¾-inch 19·3, ½-inch 20·4; in steel, 1-inch 23·0, ¾-inch 20·5, and ½-inch 19·6. That was, as nearly as he could measure it, the mean electrical HP. going into the transformer per square inch of cross section of weld, during the actual time when the current was turned on, and he had taken tolerably frequent readings during those few seconds. In another type of machine, the one used for copper, he found that the HP. was considerably less. At the standard time for a 2-inch bar it was only 14·6 per square inch. He had found in the case of copper a discrepancy which he would not then attempt to account for, namely that the net electrical HP. was nearly constant, although the time varied considerably. He made the time vary from twenty-one to thirty seconds, but the net electrical HP. per square inch of copper was in every case almost exactly 45. The actual energy varied directly as the time, as nearly as he could measure it. At one of the largest bicycle factories in the United States, at Hartford, Connecticut, he found a welding machine being used for brazing the tubular limbs into the Y-shaped fork of the front wheel of the bicycle. The fork was a nickel steel casting, into which the two tubes were to be brazed. Each tube was put into its socket, and two or three turns of fine brass wire were wound round it. The tube was held in one clamp and the socket in the other, and the current passed through and melted the wire. No pressure was exerted, but the brazing found its way into the joints, and a very excellent brazed joint was made. The managing director of the works had told him that he liked the process so much that he proposed to alter the designs of the bicycles in order that as many parts as possible might be brazed in that manner. The great cleanness of the braze was very noticeable, the borax glaze outside being not so much spread as in the case of a number of hand brazes which he saw at the same works; and the time occupied in brazing was not more than one-half that required with a gas furnace. This machine had made about 30,000 brazes in nine months. Professor Thomson, and the engineers who had worked with him, had made a great speciality in the matter of welding (galvanized) telegraphic wire, and also copper and brass wire. At one of the largest telegraph-wire works, that of Messrs. Cooper, Hewitt & Company, Mr. Spilsbury had told him that it was his duty to send in from time to time to the Postal authorities three lengths of 50 feet each of wire for testing conductivity. On one occasion he had made one of these 50 feet lengths out of 50 separate feet welded together into one length, and had sent the three to be tested without saying anything about this. All three lengths passed the test equally well! One thing that had surprised him was that a brass wire, welded in this fashion, with a mere butt weld, should stand drawing without the least harm. He had taken five little pieces of wire 4 inches long, and had them welded into one length and had the burrs removed; they were at once carried to the drawing plate and Prof. Kennedy.

Prof. Kennedy. passed in his presence six times through (the wire was of 0·125 inch diameter to begin with, and finished with a diameter of 0·03 inch), and there was not the slightest trace of the existence of the four welds. At the works of Messrs. Roebling, Sons & Company, at Trenton, he found that it was a habit to piece up all kinds of odds and ends of old wire; and a welder which was going apparently day and night had made at the time of his visit about 194,000 welds. He had found with some interest that wagons in America possess such a thing as a "fifth wheel"! It was the circular ring serving as a guide for the bogie frame of the front axle, called a perch plate. At the works of the New York Fifth Wheel Company these rings were made of channel section, about 2½ inches by 1 inch, and ⅜ inch thick. They were bent round cold to a slightly larger diameter than was intended, so that they made a complete ring. The two ends were held in clamps, the current was passed through, and they were simply pushed together during the process as in the case of straight bars, and as far as he could see the weld was as perfect as any of the others. From the time of putting in to the time of taking out, including some hammering, about four minutes elapsed; then the burr had to be ground off on an emery wheel, which took three minutes more, so that the whole operation took about seven minutes. The smith told him that in welding the rings as he had formerly done he had first to flatten down the two sides and open them out, then scarf-weld them, and then hammer up the edges again, which occupied thirty-five or forty minutes; so that the saving in time was very great, and there was certainly no comparison between the quality of welds after they were made. Whether the process would be applied to the welding up of angle-iron frames, or other parts of constructive ironwork, was perhaps questionable; but it was obviously a process by which such welding was possible, and engineers would be glad to get welded angle-iron frames instead of the built-up frames which they were now compelled to use, and which had all kinds of weak places round them. The welding of chains, he believed, had not been carried very far, but what he had seen was so satisfactory as to make him hope that the electric welding process would be used for that purpose. He believed that the idea was not to use two half links shaped like U's entirely separate and then to put them together and weld them (although he had had some links welded in that way very well), but to make the links in a C shape, so that there was only one opening, and to hold the two bends of the C in the clamps. When the current was put on, the resistance on the open side increased as it heated, so that the other side heated up also. Thus by the time the current had been kept on long enough to weld the one side, the other side was hot enough to upset, and when the pressure had been put on, the link looked as if it had been welded on both sides. The Author had alluded to the welding of wire cables. This he had seen carried out several times, and had brought some specimens back with him. Of course, the effect of the welding in such a case was simply to make a short piece of cable (perhaps equal in length to two diameters) perfectly solid. In the case he had tested, the weld was about 78 per cent. of the strength of the actual unwelded cable, which was an enormous percentage for any wire cable, and for a cable of the interlocked type it was specially satisfactory. Prof. Kennedy.

Mr. Henry Davey regretted that he only had a superficial knowledge of the subject of electricity. In the text-books he Mr. Davey.

Fig. 29. *Fig. 30.*

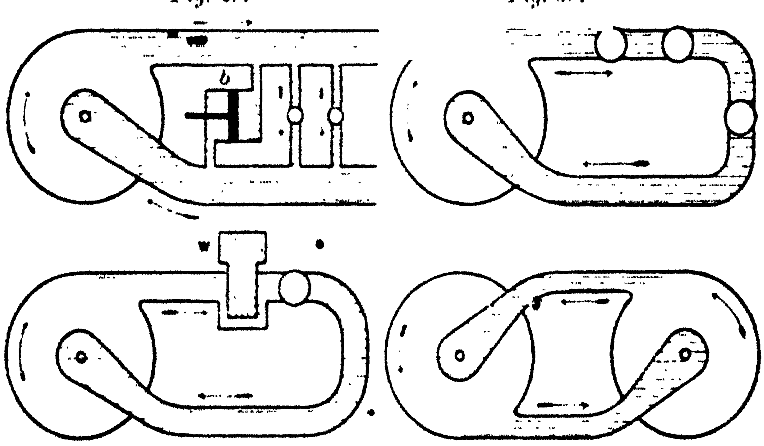


Fig. 31. *Fig. 32.*

found a constant reference to hydraulic analogy; and the statement was made that a current of electricity behaved in much the same way as a current of water. The books, however, did not go much into detail, but only dealt with the subject in a very general way. In speaking of a hydraulic engine, the first engine that naturally occurred was that of reciprocating machinery. He thought, however, that if attention was directed to hydraulic analogy in a more complete way, and machines were sought out which had a more perfect analogy, it would be of more assistance. By a little ingenuity there could be got from the centrifugal pump and the turbine almost a complete analogy as to the behaviour of electrical currents, taking the centrifugal

Mr. Davey. pump as the dynamo, and the turbine as the motor. He had in a diagram which he had placed on the wall, a centrifugal pump, which was analogous to a self-regulating dynamo. A self-regulating dynamo had a shunt, and it could be employed to supply lamps in parallel. If another lamp was added there was a greater demand for the current, and the self-regulating dynamo supplied that current. To complete the analogy with the centrifugal pump he would put in as a shunt a hydraulic cylinder (*Fig. 29*), with a piston, the rod of which was attached to a mechanism which would expand or contract the mouth of the pump. Immediately the pressure was increased on one side and diminished on the other momentarily, the shunt came into action; it opened the mouth of the pump, and the increase of the engine-power gave the increased current. That, he thought, was a more complete analogy than he had seen in the text-books. *Fig. 30* illustrated a series dynamo, and *Fig. 31* a series dynamo supplying an accumulator. Supposing the speed of the centrifugal pump (*Fig. 31*) to be reduced below what was necessary to keep up the pressure in the accumulator there was a reversed polarity. The last diagram (*Fig. 32*) showed the centrifugal pump giving motion to a turbine, or the coupling of a dynamo to a motor.

Mr. Matheson. Mr. EWING MATHESON observed that the Author had spoken of putting the pieces of metal to be welded a second time into the machine, and it appeared that the time occupied by the second process had a considerable effect in regard to the total result as compared with hand-welding. He had seen a great many pieces welded, but it was very seldom that they were put a second time into the machine. It was not essential to the process of welding. If it was required to re-heat them for any manipulation, they could be re-heated at will; but it was not necessary for the primary purposes of welding. If, therefore, the time occupied for the second operation were deducted from the total amount, which was given as one hundred and thirty-five seconds, the comparison with hand-welding would be considerably altered. Taking the gross power while the current was on at 33, and the average power when the engine was running light and produced no current, at 9, instead of giving could not be welded at all by the hand-process, namely, hard and so-called unweldable steel. To engineers, steel-makers, and toolmakers, that was a distinct advantage. He had seen some very hard Mushet steel (the hardest tool steel) welded to soft or Bessemer steel and to iron in a way that allowed the tool steel to be used right up to the end, instead of having to be thrown away when it was too short to hold in a machine. He had also seen lead welded—a curious operation, impossible by any other means, and one which he believed, in certain manufactures, was very valuable. Mr. Matheson.

Mr. B. Blount asked whether there were any data respecting the composition of the bars before and after welding. The smaller angle through which an electrically-welded bar might be bent cold might be due to some change which had occurred during the drastic operation of electric-welding; and he should be glad to know if any analyses were available which would throw light upon that point. Mr. Blount.

Mr. W. W. Beaumont had made a number of experiments with the same machine with 1⅛-inch Farnley iron, and with other sizes; and from what he saw with regard to the passage of the current, the discrepancy between what Mr. Crompton and Mr. Mordey had said was only apparent. When the ends of the pieces of iron were rounded, the centre parts, or the parts that touched first, became hot first, like the two pointed ends of a pair of carbons in an arc lamp. It might be true that the passage of the continuous current was as Mr. Crompton had stated, and the alternating current as Mr. Mordey had said; but as a matter of fact, those parts first became hot which were first in contact with each other. But then the bars were not rounded, they were flat. When the bar was sheared off, the shearing was at a slight angle, and the two pieces were placed in the clamps so that one angle became the complement of the other, and contact took place over a considerable area immediately after the current was switched on. With regard to the power taken in performing 1-inch welds, he had found, from experiment, that the maximum HP. was 22 or 23, and the average, taking the whole Mr. Beaumont.
it was being made, not much more than 12. That would
the cost given in the Paper as compared with the cost of
g the same iron by hand. He had noticed that the elec-
welded some of the bars at one operation, but when they
to be very careful to get an excellent weld, or one with
a good finish, though perhaps not stronger than the others, they took two heats. He had also observed that they almost invariably

Mr. Beaumont. left the iron where it was welded rather larger in section than the other part of the bar. That might, perhaps, explain the fact that in some cases the bending did not take place to so large an angle as in the case of some of the hand-made welds. It would be interesting if, when tests were made of the strength of electric welds, the specimens could be turned, so that the sections should be the same throughout. Mr. Mordey had mentioned the use of a small engine and heavy fly-wheel. From the figures which Mr. Beaumont had given, it appeared that a smaller engine might be used, when only one machine was needed, more economically than a large engine. Although welding by electricity might not take the place of ordinary welding for common work, the process would, no doubt, be extremely valuable in many cases where welding was now impossible, or where things had to be made out of a solid piece but could be more cheaply made in parts; and also in the work of brazing.

Mr. Mordey. Mr. W. M. Mordey said that the difference of tendency between an alternate and a direct current was this: with a direct current the part heated first was the centre; with an alternate current it was the outside; with an alternate current the heat grew inwards; with a direct current, outwards.

Mr. de Segundo. Mr. E. C. de Segundo stated that no details had been given of the increase of cost of electric welding over that of ordinary welding by a smith's fire. It was of course not fair to judge by the temporary plant exhibited at the Institution. But, even in the case of a welding machine in constant use, it was not easily seen how, generally, electric welding could compete with ordinary welding when the cost was taken into joint consideration with the time saved. Neither in the tests mentioned in the Paper, nor in those detailed by Professor Kennedy, could a saving in time of more than 50 per cent. be claimed in ordinary work, whereas the cost must be many times as great. For in the case of the smith's fire the work was brought into direct contact with the heat of the fire, and the heat was to a great extent localized by the blast, and by well-known measures adopted by smiths; but in electric welding even under the most advantageous conditions, namely, where power could be obtained cheaply, the first cost, as also the maintenance of the plant, was and must be necessarily larger than that of an ordinary forge, and the power was frittered down by two efficiencies, that of the dynamo and that of the transformer. In cases were steam-power was used, a considerable increase of loss was unavoidable, since heat being the lowest known form of energy, the transformation to a higher form and then down again

Mr. de Segundo.

to the lower could not but result in waste. Further, it must be evident that, at least for the present, the range of applicability of electric welding must be limited, for, with the machine exhibited it was certainly only possible to do work of a very straightforward character. For instance, should it be required to weld channel or other forms of iron, as related by Professor Kennedy, it was not conceivable that the same clamps would be used as for round bars; otherwise it was difficult to see how injury to the material from local heating could be avoided. If not, special clamps, or universally adjustable clamps, or special machines for each class of work, must be provided; but the first arrangement would involve a loss of time, the second would be difficult of realization owing to the contacts necessary for such large currents, and the third would involve a heavy outlay. It was, of course, extremely difficult to calculate the electrical energy required to weld iron, but the following gave some idea, however rough, of the required amount. Assuming the bar to be welded to be 1 square inch in section, and that the metal for 2 inches on each side of the weld was raised in temperature 2,000° Fahrenheit on the average, the expenditure of heat, supposing for simplicity in calculation there were no radiation and constant specific heat, would be about 250 thermal units. Now the Author's practical illustration showed clearly the enormous amount of heat lost by radiation and conduction, hence at least 50 per cent. might safely be added to this value. Of course the duration of the "heat" should be taken into account, as this would greatly affect the amount of heat radiated. Assuming, however, $250 + \frac{250}{2} = 375$ thermal units to be the amount required, this multiplied by the average counter-efficiency of the transformer, say $\frac{1}{0\cdot6}$ of the dynamo, say $\frac{1}{0\cdot85}$ of the engine, boiler, and loss in transmission by belting, &c., say $\frac{1}{0\cdot07}$, would correspond to 10,600 thermal units liberated in the furnace, or to the combustion of something like 1 lb. of coal, such as was used in a smith's forge. This, it need hardly be said, although a low estimate, was probably in excess of what was burnt at a forge for so small an operation as the welding of two bars 1·13 inch in diameter. The cost increase as the work got larger, and probably a limit soon be reached. Besides it was not probable that in the of large bars, the heat would be anything like as uniformly distributed throughout the material as if the bars had been heated smith's fire. There could, however, be little doubt that for special branches of industry electric welding would find a useful application, but it would not be prudent to predict for it wide extension in purely mechanical or civil engineering work.

Sir Frederick Bramwell.

Sir F. BRAMWELL said he had very little to reply to. Not unnaturally, the speakers had been principally electricians, and they appeared to him to have shown sufficient diversity in the opinions they expressed for one opinion to neutralize the other; the acid and alkali making a neutral salt. Mr. Preece had given the result of experiments made by him to ascertain the number of amperes needed to immediately fuse a wire, so immediately as to represent the result of a flash of lightning upon a conductor, for it was with reference to conductors that he had instituted the experiments. It appeared to Sir Frederick Bramwell that that had nothing to do with the Paper. He had not been dealing with the instantaneous effects of electricity, but with the practical welding question, and therefore the question of what number of amperes passing through any given diameter of wire of any given metal would cause instant deflagration, without the question of the loss of heat energy by dissipation coming into account, had nothing to do with the subject before the meeting. The experiments were, no doubt, interesting in themselves, but they were not germane to the matter. On the question of time being an element in the attainment of any needed temperature, there was one point in his Paper, that of the extra resistance offered by the metal as the temperature rose, the importance of which appeared to have been overlooked; to this point he should have to revert. Mr. Crompton had said that time had nothing to do with the matter. He could not understand how a gentleman of his large experience in electrical science and in its applications could have made that statement, or indeed how any one who had seen no more than the experiments carried out at the meeting could have come to that conclusion. It must have been obvious to every one that the temperature was a growing quantity, and that it continued to grow until the sources of dissipation of heat operated to such an extent that the dissipation was equal to the supply, and then it remained stationary. If a given conductor—the thing to be welded between the points that were to weld it—destroyed the well-known 33,000 foot-lbs. of electrical energy in any given time, say a minute, the utmost that could be got out of that destruction, and that which would inevitably be got out of it, was 41 or 42 heat-units. These heat-units would be obtained if the current were continued, say a minute; if continued two minutes, the number of heat-units would be doubled. There would, he agreed, be a certain amount of loss, but the product of heat-units would be doubled; and how, therefore, it could be said that the heating, depending as it did upon the destruction

Sir Frederick Bramwell.

of electrical energy, and the conversion in the conductor which destroyed that energy into heat was instantaneous and independent of time, he could not imagine. Mr. Mordey had referred to some extremely interesting experiments, but he did not appear to agree with Mr. Crompton or with Mr. Preece. His suggestion was that in alternating currents, the heat was communicated, to begin with, on the outside of the material, and that it would heat up a tube more rapidly than it would heat up a solid bar. Some of them no doubt were aware of a curious instance, in the person of one of their Past Presidents, of the effect of an alternating current upon a bar, the outside having been made so hot that his fingers were burned by laying hold of it, but afterwards, when thrown down and picked up by a labourer, it was found to be quite cold. The heat, in that case, like beauty, was only skin deep. This expression was corroborative of Mr. Mordey's views. But although this might be abstractedly true of the result of using an alternating current, it certainly did not obtain in the practical work of the machine, and Sir Frederick Bramwell was inclined to believe that Mr. Mordey, like the other speakers, had neglected the statement in the Paper to which he had before alluded, that of the effect of the increase of the resistance with the rise of temperature. He desired to be permitted to quote the passage: "This increase of resistance to the passage of the current, as the temperature increases, is of great utility in electric welding. Consider the two ends of bars to be welded, mere ordinary rough surfaces, the first contact is made upon numerous points, through these the current passes, and they become rapidly heated, and offer more resistance. As endway pressure is applied, the surfaces in contact become of larger and larger area. The greater current seeks those parts which, although in contact, are at a lower temperature, and this goes on until contact, and uniform temperature, are obtained all over." If more value had been attached to that statement it would have been seen why it was practically a matter of indifference whether the heat began at the outside or in the middle or anywhere else. It might be illustrated by the passage of water. Suppose there were a closed vessel out of which proceeded a number of tubes, some a ¼-inch, some ½-inch, and some 1 inch diameter, and that the box was supplied with a uniform pressure, and that it was desired to send water through the tubes. They all knew what the rate of flow would be through those respective diameters, how the inch tubes would prevail over the ½-inch, and the ½-inch over the ¼-inch tubes. But suppose while the water was going through the

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larger tubes with great rapidity there was deposited from it some matter inside the 1-inch and ½-inch tubes, choking them up? It appeared to him that the time would soon arrive for the other tubes to take up the running, because on the hypothesis those tubes that were the best at the beginning would be the worst afterwards. In that way, from the incident of the operation which he had suggested, they would obtain a practical uniformity at last of the currents through all the various parts of the water-conductor which he had thought of as a comparison. Similarly with electricity. Any one who had watched the two bars in contact would have seen that the glow began where the contact took place, whether in the middle or at the edge; that the points of contact then became plastic, that they were compressed by the screw, that more surfaces were brought in contact, and that those surfaces being cooler, the current sought them, heating them up next in turn, and that this operation went on until the whole surface was heated. Mr. Preece's suggestion was that the greater heat at the centre as compared with that at the edges was due to the enormous rapidity with which the heat was conducted away by the holding jaws. Although no doubt there was conduction there, he thought Mr. Preece would find that it was not, as he had put it, because the heated part was cooled down by contact with the jaws, but that the central part remote from the jaws was the hotter because it was the part of worst conduction from the very outset of the current, and became worse as the operation went on—worse to begin with because of the few points of contact, worse afterwards because of the heating up of that particular place; therefore it necessarily remained the hottest. With regard to the other speakers—Mr. Siemens, Sir Frederick Abel, and others—he could only thank them for the kind manner in which they had spoken, and for the information they had given. Professor Kennedy's statement also as to what he had seen in the United States, where the machines were in actual commercial use, was of great value to the meeting. One speaker had said that he was surprised at the amount of plant and power used for the experiments. He had already adverted to the cause, but he trusted he might be allowed to repeat that as much electrical horse-power must be destroyed as would give the needed amount of heat-units in a given time; it was a necessity, and it could not be helped, unless they were prepared to spend more time in the heating up; but this meant waste of the workman's time, and waste of the production of the machine, and waste of power, as the cooling losses were continued for a longer period. As a matter of fact, there was utilized a very

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large amount of the heat derived from the destruction of the electrical energy—of the electrical horse-power—the defect in utilizing the fuel was not at this point, but was at an earlier stage, that of obtaining in the steam-engine anything like the value of the heat-units residing in the coal consumed. If they only had the horse-power in the steam-engine for anything like the theoretical value, there would be no furnace so economical in rendering back the heat to the iron; the loss would be found to be much less than with any known mode of applying heat; but the difficulty was at the outset, the first conversion of the fuel, the turning of its latent energy into motive power; the loss was there. It remained to be seen how far, on a balance of advantages, the greater consumption of fuel (if it were greater) and the size of the plant, would outweigh the obvious conveniences connected with the certainty, the cleanliness, and the rapidity of the operation. As to the way in which the bars had shown signs of cracking when bent cold after passing through only 60°, as compared with the scarf-welds at 114°, he had already said that he thought it could be cured by annealing, but he had not as yet suggested the cause of the difference; he now desired to express his belief that it was due to the extreme localization of the heat during the welding operation. With a scarf-weld the whole length of the bar was heated up as far as the length of the scarf, and there was a considerable extension of heat beyond that; but with the electrically heated butt-weld the heat was much localized, and it appeared to him that that might result in a difficulty in the cold bending—a difficulty of no great importance, and one which might be almost certainly overcome by annealing. He thought he was justified in saying this because when the electrically-welded bars were bent hot they bent neither better nor worse than the hand-welded bars, and this difference between the hot and cold states could only be due to the fact that in the reheating the heat was diffused through a considerable length. He therefore thought that if these bars had been allowed to cool down, and had then been tested, they would have bent as well cold as the hand-welded bars. Although he had not been able in person to make the experiment, or even to superintend it, he had been told, and he had every reason to believe it was the fact, that in cases where the bars had been annealed they had given bending results as good as hand-welded bars.

[CORRESPONDENCE.

Correspondence.

Mr. Menges. Mr. C. L. R. E. MENGES observed from the diagrams, *Figs.* 23, 24, and 25, that the speed of the engine, when running light, was about 7 per cent. above the speed at maximum HP. Now, he thought such variations in speed during the use of the large welder C, *Fig.* 22, would make it at least difficult to use at the same time the small welder A, the more so as the current varied even in a greater ratio than the speed. That might be of no consequence in this temporary installation, but in a workshop all machines should be, of course, quite independent of each other. A 7 per cent. variation in speed was by no means too much for a steam-engine, and especially in such cases as this one, where the power was suddenly thrown off. He should never advise the adoption of a more sensitive, that was a more astatic, governor, for then the engine would certainly hunt. For a like reason, any of the common kind of electric regulators, such as Richardson's, Willans', the Porte-Manville, and others, would be useless; they would hunt or would be too slow. In this application of electricity, which depended upon the heat developed by the current, which was proportional to the square of the current, it was obvious that sudden variations in the speed would have a detrimental effect upon the quality and the quantity of the work. He wished, therefore, to direct the attention of those interested in electric welding to his electric governor.[1] It would exceed the limits of discussion to give here a full description of his method; as, however, many people object to the use of any complicated apparatus in a blacksmith's work, he might mention that his method consisted in a special manner of applying the current in an exceedingly simple apparatus, and that by this method variations in speed might be prevented. This was impossible with all the common kinds of regulators, because their action depended upon the variation in speed. A good regulation in this case gave still another more direct advantage. According to the Paper, pp. 25 and 31, the engine was running light during more than two-thirds of the time to make a weld, and for pieces of more difficult form, this ratio would, of course, be much greater. A reduction in speed of 7 per cent. during more than two-thirds of the time that the

[1] Elektrotechnische Zeitschrift. Berlin, 1887, p. 171; and *The Electrician* vol. xix. p. 482.

engine was at work, would thus give a saving in steam, fuel, wear and tear, &c., which was by no means to be neglected. For large welders he should like to go a step further, by using for each welder a separate steam-dynamo, governed by his method so as to run at 10 per cent., or even more below the normal speed when running light, and to get up to full speed immediately the current was switched on. Mr. Menges.

Professor SILVANUS P. THOMPSON remarked that the Author had so well and so thoroughly explained the methods adopted by the inventor for transforming electric energy, from the condition of small current at high-pressure (or potential) down to the condition of large current at low pressure, that no further explanation of this problem of practical engineering was needed. He had, however, taken the opportunity of making a number of electrical tests upon the apparatus installed at Fanshaw Street, and upon the currents supplied by the generating machine to the welding machine during the operation of welding. In these tests it was desired to measure the amount of power actually supplied electrically to the welding machine. The instruments were, therefore, inserted between the generating apparatus and the welding machines, and did not measure any of the power wasted in the belting, shafting, or bearings of the running plant. Neither did they measure any of the power wasted by magnetic friction, nor by the production of eddy-currents in the moving parts, nor that part of the power which was employed in driving the separate exciting machine, and expended in maintaining the magnetic field of the alternate current generator. The only power measured was that which passed across and entered into the primary wire of the transformer in the welding machine. Such measurements of power supplied electrically were not always easy nor simple in the case where alternate currents were used. For in this case power could not be accurately reckoned by multiplying together the two simple factors of current and potential. The custom, so familiar to all engineers, of calculating mechanical power by multiplying together the two factors, force and speed, had its electrical analogue in the two electrical factors of current and potential (or electric pressure). But engineers knew also that if the force measured were not a force exerted in the same line as the motion that was measured, but at some angle with that motion, the proper factor to employ was not the whole force, but its resolved part along the line of motion. Or, in other words, the product of the apparent values required to be reduced to its true value by being multiplied by the cosine of the angle between the two factors. Electrically, Professor Thompson.

Professor Thompson.

a similar distinction had to be observed between the apparent value and the true value of the product, whenever alternating currents were employed. For, in the case of alternating currents, the waves of positive and negative current which resulted from the application in the circuit of alternating electromotive pressures, suffered a retardation of phase, the waves of current coming to their maxima after the waves of electromotive force (or pressure) had passed their respective maxima. The maximum pressure was not acting on the circuit at precisely the same instant as the maximum current was flowing; hence the apparent product obtained by multiplying together the two maximum values would be in excess of the maximum value of the true product; and the product of the two average values would be in excess of the average value of the true product. As in the mechanical problem so in the electrical, the true value was to be obtained from the apparent value by multiplying by the cosine of the angle between them; the angle in the electrical case being the angle of phase of lag of the current; the current being assumed, like the tides, to rise and fall periodically in the manner known as "simple-harmonic." Now, in measuring the power supplied by an alternate-current dynamo to a system of conducting wires, it was clear that if an ampere-meter of suitable type was inserted in the main conductor to measure the current, and if a volt-meter of proper construction was applied across the mains to measure the difference of potential or electric pressure between them, there would still be required a third instrument to measure the angle of phase between the waves of current and the waves of pressure. And, if three such instruments were set up in the system, it would be needful to take three simultaneous readings in order to evaluate the power supplied at any time. But in the case of the operations of welding, which lasted for but a few seconds, and in which by the very nature of things the power was continually increasing or decreasing, it became impracticable to take such sets of readings. Resort must be had to some simpler method, even though it might not be susceptible of so great refinement. It was known that when a transformer of alternate currents was used, the retardation of phase of the currents behind the electromotive forces was at its maximum when the transformer was doing no work; and that on the other hand the retardation became practically zero when the work done by the transformer was at or near its maximum. Hence, it was fair to take, as a sufficient approximation for most purposes, the assumption that the retardation of phase would be small enough to be neglected, whenever power above a certain value was being supplied to the transformer. Further it was possible to construct instruments in which the difference of phase between current and pressure was actually taken into account; such an instrument being existent in the watt-meter of the late Sir William Siemens. A watt-meter, specially adapted to the purpose, by having its fine-wire circuit arranged to offer a very large resistance, in proportion to its electric inertia, was therefore employed in the Hoxton tests. The thick wire coil was inserted in the main circuit, and the fine wire coil, augmented by suitable resistance coils, was inserted as a shunt across the mains. With such an apparatus it was possible to obtain four or five readings of power during the operation of a single weld. He was present, and made electric tests, during the eighty weldings conducted for the Author of the Paper. He would, therefore, speak first of these welds. They were all made on 1⅛-inch wrought-iron; and the power required was found to vary somewhat with the rate at which the operation was conducted. If only moderate power was applied, more time was required to heat up the joint, than if more power was applied. The time during which the current was actually on (not including the re-heating before using the swage) was noted, and the average duration was actually only thirty-two seconds and one-tenth for each weld. The average power supplied electrically during this time (the average being taken for the whole eighty welds) was 13·17 kilo-watts, or 17·5 HP. When the operation was conducted more rapidly the power rose. The last ten welds were made more quickly than the average, their average duration being twenty-eight seconds and a half, and the power applied electrically was 13·34 kilo-watts, or almost exactly 18 HP. But in the first ten welds which were made more slowly, taking on the average thirty-three seconds and seven-tenths, the power supplied was 12·82 kilo-watts, or 17·1 HP. In another individual case a single similar weld conducted in thirty seconds, required 17·01 kilo-watts, or 22·8 HP. In the re-heating of the eighty welds, the average power expended electrically was 15·19 kilo-watts, or a little over 20 HP., for an average duration of twelve seconds and nine-tenths. In welding ¾-inch round steel bars the average power employed was 11·4 kilo-watts, or 14·2 HP. for sixteen seconds. In welding some larger wrought-iron bars of rectangular section, about 2½ by 1⅛-inch in the sides, there was required an average power of 24·98 kilo-watts, or 33·4 HP. for a duration of twenty-eight seconds and a half. He did not think that any proportion could be drawn between cross section and power required for welding, as the main expenditure of energy was due to the Professor Thompson

Professor Thompson. escape of heat from the surface. More power was required to weld square bars than to weld round bars of equal section and similar material. He had also made some tests upon the electric conductivity of joints thus electrically welded; these showed that the conductivity of joints was scarcely inferior to that of the solid material, if at all. It was to be hoped that the Postal Telegraph Department of the British Government would not be slow to adopt an electric method of welding its line wires instead of using the present comparatively clumsy modes of jointing them. As doubts might arise concerning the safety of such apparatus as the electric welder, he might state that more than once during a welding, he had grasped the two clamps with both hands, and could not feel the slightest sensation. The parts of the machine where the high-pressure circuit came in and went out were amply protected, so that any part of the apparatus might be handled without its giving a shock. Doubtless it might be possible to apply to welding in some similar way the direct electric current instead of the alternating one, though the direct current, whether supplied from dynamo machines or from accumulators would be far less convenient to regulate and control than was the alternating current. One phenomenon of high interest to engineers could be shown in perfection by means of the welding machine; namely, the recalescence of steel. If a steel file was placed in the machine, and gently heated up, a sort of dark wave might be perceived passing over its surface as the critical temperature was reached and surpassed. Then if the file was taken out and allowed to cool, a wave of brighter red light might be noticed to move gently from the ends toward the middle as the critical temperature was again reached during cooling. Lastly, he should like to point out the triply automatic nature of this most ingenious process. Not only was the heat produced just at the place where it was wanted, because the greatest resistance to the electric flow was there; but directly any portion of the metal was heated sufficiently, it flowed aside under the application of pressure, and fresh parts of the joint were brought into the path of the current. As the joint grew more perfect it necessarily conducted better, and more current flowed, so automatically keeping up the heat over the greater area. And not only so, but this action must necessarily take place precisely at that temperature which was needful for welding, simply because so soon as that temperature was reached the softened portions moved aside, and colder portions were brought up to be heated. It was seldom that such advantage could be taken of the facts of nature, rendering them simultaneously automatic in a single industrial process, the very simplicity of which attested its intrinsic merit as a great invention. Professor Thompson.

Mr. S. ALFRED VARLEY observed that, as a pioneer in electro-dynamics, he took considerable interest in any electrical advance. He desired to ask whether the Author could state the actual ampere current necessary to weld a given section of iron. The conclusion at which he had arrived from a close study of electro-dynamics now for more than thirty years, was, that what was described as hysteresis was simply attributable to the inertia inherent to all electrical conductors. Inertia was opposed both to the setting up electrical motion and also to the cessation of such electrical motion after it had been set up in a conductor, much in the same way as matter resisted a sudden change from a condition of rest to a state of motion, or from a state of motion to a condition of rest; and, as active magnetism was developed in the conductor in proportion to the inertia, the inertia which conductors opposed might be fairly termed magnetic inertia. This, for the different metals, varied very much in the same way as their respective specific gravities varied; and the magnetic inertia opposed by a conductor was directly as its specific magnetic inertia multiplied by its mass. The specific magnetic inertia of iron was many hundreds, probably many thousands, of times greater than that of any other conductor; that was to say, if the specific inertia or gravity of iron were expressed in terms of magnetic instead of terrestrial gravity, the iron would be by far the densest of all substances, and it was not too much to say, that were it not that iron possessed magnetic inertia in so large a degree relatively to all other conducting matter, there would be neither dynamos nor transformers. When a primary circuit wrapped on an iron core was surrounded by a closed secondary circuit, as in a working transformer, much less magnetic inertia was encountered than if there was no secondary circuit. The action of the secondary circuit resembled very much that of a brattice which, by dividing an air shaft into two sections, enabled two currents of air to travel through the shaft freely in opposite directions to one another at the same time. The iron bar to be welded was interposed in the secondary circuit of the transformer, but outside of it; and, as there was no separate conducting channel surrounding the iron bar, the inertia of the iron to sudden reversals of the direction of the electric motion tended to produce secondary currents in the iron bar itself; in other words, to set up two currents in an opposite direction to one another. What followed was much the same as that which occurred when the Mr. Varley.

Mr. Varley. brattice of a mining shaft was suddenly destroyed; the energy transmitted through the medium of the transformer being unable to develop in the iron two currents in an opposite direction to one another, it had to overcome the magnetic inertia of the iron, and consequently energy became dissipated locally, by developing heat in the iron in a much larger degree than throughout the secondary circuit generally. Transformers were so far self-regulating that they were capable of accommodating themselves in some degree to the conditions that prevailed, and approximately the voltage of the currents developed in the secondary circuit of the transformer was raised as the inertia resistance of the iron bar increased, the amperes becoming correspondingly reduced. The practical outcome was that the heat developed was confined in a greater degree in the weld itself, which it was desired to heat. He considered this a fair analysis of what occurred when a bar of iron was heated by electric alternations, and which physicists seemed to think sufficiently explained by coining the term hysteresis.

Mr. Walker. Mr. SYDNEY F. WALKER, upon the question of the use of the spark, or the electric arc, in electric welding, as against the use of a dead metallic resistance, observed that electrical engineers knew, to their cost, that when a spark passed between any two points, say when a wire was broken, a switch was making faulty contact, or the brushes of a dynamo were badly set, the heat generated was far in excess of that which would be generated when the spark was not present. In fact, apart from the loss of energy which sparking at the brushes of a dynamo entailed, the great importance of reduced sparking was to keep the machine cool, thereby increasing its possible output, as well as its efficiency. It was also well known that the light given out by an arc lamp was generated at the cost of one-tenth of the energy that would be required to produce the same amount of light from a glow-lamp. Now, seeing the large power required for electric welding—50 indicated HP. for the experiments conducted under the superintendence of the Author of the Paper—the question arose, could not the arc be used for welding in place of the dead metallic resistance, since, if it could be used, a 5-HP. plant could be substituted for the 50-HP. one, and be much more within the means of manufacturers generally? And if the cost could be reduced also, might not electric welding be substituted for soldering and brazing in a number of operations? In the construction of dynamos, for instance, and in electric light mains, wires were getting larger and larger, and still no satisfactory method of jointing had been discovered equal to the old-fashioned method of soldering or brazing; while the great difficulty of making a good soldered joint between large masses of metal was a matter of common experience. Apart from this, the soldered joint had a higher resistance than the lengths of the two wires or cables to be connected, and certainly higher than a welded joint. He was aware that the dead metallic resistance was far more manageable, and therefore more convenient than the arc, just as the glow-lamp was better than the arc light wherever it could be used. But he suggested, in view of the saving to be effected in cost and on capital account, that since the apparatus would always be in skilled hands, and the arc would only be required for a few seconds at a time, the problem of using the arc for welding was well worth solving. Again, not more power was required with the alternating than with the continuous current to produce a certain heating effect; but it was a question whether the metal to be welded was affected by the fact that the heat appeared to go from within outwards with one form of current, and from outside inwards with the other. If it was not affected, then the balance of convenience would appear to be with the alternating current. The periodicity of the alternations was, however, an important factor in the case. In the cycle of operations which ruled with alternating currents, the metal would have a certain time to cool between the times when the current was at its greatest strength. If this time was very short, so that practically none was allowed the metal for cooling, then the time required for heating a weld with the alternating current would be the same for the same current strength—the maximum current strength, of course—as with the continuous current. But if the alternations were very slow, a larger current must be employed than with the continuous current, or the welding must take a longer time, owing to the time allowed the metal to cool between the times of maximum current. However, any increase of the number of alternations beyond that required to prevent loss by cooling would give rise to waste of power, as it would increase the dead charges on the dynamo and transformer where one was used. Mr. Walker.

22 April, 1890.

SIR JOHN COODE, K.C.M.G., President,
in the Chair.

The discussion upon the Paper by Sir Frederick Bramwell, on "The Application of Electricity to Welding, Stamping, and other Cognate Purposes," occupied the evening.

29 April, 1890.

SIR JOHN COODE, K.C.M.G., President,
in the Chair.

Sir Frederick Bramwell replied to the remarks upon his Paper on "The Application of Electricity to Welding, Stamping, and other Cognate Purposes"; after which the discussion upon the Paper by Mr. John Robinson on "The Barry Dock Works,"[1] &c., which was commenced on the 1st of April, was resumed and concluded.

[1] Minutes of Proceedings Inst. C.E., vol. ci.

6 May, 1890.

SIR JOHN COODE, K.C.M.G., President,
in the Chair.

The following Associate Members have been transferred to the class of

WALTER HENRY COBLEY.
WILLIAM GORDON LYNCH COTTON.
HENRY ELLIS HILL.
HERBERT DENT JOHNSTON.
ROBERT PATRICK TREDENNICK LOGAN.
ROBERT JOHN COURTENAY MOSTYN.
THOMAS FRANCIS O'MEARA.
FRANCIS ORANGE.
JAMES ORANGE.
ALFRED WEEKS S2

The following Candidates have been admitted as

ELISEO ANZORENA.
WALTER GEORGE BARNETT.
JOHN JOB CREW BRADFIELD, B.E.
FREDERIC EDWARD THEODORE COBB.
ADRIAN CHARLES COLLINS, A.K.C.
ARTHUR CHARLES DEVEY.
ALFRED GRENIER DRIEBERG.
ED EFFLATOUN.
ARTHUR JOHN ESTCOURT.
JOHN FERGUSON.
PATRICK FLETCHER.
ROBERT ALEXANDER FLETCHER.
ARCHIBALD HENRY
PHILLIPS BATHURST
PHILIP GEORGE WILLIAM PARKMAN.
JOHN MORRIS ROBERTS, B.E., B.A.
HERBERT ARTHUR SWAN, JUN.
ARTHUR NOEL THORPE.
ROBERT WALKER, JUN., B.E.
HERBERT MORTON WILLMOTT.

The following candidates were balloted for and duly elected as

Members.

CHARLES THOMAS EVANS.
CHARLES EDWARD RHODES.
ROBERT THOMPSON.

Associate Members.

ARTHUR ROBERT ANDERSON.
ROBERT CARY HENSLOW BARNARD.
ALFRED HARPER CURTIS, B.A.
JOHN
DREW.

Associate Members—continued.

William Beedie Esson.
John Gregson.
George Moss Harriott.
John Brown Harvey.
Charles Hassard.
James Isaac Haycroft.
Harry Heatly.
Herbert Nicholson Lipscomb.
John Bruce King Macbeth.
John Clarkson Phillips Maynard, Stud. Inst. C.E.
Claud Monckton.
John Mitchell Moncrieff.
John Thomas Newman.
Thomas Pritchard, Stud. Inst. C.E.
Thomas Raynes.
Edward Richard Salwey.
William Marsland Francis Schneider, M.A.
Charles Mitford Smith.
William Stringfellow, Stud. Inst. C.E.
Charles Nelson Tween.
Walter Clifford Tyndale.
David Tyzack.
'e Fletcher White.
Edward Whytehead.
Henry Herbert Wyatt, Stud. Inst. C.E.

(*Paper No. 2461.*)

"The Screw-Propeller."

By Sydney Walker Barnaby, M. Inst. C.E.

The last Paper read before this Institution upon the subject of the Screw-propeller was written by Sir Francis Knowles in 1871.[1] Sir Francis came to the conclusion that "there must be some fixed form" of helix "which is better than any other," and he sought, by an elaborate mathematical analysis, to discover what that best form was.

In striking contrast with this opinion as to the importance of form, was the statement made by Robert Griffiths, at the close of almost a life's work upon the screw, that "four strips of plate iron, set at an angle on the shaft which would hold the engine to the speed you required, would give you within half a knot of the best screw ever made."

There seems little doubt that the truth must be sought between these two extremes.

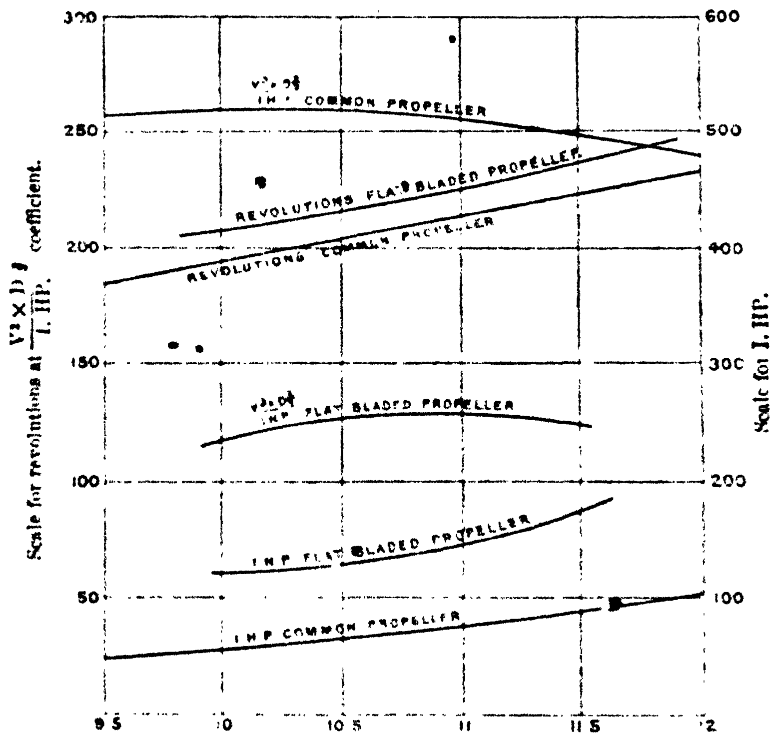
On the one hand, there does not appear to be much reason to suppose that one fixed relation of pitch to diameter is better than any other; and still less, that a great improvement can be effected by adopting a particular form of blade. On the other hand, it is certain that the flat blades referred to by Griffiths, not perhaps quite seriously, form an exceedingly bad propeller. Careful comparative trials, with a flat-bladed propeller and one of ordinary

[1] Minutes of Proceedings Inst. C.E., vol. xxxii. p. 219.

form, showed that twice as much power was expended to obtain a particular speed with the flat blades as was required by the others (*Fig. 1*).[1]

When designing a screw from which a given propulsive effort is to be obtained, the problem to be solved is not, "What is the best form of blade?" but, "What is the best relation between the

Fig. 1.



COMPARATIVE TRIALS WITH COMMON AND WITH FLAT-BLADED PROPELLERS.

diameter, pitch, and revolutions of the screw?" The amount of blade-surface, although not without influence, appears to be of secondary importance.

[1] A simple form of flat-bladed propeller can be made by setting a portion of a disk at an angle on a shaft. No propelling effect can be obtained if the whole disk is retained, as the action of one half counteracts that of the other; but if a quadrant be cut out from a particular part of the disk, the quadrant will be found to have an increasing pitch, varying from nothing on the leading edge to any desired maximum on the after edge, depending upon the angle at which the disk is inclined to the shaft. The pitch will also increase from the root towards circumference. To make a two-bladed propeller portions of two disks are inclined in opposite directions.

The Author will endeavour to put before the Institution, in the simplest and most useful form, the results of recent experimental research, so far as they bear upon the solution of this problem.

Mr. B. F. Isherwood made a valuable series of trials of screws in a small launch, and published the results in 1875.[1] Mr. A. Blechynden, in 1887, in a Paper on "The Reaction and Efficiency of the Screw-propeller,"[2] analysed these trials and drew a number of interesting conclusions from them; but instructive as they are, the results have not been put into such a form as to make them generally useful.

In the year 1883, Mr. John I. Thornycroft devoted a great deal of time to an experimental examination of the subject by means of model screws.

A steam-launch was fitted with a small shaft passing through the bow to carry the models, the shaft projecting sufficiently in front of the launch to ensure that they should work in undisturbed water. This shaft could move freely in its bearings to and fro, and the inboard end was attached by means of a steel wire to a spring, so that the thrust exerted by the propeller could be recorded.

The following measurements were made:—

1. The thrust exerted by the model;
2. The revolutions of the model;
3. The speed of the launch;
4. The turning effort expended in driving the model;
5. Equal intervals of time.

All these measurements were electrically recorded upon a revolving drum.

The speed of the launch was found by passing a measured distance on shore of 300 feet. As the experiments were made in a tideway, two runs were necessary to determine the speed for every observation, one up stream and one down. The launch, which was driven by an independent screw, maintained a constant speed of about 4½ knots, and a number of observations were taken at different revolutions of the model, and plotted as shown in Plate 1, Fig. 1. Curve *a* is the thrust of the model; *b* is the useful work in foot-lbs. per minute, being the product of the thrust into the speed through the water; *c* is the work expended in foot-lbs. per minute. The useful work, divided by the work expended, is a measure of the

[1] *Engineering*, November 5th, 1875, vol. xx. p. 369.

[2] Transactions of the North-East Coast Institution of Engineers and Shipbuilders, vol. iii. p. 179.

efficiency of the model, as shown by curve *d*. It will be seen that the efficiency is a maximum at a certain number of revolutions, the position of the maximum varying with the pitch-ratio. Each ratio of pitch to diameter demands a particular amount of slip, in order that the propeller may give its best effect. The highest efficiency obtained was 70 per cent. If the slip is too small, the efficiency, as shown by curve *d*, is very bad; as the slip is increased, the efficiency attains a maximum, and afterwards falls again.

A convenient way of utilizing the results thus obtained is to construct a constant which will express the relation between disk-area, power, and speed at the slip-ratio corresponding to maximum efficiency. A second constant can be formed expressing the relation between diameter, speed, and revolutions.

These constants, the form of which was suggested by Mr. Thoms, depend upon the following laws:—

1. The disk-area is proportional to the HP., and inversely proportional to the cube of the speed.

2. The revolutions per minute are proportional to the speed, and inversely proportional to the diameter.

The constants are of the following form:—

$$C_A = \text{disk-area in square feet} \times \frac{V^3}{\text{HP.}},$$

$$C_R = \text{revolutions per minute} \times \frac{D}{V};$$

where V = the speed of the screw through the water;
D = diameter of screw in feet;
HP. = effective HP. in the screw-shaft.

By the aid of these constants it is possible to determine approximately the best dimensions of screws to propel vessels of any given speed and HP.

By constructing constants corresponding to different amounts of slip, a row of figures is obtained such as is shown in Table I (Appendix), which have been placed in their proper relative positions under a curve of efficiency, and from those figures it is possible to design a screw for any given HP. and speed, which should work at any given slip-ratio that might be selected.

The diameter of the propeller, and the number of revolutions as determined by the constants for any particular vessel, will obviously depend upon the amount of slip-ratio selected. The smaller the slip-ratio, the larger will be the diameter, and the slower the rate of turning.

The best dimensions can only be determined approximately for any required power or speed, because, unless the model screw is placed behind a model of the vessel it is intended to propel, the effect of the wake upon the screw, and of the screw upon the resistance of the vessel, is still a matter of uncertainty in the case of any new and untried form of vessel. The ratio of brake HP. to indicated HP. has also to be taken into consideration. It is possible to obtain, quite accurately from the model experiments, the best proportions of screw to propel what Mr. Froude has happily called a "Phantom Ship"; that is, a ship which shall require the same thrust to propel it at any given speed as a real ship, but which will create no disturbance in the water, driven by what the Author might describe as a "Phantom Engine"; that is, an engine without friction.

In applying the results of model screws, tried in undisturbed water, to the determination of the proportions of a screw to work behind a real ship, it is necessary to make certain assumptions as to the speed of the following current, and as to the propulsive coefficient.

The assumptions that have been made will be described later.

In the year 1886, Mr. R. E. Froude read a Paper on "The Determination of the most Suitable Dimensions for Screw-Propellers,"[1] describing a series of experiments made with small screws in the Admiralty tank at Torquay. This Paper is one of the greatest value, and describes experiments carried out upon a much more comprehensive scale than was possible at Chiswick, where the trials previously referred to took place in the river, subject to all the inconvenience of passing traffic and variable weather. Nevertheless, the results obtained under these circumstances were generally corroborated, so far as they went, by the Torquay trials. This fact ought to encourage engineers to carry out model trials for themselves, as it shows that valuable and trustworthy results can be obtained with moderately simple appliances.

There was one particular in which the results at Chiswick were not in agreement with Mr. Froude's experience.

Mr. Thornycroft appeared to find that a pitch-ratio of between 1·1 and 1·2 gave the highest efficiency; while Mr. Froude found—to his surprise—that within so large a range of pitch-ratio as from 1·2 to 2·2 there was little, if any, difference in efficiency.

It was satisfactory to learn, from Mr. Froude's more extended

[1] Transactions of the Institution of Naval Architects, 1886, vol. xxvii. p. 250.

investigations, that the limits of good work were not so restricted as would otherwise be the case. It is possible that the results obtained at Chiswick were affected by the manner in which the change of pitch was obtained, that is, by twisting the blades in the boss, because it was noticeable that the pitch which gave the best efficiency was that for which the blades were cast. When a blade is so treated the pitch is not altered uniformly: there are only two sections of the blade which receive the same change of pitch, and these are situated at the radii corresponding to a pitch angle of 45° in the case of the original and augmented pitches respectively. Sections between these points receive a less change of pitch, and sections outside them a greater, in proportion to their distance from them. The effect produced therefore by twisting through any given angle depends upon the pitch ratio; if this is small the critical points are near the boss, and twisting to augment pitch causes the pitch to increase throughout the greater part of the length of blade, the maximum occurring at the tip. If the pitch ratio be such that the critical points fall about the middle of the length, twisting to fine pitch will then result in a blade having the maximum pitch in the centre, a form adopted by Mr. Thornycroft in his very successful type of screw.

The Author has Mr. Froude's permission to give the results of the Torquay experiments in an Appendix to this Paper, and he has put them into a form which appears to him to be more compact and easier to understand than Mr. Froude's own arrangement. It is not so ingenious, and involves, in some cases, "trial and error," which the other does not; but in the Author's opinion it is the best, on account of its comparative simplicity.

The form selected is that of a series of constants, such as have been already described, and arranged as shown in Table I (Appendix). These all occupy their proper relative position under the curve of efficiency. Each of the horizontal lines of figures, corresponding to a particular pitch-ratio, is calculated from a complete set of curves such as that shown in Plate 1, Fig. 1.

The Table, therefore, embraces the whole of the experiments possible with a particular type of screw, including pitch-ratios extending from 0·8 to 2·5, and slip-ratios from the lowest to the highest which is considered practicable. It is shown in the Appendix how to make corrections for screws of two and of three blades, the Table being primarily correct for four blades, and also the corrections which may be considered necessary for abnormal speeds of wake and propulsive coefficients.

Table II (Appendix) contains a number of different coefficients by which the speed of the vessel V is to be multiplied, depending upon the fulness of the lines of the vessel, the effect of the correction being to increase the size of screw for vessels of full form.

The Tables would be used in the following manner :—

Let it be supposed, for example, that the size of the screw is limited by the draught of water. If the given disk-area is multiplied by the cube of the speed of vessel in knots, and divided by the indicated HP., the constant C_A is obtained. Suppose it is 360. The nearest figure to this in the column under the maximum efficiency should be sought, and its position when found indicates the pitch-ratio 1·6, which will be in the same line, at the left-hand of Table. Adjoining the disk-area-constant 360, will be found the revolutions-constant 71. This number, multiplied by the speed of the vessel in knots, and divided by the diameter of the screw in feet, will give the number of revolutions at which a four-bladed screw should run to obtain the maximum efficiency.

It is evidently desirable to select the constants from the column under the maximum efficiency; but in special cases, when the revolutions are required to be either exceptionally high or exceptionally low, in order to suit existing engines, the same disk-area-constant may be taken from one of the other columns, where it will be found associated with either a lower or a higher value of C_R, according as the slip-ratio is greater or less; and it is possible to see at a glance what sacrifice it is necessary to make in efficiency in order to obtain the required result.

The same constants are presented in a graphic form in Plate 1, Fig. 1, Appendix, in which each vertical column of Table I is plotted as a curve, and values of C_A and C_R corresponding to intermediate pitch-ratios may be thus obtained.

It is well known that vessels intended for towing require exceptionally large screws. Suitable dimensions for such propellers can be obtained from Table I, if the speed which the vessel is expected to attain when towing its average load is used, instead of the speed when running alone. The propeller will then work at a slip corresponding to its best efficiency when the vessel is towing; whereas, if designed to suit the small resistance of the tug alone, the slip when towing will be excessive, and will cause a large waste of power.

Assuming the Table to be correct, it will be obvious that if consideration is confined to the screws alone, apart from the vessels they are designed to propel, and the services these vessels are intended to perform, within certain limits the efficiency is independent of the absolute size of the screw. For example, take the case of a vessel of good form, having engines of 500 indicated HP., and expected to attain a speed of 10 knots. From Table I equal efficiency may be expected with a screw having a disk-area-constant of 157, and 0·8 pitch-ratio, and with one having a disk constant of 381 and a pitch-ratio of 2·5. The first would be 10 feet in diameter, and would run at 138 revolutions per minute; the second would be 15½ feet in diameter, and would run at 33½ revolutions per minute. Each of them is credited with an efficiency of 69 per cent.[1]

But in considering the relative efficiency of large and small screws, other things must be taken into account. In the first place, the conditions under which the models are tried differ from those of a screw in the wake of a vessel. A model advancing through undisturbed water is in a stream of uniform speed throughout its disk-area; but a screw in the wake of a ship is in a stream of different velocities at different levels, the forward speed of the wake being very different at the surface from the speed at the keel. The thrust of the upper blades is always in excess of that of the lower, tending to cause vibration and loss of efficiency. For this reason the small screw has an advantage, since the variation in the speed of the stream in which it works is less. The reduced chance of the smaller screw becoming emerged by the pitching of the vessel is also in its favour, as the waste of power when the screw breaks the surface of the water is very large.

For certain services, however, a large screw has advantages. When it is desired to maintain a high speed against head-winds and sea, the propeller should be so designed that the slip-ratio is not excessive in this condition. The case is somewhat analogous to that of a tug. The desired object will not be obtained by associating increased diameter with increased pitch-ratio. The propeller of 15·5 feet diameter, and 2·5 pitch ratio, would probably waste as much power when working against a head-sea, as the 10-foot propeller of 0·8 pitch-ratio.

The best proportions will be obtained by designing for a speed less than the maximum smooth-water speed, but such as the vessel might be expected to maintain over an average passage. The propeller would have a somewhat reduced efficiency when the vessel was developing her full power in smooth water—would in fact be too large—but would work at its maximum efficiency at

[1] The limits within which this has been experimentally established extend from pitch-ratios of 1·1 to 2·2. There is some doubt in the Author's mind as to whether such an efficiency can be fairly extended to so extreme a ratio as 2·5.

the speed assumed as the average, and should effect a saving of fuel on the voyage.

Some interesting trials were made last year in Holland by Mr. Murk Lels, for the purpose of ascertaining the thrust of an actual screw as shown by a dynamometer attached to the thrust-block. The vessel upon which the experiment was made was 70 feet in length, and of 69 tons displacement. The thrust-block had lugs on each side, to which were attached a pair of Duckham's hydrostatic weighing-machines. The thrust-block was free to move fore and aft, and the screw-shaft was turned by carriers upon the crank-shaft. Some difficulty was experienced at first in getting readings, as the unequal turning-effort caused the pointer on the gauge to oscillate considerably; but the difficulty was overcome by introducing a small valve between the oil-cylinder and the Bourdon gauge, which acted as a cataract, and readings could then be easily obtained.

As dynamometric trials are very rare, the Author thinks these experiments are of great interest, and, by the kind permission of Mr. Lels, they are given in the Appendix, Table III, and Plate 1, Figs. 2, 3, 4 and 5 (Appendix). The results afford a very satisfactory confirmation of the model experiments, the revolutions and disk-constants obtained from them being in close agreement throughout the range of slip-ratio experimented upon with those given in Table I (Appendix), as proper for a four-bladed screw, with a pitch-ratio of 1·22, which was the ratio of Mr. Lels' screw.

At the maximum efficiency, corresponding to a speed of 10·84 knots, the results may be said to agree almost exactly with what would have been predicted by the curves. For example, for a diameter of 6·25 feet, pitch-ratio 1·22, I.HP. 230·6, and speed 10·84 knots, the curves in Fig. 1 (Appendix) would predict 175 revolutions and 69 per cent. efficiency. On the trials the revolutions were 175, and the efficiency 70 per cent.

In the s.s. "Teutonic," built by Messrs. Harland and Wolff, the screws have overlapping disks, one being set 6 feet 3 inches behind the other. The diameter of each screw is 19 feet 6 inches, and the distance between the shafts 16 feet. The inconvenient projection of the propeller blades has been a stumbling-block to the introduction of twin-screws in the long narrow ships of the merchant service. The success of the "Teutonic" confirms previous experience with smaller vessels, and shows that the projection of the blades can be reduced, and the length of the exposed screw-shafting, with the concomitant resistance of external supports, reduced also by overlapping the screws without appreciable loss of efficiency.

The screws are right- and left-handed, and turn outwards. It has been suggested by Mr. Normand that when screws are arranged in this way they should both turn in the same direction. The overlapping blades would then cross one another, and the water thrown up by the ascending blades of the one screw would be met by the descending blades of the other, which should have the effect of reducing the slip and increasing the efficiency.

There has not, up to the present time, been much experience of the working of triple screws. An interesting series of comparative trials with twin and triple screws was made by Mr. Marchal, and described by him in a Paper read at the Institution of Naval Architects in 1886. His experience was that for vessels of suitable form "three screws are, from the point of view of speed, very nearly equivalent to two screws of the same propulsive surface, and immersed to the same depth, when the most favourable position is chosen for each system."[1]

The Author confessed some surprise that triple screws had not been more extensively adopted in high-speed ships of war.

With two screw-turbines, and one common screw placed between them, the projection of the blades of the outer screws from the sides of the vessel would not exceed that of two screws; and, moreover, the blades of the screw-turbines would be well protected by their casings.

Fig. 2 shows the two screws of the "Blake," replaced by the combination suggested. The centre screw only would be used for going astern, and the port and starboard engines might be much simplified and cheapened by suppressing the reversing gear.

Recent examples of the application of three screws were the French armoured cruizer "Dupuy de Lôme," not yet completed, and some Italian torpedo cruizers, engined by Messrs. Hawthorn, Leslie, and Co. Fig. 3 shows the arrangement of screws in one of these, the "Tripoli."

Griffiths designed a feathering screw intended to prevent unequal pressures upon the blades from being produced by the irregular speed of the wake already referred to. The blades were free to turn on their axis, being so connected together within the boss that they automatically adjusted their pitch until the pressure on each was equal. A somewhat similar propeller has been lately introduced by Mr. Vogt (Fig. 4). The blades do not have their motion limited by stops, as in Griffiths' propeller—an arrangement which would not stand wear and tear—but are free to turn right

[1] Transactions of the Institution of Naval Architects, vol. xxvii. p. 239.

round, and do so when the vessel is backed. It would appear that the engine would require to be exceptionally well governed, since, if the vessel pitched sufficiently to throw the upper blade out of the water, the lower blade would offer no resistance, and the engine, if free, would race excessively.

A feathering screw should have a higher efficiency than one with fixed blades when working in a wake, and it has also the property of greatly increasing the turning power of a vessel. A screw with rigid blades offers considerable resistance to lateral movement. The pressure on the blade which is moving in the same direction as that in which the stern of the vessel is turning is increased, while that on the blade moving in the opposite direction is reduced. That is to say, if the screw is right-handed, and the vessel is under port helm, the stern consequently travelling to port, the resistance of the lower blade, which will be moving towards the port side, will be increased, and the resistance of the upper blade, which will be moving towards the starboard side, will be diminished, because the one is meeting the water, and the other is receding from it. The change of pressure will be proportional to the square of the angular velocity of the stern. The irregular pressure causes the vibration which is generally noticeable when a screw-vessel is rapidly turning. This resistance to lateral motion is not without value, because if it is removed the condition of a vessel moving in a straight line is one of instability. If the vessel make the least angle to the direction in which it is moving, the excess of pressure, due to undisturbed water at the bow, tends to increase the divergence, and this tendency is resisted by the propeller. It seems probable that a vessel never maintains a line of advance in the exact direction of its axis, but always at a small angle with it. It might be expected, therefore, that the effect of the feathering screw would be to greatly increase manœuvring power, but at the same time to render a vessel somewhat less steady on her course, and more dependent on the helm for maintaining it. Although a fixed screw affords the resistance to lateral movement just described, it will, at the same time, itself tend to produce sideways motion of the stern, if it works in a wake of different velocities at different levels. The condition of stable motion in such a case occurs, not when the vessel is proceeding in a straight line, but when moving round the very large circle that it would describe under the influence of the screw with the helm fixed amidships.

It might be thought that at the present time it would be difficult to bring forward anything which might be described as a novelty in relation to the screw-propeller. The Author had his attention directed last year to an invention intended to utilize a certain amount of energy, which was said to be wasted by the screw in a manner hitherto unrecognized. It is no doubt rash to describe anything as novel in this Institution, and the Author is in nowise interested in claiming the priority of the idea for Messrs. Desgoffe and de Georges; but he is not aware of any attempt having before been made to use this particular source of power.

The inventors say that the viscosity of the water in which any helical propeller revolves causes an appreciable current to be set in rotation just beyond the tips of the screw-blades. It is contended that a series of helical surfaces, opposed in direction to those in the screw proper, will receive a thrust from the revolving ring of water, which can be utilized for propulsion. The "Anti-spire," as it is called, can be placed around a propeller of any form. It is shown in Fig. 5.

Although the experiments which the Author witnessed at the Brussels Exhibition last year were much reduced in value by the fact that the apparatus was in a tank, and was not in motion through the water, and that therefore the friction of the outer surface of the ring was not deducted from the observed thrust, still, the experiment showed such a large increase of thrust due to the ring, that it would possibly more than counterbalance the friction upon its surface, and exert a real propulsive force. It is reasonable to suppose that there is such an unutilized reservoir of work in revolving currents external to the propeller disk.

Rings or bands, without helical blades, have been used for protecting screws and for giving increased manœuvring power, but these plain rings do not increase the efficiency of the screw, and the addition of the blades would certainly be found advantageous in such cases, and may be worthy of a still wider application.

Two valuable additions to the knowledge of the action of the screw were made, in the Author's opinion, by Mr. R. E. Froude and by Mr. Thornycroft, last year, on the occasion of the Paper read by the former gentleman, "On the Part Played in Propulsion by Differences of Fluid Pressure." [1]

Mr. Froude substitutes for a screw-propeller an instrument which he calls an "actuator," and which may be described as "an advancing surface of instantaneous change of pressure."

He conceives a thin vertical plate of finite area, deeply immersed in water, and acted upon by a finite normal force. After the plate

[1] Transactions of the Institution of Naval Architects, 1889, vol. xxx. p. 390.

has operated with that force for only an infinitesimal instant, and therefore before it has acquired any finite speed, it is abolished, and its place taken by a similar plate similarly actuated, inserted at an infinitesimal distance in front of it, this one in turn giving place to another, and so on.

Mr. Froude shows that with such an instrument, when the whole acceleration is external to it, one half must take place in front and one half behind, and that the mean speed of the stream in which the propeller works is $V + \frac{S}{2}$; where V is the velocity of feed and S the acceleration. It is important that the full meaning of this proposition should be grasped. Rankine has clearly laid down that the efficiency of a propeller which imparted velocity to the water suddenly was $\frac{V}{V + S}$, and he has instanced the common uniform-pitch screw as an example of a propeller which acts in this manner. He then proceeds to show that if the propelling instrument commences to act upon the water at the velocity of feed V, and gradually accelerates it up to the speed of discharge $V + S$, then the loss of work is the least possible, and the efficiency is $\frac{V}{V + \frac{S}{2}}$. He gives, as an example of a propeller which partially complies with this condition, the gaining-pitch screw. Mr. Froude's proposition is, that there can be no such thing as suddenness of change from velocity of feed to velocity of discharge in the case of a submerged propeller; that, no matter for how short a time the propelling surface acts upon the water, the acceleration must be gradual, and that half of it would take place before the blade, towards which the water would run in obedience to a defect of pressure in front, and half would take place behind, in obedience to an excess of pressure produced there by the blade, the final velocity being greater than that of the propeller. If a screw can be expected to behave in the same manner as the "actuator," then it means that a uniform-pitch screw will have the same qualities as an ideal gaining-pitch screw, and if this be true the object of the screw-turbine seems to disappear.

This induced Mr. Thornycroft to make a careful study of Mr. Froude's reasoning, and it appears to be perfect for a propeller which does not produce rotation of the race. Mr. Froude stated he had not examined in what way the rotation of the race would affect the relation between the precedent and subsequent acceleration, but he did not anticipate that it would do so at all.

Upon this point Mr. Thornycroft joined issue, and showed that the effect of the rotation must be to produce a change in this relation proportionate to the amount of the rotation, and that only in the limiting case, namely, when no rotation was given to the race, could the acceleration be equally divided before and abaft the propeller, and that all existing open propellers occupied some intermediate position; that is, they worked in a stream whose velocity varied between $V + S$ and $V + \frac{S}{2}$, depending upon the greater or less rotation produced. What is claimed for the screw-turbine is that it is in the same condition as an open propeller, which, like Mr. Froude's "actuator," imparts no rotation. This appears the more reasonable, when it is remembered that the absence of rotary motion in the race is the peculiarity of the screw-turbine, and affords *primâ facie* grounds for supposing that it would compare with an open propeller which should have the same property.

Sir Francis Knowles said, in his Paper of 1871,[1] that negative slip was an impossibility unless the screw was assisted by sails, and that when it was recorded to have occurred in screws not so assisted, it was the result of incorrect observation. Mr. Gisbert Kapp has said: "A strong draught of dead-water cannot negative the apparent slip; . . . even in the most favourable case, viz., when all the water moved by the ship is afterwards consumed by the screw, only a state of equilibrium, but no surplus of thrust to keep the vessel in motion, can be expected."[2] The Author agrees with Mr. Kapp except as regards apparent negative slip, which he thinks Mr. Kapp confuses with real negative slip.

The late Mr. W. Froude, in the discussion upon Sir Francis Knowles' Paper, showed that apparent negative slip is possible, and may be expected in certain circumstances. He describes an ideal case in which the whole of the resistance of a vessel consists in skin-friction, wave-making and other factors being excluded. The dynamic equivalent of the propulsive force employed in keeping her in motion is found in the frictional wake, and a propeller which should pervadingly operate upon the wake in such a manner as to bring it gradually to rest would, in thus neutralising it, maintain the propulsive force, and, given established motion, a theoretically perfect propeller, quite clear of the ship's stern, would maintain that motion, and exhibit an apparent negative slip equal

[1] Minutes of Proceedings Inst. C.E., vol. xxxii. p. 219.

[2] *Ibid.* Vol. xli. p. 332.

to half the forward mean velocity of the wake at the point where the propeller operated. Mr. Froude's explanation, however, of the phenomenon of negative slip was intended to apply only to a propeller of increasing pitch, and depended upon the fact that the speed of advance of such a screw is assumed to be equal to the mean of the pitches of the forward and after edges, and negative slip would disappear if the speed of advance of an increasing pitch propeller, whose after edge had a pitch equal to the speed of discharge V + S, were calculated from this pitch instead of from the mean.

Moreover, it did not explain how negative slip could be obtained with a screw of uniform pitch. But there are authentic cases with such propellers, as in H.M.S. "Edinburgh" and "Collingwood." The screws of the "Collingwood," with a pitch-ratio of 1·5, gave 1·26 per cent. negative slip, and this was increased to 2·56 per cent. when the pitch-ratio was reduced to 1.[1]

It was not until Mr. R. E. Froude read his Paper last year, already referred to, that the Author was able to find a satisfactory explanation of this phenomenon. The demonstration then given that, under certain conditions, one half the acceleration will be produced behind and one half before a propeller, seems to him to supply what was wanting for the construction of a complete theory of negative slip. Although it has been shown to be true only in the limiting case, still a uniform pitch screw of very small pitch-ratio, which would cause but a small amount of rotary motion, would approach very near to this condition, and might impart a sternward velocity to the race sufficiently greater than the product of its pitch into the number of revolutions, to produce apparent negative slip.

The Paper is accompanied by several diagrams, from which Plate 1, and the woodcut, *Fig. 1*, page 75, have been prepared.

[1] Minutes of Proceedings Inst. C.E., vol. xci. p. 385.

APPENDIX.

EXAMPLES IN THE USE OF TABLES I AND II.

Example (1).—Find the diameter and revolutions of a screw to work at maximum efficiency for a vessel of 20 knots speed and 6,000 I.HP. Pitch-ratio to be 1·2.

The disk-area-constant (C_A) in the Table for this pitch ratio is 288.

The revolutions " (C_R) " " " 92.

$$\text{Disk-area} = C_A \times \frac{\text{I.HP.}}{(\text{speed in knots})^3} = 288 \times \frac{6{,}000}{20^3} = 216 \text{ square feet.}$$

$$\therefore \text{ Diameter} = 16 \cdot 5 \text{ feet.}$$

$$\text{Revolutions} = C_R \times \frac{\text{speed in knots}}{\text{diameter in feet}} = 92 \times \frac{20}{16 \cdot 5} = 111.$$

Example (2).—Find the pitch and revolutions of a screw to work at maximum efficiency for a vessel of 20 knots speed and 6,000 I.HP. Diameter not to exceed 15·5 feet.

Disk-area = 189 square feet.

$$C_A = 189 \times \frac{20^3}{6{,}000} = 252.$$

Nearest disk-area-constant in Table under maximum efficiency is 251.

Pitch ratio 1·0. $\therefore$ Pitch = 15·5 feet.

$$\text{Revolutions, } 109 \times \frac{20}{15 \cdot 5} = 141.$$

Example (3).—Find the pitch-ratio and efficiency of a screw for a vessel of 20 knots speed and 6,000 I.HP. The diameter to be 15·5 feet, and the revolutions about 80 per minute.

Disk-area = 189 square feet.

$$C_A = 189 \times \frac{20^3}{6{,}000} = 252.$$

$$C_R = 80 \times \frac{15 \cdot 5}{20} = 62.$$

The nearest constants in Table are at pitch-ratio 2·2, and efficiency 68 per cent.

Where the diameter and revolutions are both limited, the curves on Plate 1, Fig. 1, Appendix, will probably be found more convenient, as intermediate pitch-ratios can be selected.

The constants in the Table assume certain standard values for the speed of the wake and for the propulsive coefficient. The former has been taken as 10 per cent. of the speed of the vessel. In a very full ship it might be as much as 30 per cent.

Therefore V the speed of the ship should be reduced, when using the constants, by 20 per cent. for a very full ship, and by amounts varying from 20 per cent. to nothing, as the fulness of form varies from "very full" down to what may be considered a "fairly fine" vessel, when no correction need be made.

Plate 1, Table II, gives the value of the wake correction for a few vessels.

Example (4).—Find the diameter and pitch of a screw to work at maximum efficiency for a vessel of 20 knots speed and 6,000 I.HP. Revolutions to be 85.

Wake correction to be made for a form of the fulness of H.M.S. "Devastation," corresponding to a wake percentage of 15·8. The multiplier from Table II is 0·942; 20 × 0·942 = 18·8 knots.

By trial and error it will be readily found that the constants 306 and 85 for disk-area and revolutions respectively, at 1·3 pitch-ratio, will give the required number of revolutions, thus:—

$$306 \times \frac{6,000}{(18 \cdot 8)^3} = 276 \text{ square feet}; \quad \therefore D = 18 \cdot 75 \text{ feet};$$

and $$85 \times \frac{18 \cdot 8}{18 \cdot 75} = 85 \text{ revolutions nearly.}$$

A correction can be made for any deviation from the assumed value of the propulsive coefficient, which has been taken at 0·5, or $\frac{\text{E.HP.}}{\text{I.HP.}} = \frac{50}{100}$.

If, for example, the E.HP. is estimated at 55 per cent. of the I.HP., the I.HP. must be multiplied by the ratio $\frac{55}{50}$, but Mr. Froude considers that in practice it would be seldom necessary to introduce the correction for deviation from this value.

The constants are primarily correct for four-bladed screws. They can be used for three-bladed or two-bladed screws by multiplying the I.HP. by $\frac{1}{0 \cdot 865}$ or $\frac{1}{0 \cdot 65}$ respectively.

Example (5).—Find the diameter, pitch, and revolutions of a three-bladed screw to work at maximum efficiency for a vessel of 20 knots speed and 6,000 I.HP. Pitch ratio to be 1·2.

$$C_A = 288. \qquad C_B = 92. \qquad 6,000 \text{ I.HP.} \times \frac{1}{0 \cdot 865} = 6,940.$$

$$288 \times \frac{6,940}{20^3} = 250 \text{ square feet.} \qquad \therefore D = 17 \cdot 8 \text{ feet.}$$

$$92 \times \frac{20}{17 \cdot 8} = 103 \text{ revolutions.}$$

Pitch 17·8 × 1·2 = 21·3 feet.

The model screws were of uniform pitch, and the blades were elliptical. The width in the middle of developed blade was $0 \cdot 4 \frac{D}{2}$.

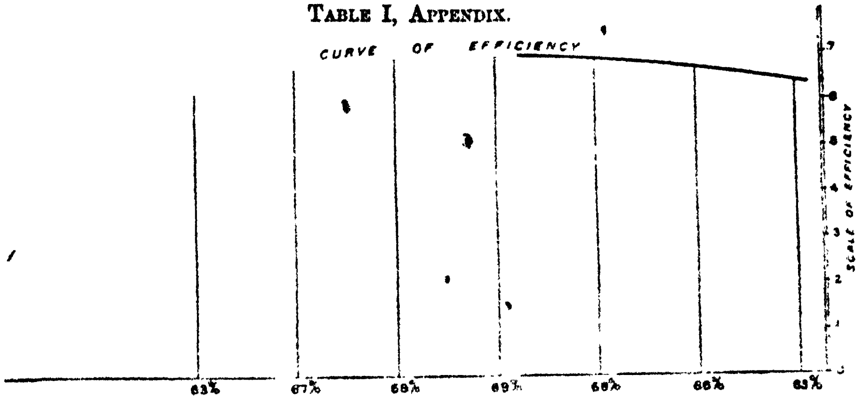
It follows that the developed surface—

For a four-bladed screw = disk-area × 0·4
„ three „ = „ × 0·3
„ two „ = „ × 0·2

TRIALS OF S.S. "VLAARDINGEN." BY MR. MURK LELS.

Table III gives the results of a series of dynamometer trials with a behind a vessel, exactly analogous with those described in the text as having been made with models at Chiswick. The same measurements were taken, and Plate 1, Fig. 2, Appendix, shows the results plotted in a similar manner to those of the models in Plate 1, Fig. 1, Appendix. In Plate 1, Fig. 3, Appendix, are given curves of revolutions, I.HP., and slip. Mr. Lels has calculated the thrust from Rankine's formula (Rules and Tables, p. 275), and compares it with the observed thrust in Plate 1, Fig. 4, Appendix. Plate 1, Fig. 5, Appendix, represents the screw of the "Vlaardingen."

TABLE I, APPENDIX.



Pitch Ratio.	C_A	C_B	C_A	C_B	C_A	C_B	C_A	C_B	C_A	C_B	C_A	C_B	C_A	C_B
0·80	468	122	304	128	215	134	157	142	115	150	86	160	65	171
0·90	506	109	329	114	234	120	170	127	125	135	93	144	71	154
1·00	546	99	355	104	251	109	184	115	135	123	100	131	76	140
1·10	585	91	380	95	270	100	196	105	144	113	107	120	82	128
1·20	625	83	405	87	288	92	210	97	154	104	115	111	87	119
1·30	665	77	431	81	306	85	224	91	163	97	122	103	93	111
1·40	704	72	456	76	325	80	236	85	173	90	129	97	98	104
1·50	742	67	482	71	342	75	250	79	183	85	136	91	104	98
1·60	780	63	507	67	360	71	263	75	193	80	144	87	109	93
1·70	..	..	533	63	378	67	276	71	202	76	151	82	115	88
1·80	..	..	558	60	396	64	290	68	212	73	159	78	120	84
1·90	..	..	584	57	415	61	304	65	222	69	166	73	125	81
2·00	..	..	609	55	432	58	315	62	231	67	173	72	131	77
2·10	..	..	635	52	450	56	329	59	241	64	180	69	136	75
2·20	..	..	660	50	469	54	342	57	250	62	187	67	142	72
2·30	..	..	685	48	486	52	355	55	260	59	194	64	148	69
2·40	..	..	710	47	505	50	369	53	270	57	202	62	153	67
2·50	..	..	736	45	523	48	381	52	280	56	209	60	159	65

5 7 9 11 13 15 17

Scale of Abscissa value.

Disk area $= C_A \times \frac{\text{I. HP.}}{(\text{Speed in Knots})^3}$. Revolutions $= C_B \times \frac{\text{Speed in knots}}{\text{Diameter in feet}}$.

TABLE III.—S.S. "VLAARDINGEN."

Result of trials held on February 25th, 1889, on the measured mile of 6,080 feet at the isle of Rozenburg.

GENERAL DIMENSIONS OF MACHINERY.

Cylinders	12¾ inches × 25 inches.
Stroke	18 inches.
Diameter of propeller	6 feet 3 inches.
Mean pitch "	7 feet 7¼ inches.
Projected area propeller	11·27 square feet.
Developed area propeller	15 square feet.
Number of blades	4
Heating surface in boiler	474 square feet.
Grate area	15·6 square feet.
Working pressure	100 lbs. per square inch.

GENERAL DIMENSIONS OF SHIP.

Length between perpendiculars	70 feet.
Beam	14 feet 9 inches.
Depth moulded	8 feet 6 inches.
Draught forward	3 feet 10 inches.
" aft	7 feet 4¼ inches.
Total displacement	69 tons.

Number of Run.	Thrust in lbs.	Mean Thrust in lbs. = T.	I.HP. per run.	Mean I.HP.	Speed of Ship in Knots = V.	Speed of Screw in Knots.	Slip in Knots.	Slip in per cent.	Useful work = T V.	Efficiency $\frac{TV}{I.HP.}$	Number of Revolutions per Minute.		$C = \frac{V^3 \times D^{\frac{2}{3}}}{I.HP.}$
										Per cent.			
1 against tide	919	924	33·25	31·03	6·97	7·08	0·11	1·55	19·76	63·68	96	94·0	183·3
1 with "	930		28·80								92		
2 against "	1,371	1,339	48·06	50·56	8·07	8·36	0·29	3·47	33·16	65·58	110	111·0	174·5
2 with "	1,307		53·06								112		
3 against "	1,979	1,923	81·40	80·24	9·02	9·60	0·58	6·04	53·22	66·32	128	127·5	153·6
3 with "	1,867		79·09								127		
4 against "	2,885	2,894	132·82	132·35	10·07	11·14	1·07	9·60	89·43	67·57	148	148·0	129·6
4 with "	2,903		131·89								148		
5 against "	3,648	3,699	167·05	170·83	10·47	12·09	1·62	13·40	118·85	69·57	160	160·5	112·8
5 with "	3,750		174·61								161		
6 against "	4,967	4,852	234·13	230·58	10·84	13·12	2·28	17·37	161·40	70·00	175	175·0	92·8
6 with "	4,737		227·04								175		
7 against "	5,317	5,336	255·12	260·32	11·01	13·60	2·59	19·04	180·29	69·25	180	180·5	81·1
7 with "	5,355		265·52								181		

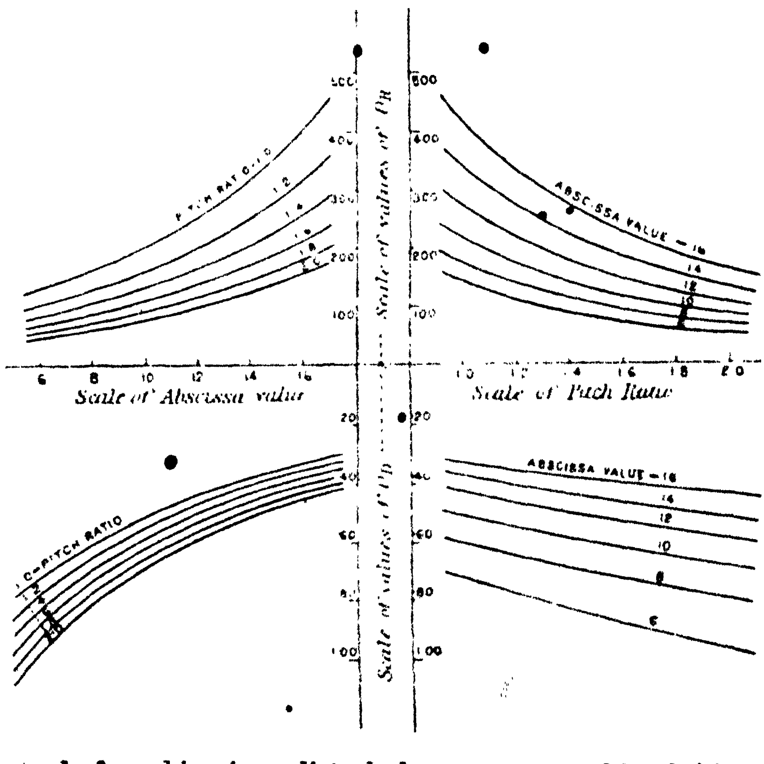
Discussion.

Mr. R. EDMUND FROUDE said that the subject treated in the Paper was a very intricate one, and the Author had given a comprehensive and complete review of it in a succinct, intelligible, and serviceable form. In his historical review he had confined himself mainly to references to those contributions to a knowledge of the subject which took the form of experimental data. Mr. Froude wished to refer to some other contributions of a more theoretical nature, but which were important as having assisted in the formation of what might be called the grammar of the subject, by means of which the experimental data had been systematized and rendered fruitful. The first contribution of that kind to which he would refer was a Paper by his father read at the Institution of Naval Architects in 1878. In that Paper[1] the screw-propeller was represented by the ideal conception of a small element of helical surface rotating at the end of a non-resisting radial arm. By means of that conception his father deduced by theory for the screw-propeller, curves of thrust, HP., and efficiency, precisely similar to those which had been yielded by experiment as described by the Author and illustrated in Plate 1, Fig. 1. The next Paper to which he would allude was one contributed by himself to the Institution of Naval Architects, on a method of experimental investigation of the effect upon the operation of the screw of the presence in front of it of the hull of a ship or of a model.[2] The results were of importance in reference to the present Paper, because only by means of the results yielded by that method of experiment could the data be applied which were given in the Tables, obtained from experiments on a screw working in undisturbed water, to the condition of a screw working behind the hull of a ship. The Paper was read in 1883; but the experiments with which it dealt had been continuing at the Admiralty Works for a long time previous. The system of experiments had been described substantially in all completeness by his father in the discussion on a Paper by Mr. Holt, read in 1877, on the Progress of Steam-shipping.[3] In his Paper of 1883, before the Institution of

Mr. Froude.

[1] Transactions of the Institution of Naval Architects, vol. xix. p. 47.
[2] *Ibid.*, vol. xxiv. p. 231.
[3] Minutes of Proceedings Inst. C.E., vol. li. p. 38.

Mr. Froude. Naval Architects, he represented the method of investigation mainly as a comparison between two contrasted conditions of experiment. In one of those conditions the screw was working in undisturbed water, and the speed of advance, the speed of rotation, the revolutions per minute, the thrust yielded, and the force of rotation—in other words, the HP.—were all measured by dynamometric apparatus. In fact, that condition of experiment precisely corresponded to the condition of experiment from which the data given in the Tables were obtained. In the other condition of experiment, the only difference consisted in this, that the screw,



instead of working in undisturbed water, was working behind the hull of the model, placed just as would be the screw of a ship; and the effect of the presence of the model in front of the screw was of course to produce important differences in the condition of its working. He only wished to refer to two of those differences. One of them was that in order that the screw working behind the model should give the same thrust with the same number of revolutions as it gave in undisturbed water, the whole system—model, screw, and all—must be advancing at a speed greater than the speed in undisturbed water, by the mean amount of the forward motion of the water behind the hull of the model where the screw was working. That difference in speed was what was commonly called the wake, and it was to correct for variations in this value that Table II, in the Appendix, had been devised. The other difference consisted in this, that the forward current in which the screw worked was not a uniform forward current; consequently, although the true slip of a screw when working behind the model and giving the same thrust with the same revolutions as in undisturbed water—although this mean true slip was the same as in undisturbed water, the true slip was different in different parts of the screw's disk, as the Author had mentioned. That was a condition which at first sight appeared unfavourable to efficiency; therefore it would be expected that when the screw was delivering the same thrust with the same revolutions, the force required to maintain the rotation of the screw would be greater behind the model than in undisturbed water. But the experiments did not bear this out. No clear difference could be detected between the turning moment required to maintain the rotation of the screw behind the model and that in undisturbed water. Therefore he thought it might be laid down almost certainly, that when a ship was being propelled by a screw, and the screw was delivering a certain thrust with a certain number of revolutions, the same screw would in undisturbed water give the same thrust with the same number of revolutions with practically the same indicated HP. And that was a result which was of importance in reference to the remarks of the Author, page 78, and further on in the Paper, on the loss of efficiency which might be expected in a screw-propeller, from the fact that the speed of the wake in which it worked was not uniform, and on the expedients devised in the form of feathering blades, and so on, for diminishing that supposed loss of efficiency. The Author had referred to the experiments made by Mr. Thornycroft in 1883, and also to the experiments which had been made in the Admiralty Works at Torquay, and described by Mr. Froude in a Paper read before the Institution of Naval Architects in 1886. The experiments at Torquay were, as the Author had said, conducted under more favourable conditions, in virtue of being made in a covered waterway, and so forth, and the results there obtained had been utilized by the Author in Table I. In fact, his constants C_A and C_R were the one the ordinate, and the other the reciprocal of the ordinate of the curves of Fig. 4 in Mr. Froude's Paper.[1] In reference to

Mr. Froude.

[1] Transactions of the Institution of Naval Architects, vol. xxvii. plate xxviii.

Mr. Froude. the form in which the Author had presented those results for use, his feeling was that he was indebted to any one who would do as the Author had done, and not only make use of the results, but also find new and convenient forms into which they might be thrown for purposes of use. And those persons were the most competent to give an opinion upon the form most convenient for use, who were professionally employed in determining the dimensions of propellers suitable for various conditions. The form into which the results were thrown in the Paper of 1886 was the form used at that time in the Admiralty Experiment Works, and it was one which then appeared to be most convenient for the purposes; but he admitted that he agreed somewhat with the Author, that it was rather too—what he had euphemistically called "ingenious," but what others might have called "too clever by half." That form was afterwards practically discarded in favour of another, which bore more resemblance to the Author's form. It consisted of two constants, O_R and O_D, as followed:—

$$O_R = \frac{\text{Tens of revolutions per minute} \times (\text{I.H.P.})^{\frac{1}{3}}}{(\text{Speed in tens of knots})};$$

$$O_D = \frac{\text{Diameter} \times (\text{speed in tens of knots})}{(\text{I.H.P.})^{\frac{1}{3}}}.$$

It would be seen that, in terms of the Author's constants C_R and C_A, these became

$$O_R = \frac{C_R}{\sqrt{C_A}} \times \sqrt{\frac{1,000\,\pi}{4}} = 28\,\frac{C_R}{\sqrt{C_A}};$$

$$O_D = \sqrt{C_A} \times \sqrt{\frac{4}{1,000\,\pi}} = \frac{\sqrt{C_A}}{28}.$$

These constants, O_R and O_D, were plotted in curves of the kind shown by *Fig. 2*, of which either the right-hand or left-hand half might be used according to convenience. The correct ordinates for the curves were given in the Table, page 97.

This Table was correct for four-bladed screws and standard "wake." For other numbers of blades, the intended I.H.P. must be multiplied by $\frac{1}{0 \cdot 865}$ for three-bladed, and by $\frac{1}{0 \cdot 65}$ for two-bladed screws. For other "wake" values, in the expressions for O_R and O_D, M V must be substituted for V, where M was the multiplier shown in the Author's Table II, in the Appendix. Of course the form into which results of that kind should be thrown for practical pur-

Mr. Froude.

—		Values of O_G.						Values of O_D.					
Abscissa Value.		6	8	10	12	14	16	6	8	10	12	14	16
Pitch-Ratio.	1·00	138·9	174·4	215·3	265·4	330·8	408·7	0·733	0·609	0·518	0·445	0·382	0·331
	1·20	108·2	136·7	169·4	209·1	261·2	322·4	0·788	0·655	0·558	0·478	0·411	0·356
	1·40	88·1	111·2	138·3	171·7	214·2	264·7	0·839	0·697	0·593	0·509	0·437	0·379
	1·70	67·9	86·4	107·8	133·6	166·9	208·0	0·906	0·753	0·641	0·550	0·472	0·409
	2·00	54·9	69·9	87·8	109·0	137·1	170·1	0·967	0·804	0·684	0·587	0·504	0·436
	2·20	48·6	62·1	77·8	97·1	121·9	152·3	1·005	0·835	0·710	0·610	0·524	0·454
	2·40	43·3	55·9	70·0	87·5	110·5	137·9	1·040	0·864	0·735	0·632	0·542	0·470

Mr. Froude. poses depended very much upon the shape which the problem took. The shape in which it generally presented itself at the Admiralty Experiment Works was this:—A new ship having been designed, the intended speed being fixed upon, and the HP. corresponding to that speed having been determined by experiment, the revolutions were next decided by the engineers, so that the proposed HP. might be most advantageously developed by the type of engine intended to be employed. Consequently there were the speed, the HP., and the revolutions, as fixed quantities from which to work. He wished now to refer to his Paper read at the Institution of Naval Architects last year. The distinction which the Author referred to between $V + S$ and $V + \frac{S}{2}$ belonged to a very old controversy. He believed that it was in a communication on the jet propeller to the Institution in 1854, that the late Mr. Gravatt first pointed out that the theoretical waste of power of a propeller in slip consisted of the thrust exerted, multiplied, not by the speed imparted to the water, but by half that speed.[1] That proposition depended upon this condition, that if friction was neglected, that was, assuming the whole of the waste work of the propeller to be represented by the motion of the water left behind the propeller, then the water left behind (commonly described as the screw-race) must show two things—it must show a sternward momentum corresponding to the forward force of the thrust: it must also show an energy corresponding to the waste of power; and those two accounts of momentum and of energy could only be made to conform, by the condition that the waste power in slip was to be represented by the forward force multiplied by half the speed imparted. It could only be supposed that the waste power was greater than that, by assuming that some of the motion left behind in the water was other than in the opposite direction to the force exerted. The same proposition, *mutatis mutandis*, applied in the case of a propeller acting spirally like a screw-propeller to the rotary forces and rotary motions. The effect of that proposition, as applied to a screw-propeller of uniform pitch, was practically this: that it must be supposed that the propeller was dismissing the water with a speed greater than the speed which itself had. That at first sight appeared a paradox; and (as the Author had said) in the Paper which Mr. Froude read at the Institution of Naval Architects in 1889, he suggested a way in which that might

[1] Minutes of Proceedings Inst. C.E., vol. xiii. pp. 370-382; and Tracts, 8vo. vol. 153.

occur. The conception which he presented was that the axial acceleration to which the thrust was due might be supposed to take place, not in the moment of passing through the screw, but partly before and partly after it. The water passed simply through the screw at a speed of $V + \frac{S}{2}$, and it received from the screw not an increase of speed, but an increase of pressure. That increase might be conceived as consisting of two parts: one part replacing the pressure which had been lost in acquiring the increase of speed from V to $V + \frac{S}{2}$, the other adding the further pressure necessary to give the increase of speed from $V + \frac{S}{2}$ to $V + S$. Mr. Thornycroft took exception to that theory of his; not, as he understood, to the conception of the whole acceleration taking place without the screw (he appeared to approve of that conception), but he objected that the rotation of the screw race required a certain reduction of pressure within the race, and consequent increase of axial speed, which raised the speed above the critical speed $V + \frac{S}{2}$. He could not entirely follow that reasoning; he did not at present see the solution of it; but it did not appear to him that Mr. Thornycroft had quite made out his case, because, according to Mr. Froude's solution, the energy wasted in slip should be represented by two terms: one, the rotary force into half the rotary speed communicated: the other, the axial force or thrust into half the axial speed communicated—that was, the energy represented by the speed which was supposed to be communicated to the race; and unless Mr. Thornycroft could show that the race had some other speed than that, speeds in other directions than opposite to the forces exerted, he did not see how he could show that the waste of power was greater than Mr. Froude had suggested. Mr. Froude.

Mr. WILLIAM JOHN said that the subject was one in which he had taken great interest. Reference had been made to negative slip; and Mr. Froude had referred to a Paper by his father read in 1878 at the Institution of Naval Architects. Mr. John's earliest serious thought about negative slip dated back to a period much anterior than that. In a Paper read at the Institution of Naval Architects in 1867, Mr. W. Froude attempted to account for negative slip by the dead-water abaft the stern-post of full-formed ships, and by a sort of intermittent action by which the blades passing through the dead-water pro- Mr. John.

Mr. John. duced more effect in stopping the wake than was usually attributed to a propeller working in a complete wake; and he believed Mr. Froude drew a parallel between that and the intermittent action of a man rowing. In the same year or the following one he believed Dr. Rankine read a Paper in which he accounted for negative slip by the motion of the particles in the wave which followed and enveloped the stern of a ship; and Mr. John thought that that, combined with the difference in the velocity of the flow of water at the surface and farther down, as described by Professor Reynolds, accounted for negative slip perfectly. The forward motion of the particles, where the crest happened to come over the propeller, was checked by the propeller, which threw the wave-motion, as it were, out of equilibrium, and allowed the water flowing backwards in the hollow to pursue its course, instead of having to conform to the rotary motion. That, to his mind, accounted for the negative slip quite as well as what Mr. Froude and the Author had referred to as the action before the propeller, as well as behind the propeller. The Author had spoken of one of the tables of efficiency giving 2·5 pitch and 0·8 pitch. He did not see how that could be, and perhaps the Author would account for it. He approved of what he had said with regard to the larger propeller of tug-boats. It quite agreed with his experience that a larger disk area was required; but not a larger pitch-ratio —rather the contrary. For the same reason, he thought, a vessel with twin screws required a comparatively smaller disk area, and a larger pitch-ratio. It was something in this way: if a vessel under sail was capable of steaming, and sailing before the wind 5 or 6 knots an hour, and it had a propeller revolving at that speed, it was practically creating no thrust, and doing little or no good. A coarser pitch was wanted for a vessel assisted by sails, with a single screw, than was needed for a vessel not assisted by sails, and entirely dependent upon the single screw; and he believed the self-same thing took place with two screws, because it mattered very little to the one screw whether the ship was being pushed along 5 or 6 knots by sails, or whether it was by a screw on the other side. Experience with twin screws was not very large, but it was rapidly increasing, and he believed it was in that direction that both the mercantile marine and the Royal Navy might turn their attention. He hoped that gentlemen like the Author and Mr. Froude would pursue the theory and science of the screw-propeller, and show still more definitely the direction in which to get better efficiency out of twin screws, and also out of single screws.

Mr. C. HUMPHREY WINGFIELD observed that Mr. Froude had pointed out that the problem, as usually presented to the Admiralty officials, was to determine the best diameter and pitch when the revolutions, as well as the HP. and speed, were already decided upon. The constants given by the Author, valuable as they were, only admitted of the solution of this problem by trial and error, as shown in the example given in the Appendix, p. 90. There was a definite relation between the two constants C_R and C_A in the Author's Table which was Mr. Wingfield

$$\frac{C_R^2}{C_A} = \frac{\text{I.HP.} \times \text{revolutions}^2}{0 \cdot 7854\ V^5}.$$

He would suggest the addition of a third column in Table I. (between those giving C_R and C_A) showing the value of $0 \cdot 7854 \frac{C_R^2}{C_A}$. The value of $\frac{\text{I.HP.} \times \text{revs.}^2}{V^5}$ having been calculated, the nearest number to this result, in the new column he had suggested, would be found to be between the constants for diameter and revolutions suitable for the prescribed conditions. The actual speed would have to be multiplied by the factor for wake correction before being raised to the fifth power. If the wake was assumed to have a speed = 10 per cent. that of the vessel, no correction would be required. He thought it always preferable, in plotting results of experiments, to so arrange them, if possible, that the results fell in straight lines rather than curved ones. In drawing a straight line through a number of points, its proper direction could always be determined with greater accuracy than if it were curved. The values of C_R were plotted as curved lines in Table I. Appendix; but he had found that, by taking the reciprocals of the pitch-ratios for the base line, the curves became straight lines. The values of C_R fitted so well on these lines that they gave him great confidence in the accuracy of the Author's figures. He ought perhaps to say that the values given for pitch-ratio 0·8 did not quite fall in, and he thought that they might perhaps require revision. He had constructed the following formulas from the data given in the Paper, which might be found useful for interpolating or for extending the Table, if it should be thought advisable:—

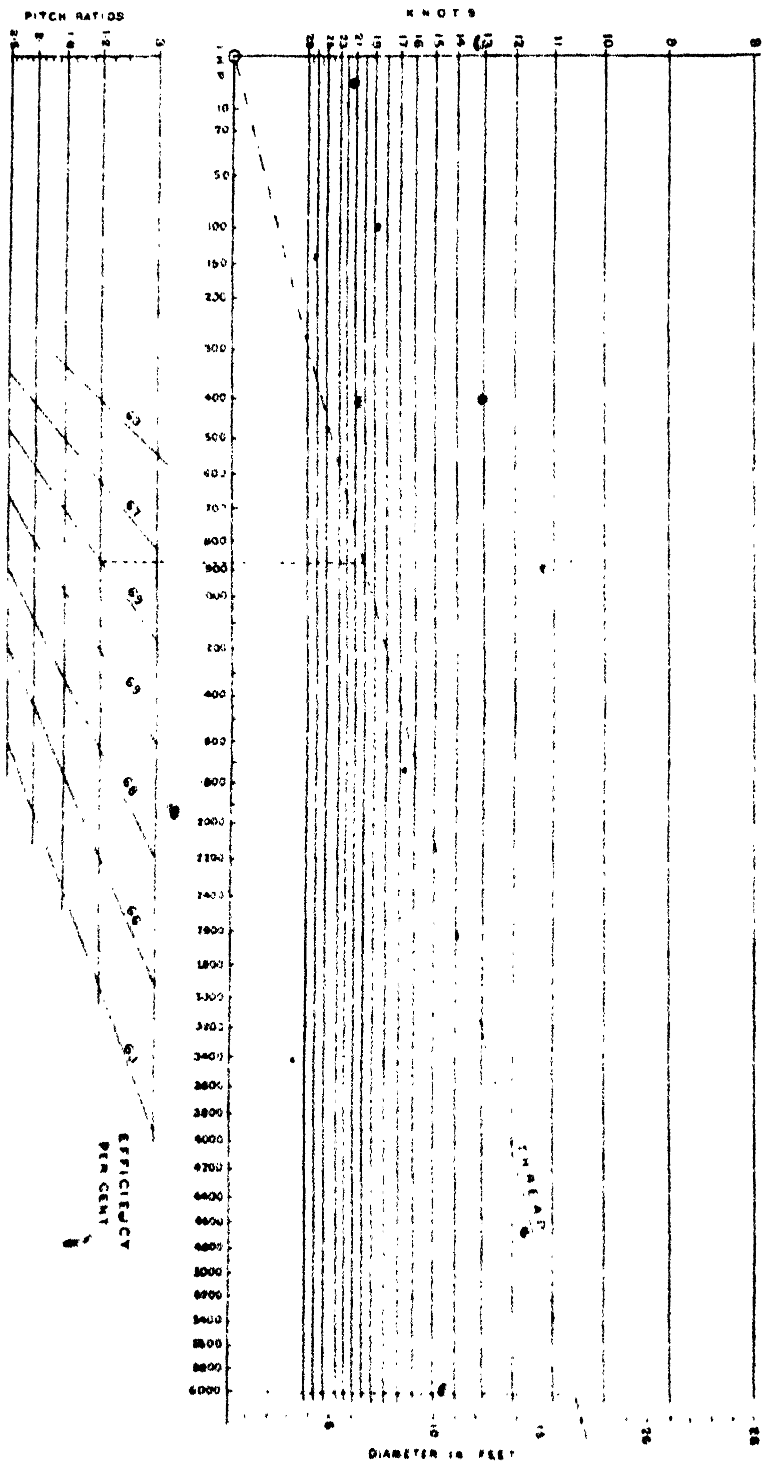
$$C_A = a\,(R + 0 \cdot 39)$$

$$C_R = b\left(\frac{1}{R} + 0 \cdot 35\right) - 28.$$

where R = pitch-ratio and a and b were empirical constants.

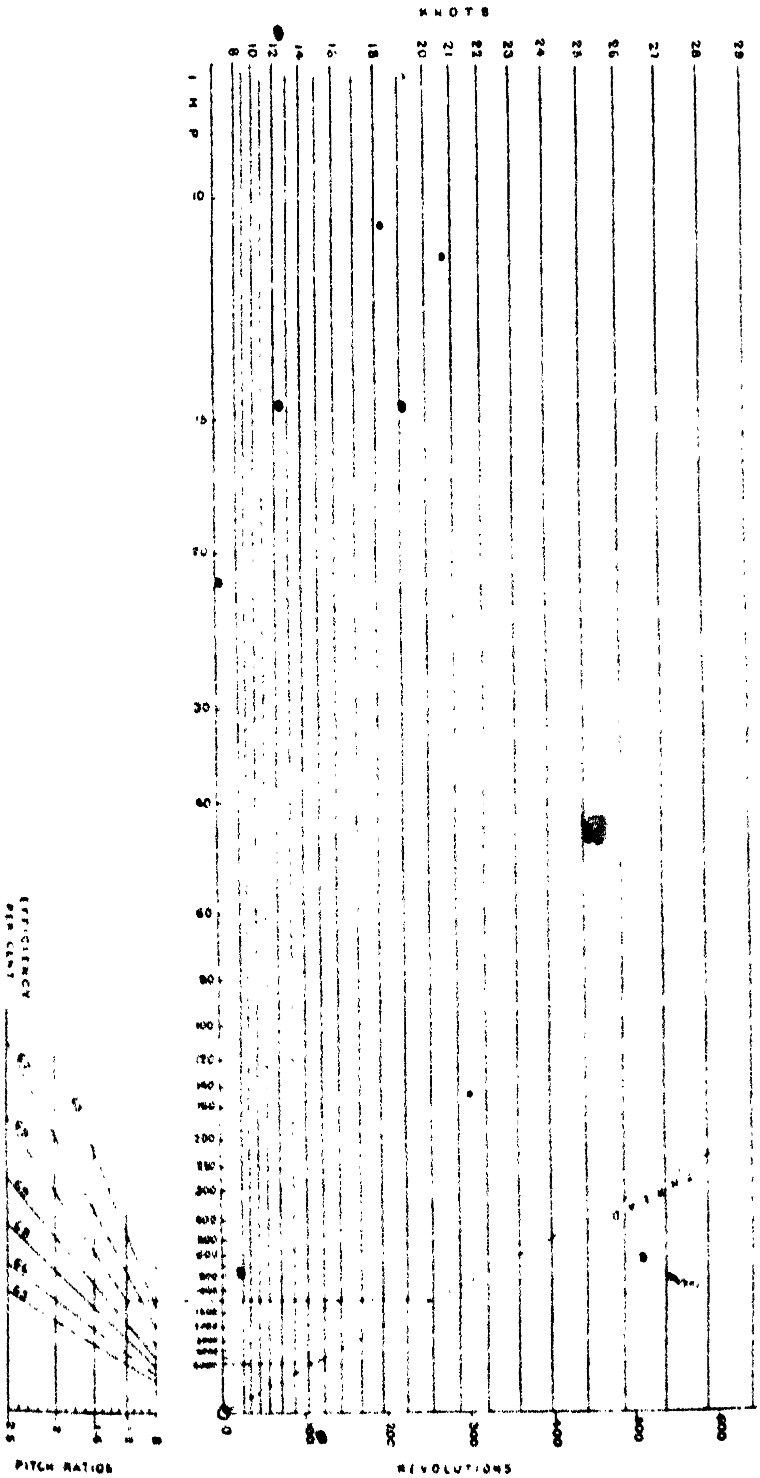
Mr. Wingfield.

Fig. 3.



Mr. Wingfield.

Fig. 4.



Mr. Wingfield. The following Table gave values for these constants which would be found to furnish results agreeing closely with those in the Paper:—

Efficiency.	a.	b.	Column in Table I.
63	393·0	93·5	5
67	255·5	97·4	7
69	181·0	101·5	9
69	132·0	106·0	11
68	96·7	112·0	13
66	72·3	117·4	15
63	55·0	124·2	17

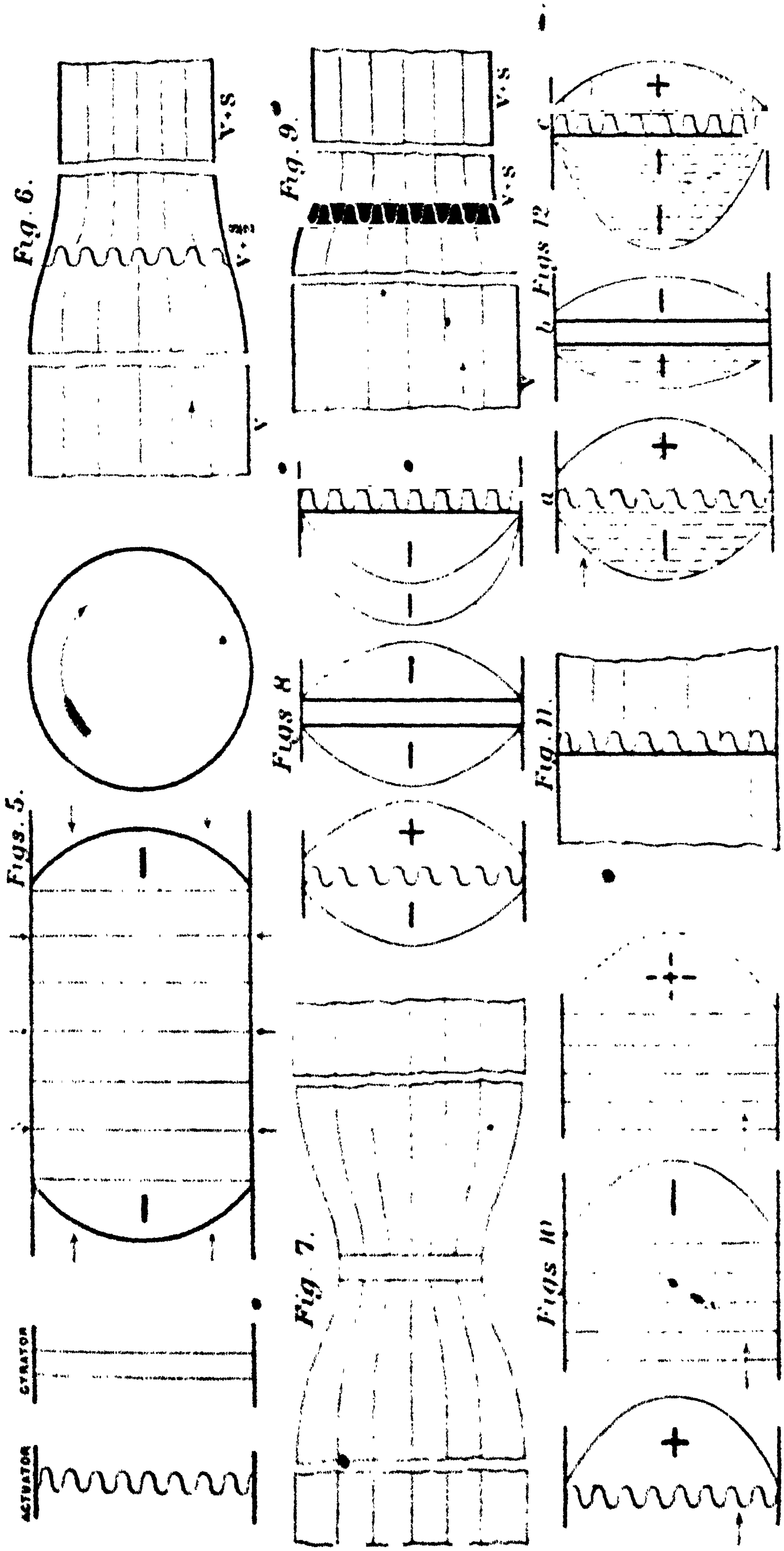
He had designed a diagram by the aid of which any one of the quantities, HP., diameter, revolutions, speed, pitch-ratio, and efficiency, could be read off without calculation. With the help of the slide-rule he would prefer to use the Author's Table; without it he thought his own diagrams (*Figs. 3* and *4*) might have some advantages. The first dealt with problems where the diameter was involved; the second with those into which the revolutions entered as a factor. The upper part of each diagram was crossed by horizontal lines, each marked with the speed in knots which it represented. Below these were scales of HP., and below these again were scales of pitch-ratio and efficiency. A thread or hair was attached to one end of each HP. scale at the points marked by thick circles. Taking the Author's first example as an illustration, the following would be the mode of procedure: Required to find the diameter and revolutions of a screw for a vessel of 20 knots speed and 6,000 I.HP., pitch-ratio to be 1·2 and efficiency 69 per cent.: find the intersection of the 69 per cent. efficiency line with the line of pitch-ratio 1·2; draw (or imagine) a vertical line from this point to cut the line corresponding to the given speed of 20 knots, and stretch the thread so as to pass through this point on the 20 knot line, as shown by the chain-dotted lines; ordinates to the I.HP. scale, erected at any I.HP., would be cut by the threads at heights corresponding in *Fig. 1* to diameters, in *Fig. 2* to revolutions of the propeller of the pitch-ratio 1·2 and efficiency 69 per cent., for which the threads were set:—thus, measuring up from 6,000 I.HP. to the threads, the height in *Fig. 3* gave a diameter of 16½ feet, and in *Fig. 4* of 111 revolutions, as in the Appendix. Supposing the same efficiency, revolutions, I.HP., and speed had been given, but the pitch-ratio and diameter were unknown. The thread in *Fig. 3* would be set so that a vertical line at 6,000 I.HP. was cut by it at a height corresponding to 111 (the given number of revolutions). From the point of intersection of the thread with the 20-knot line a perpendicular would be dropped cutting the 69 per cent. efficiency line at a point, the level of which, being found to correspond with 1·2 on the lower scale, gave that value for the pitch-ratio. The I.HP., speed, efficiency, and pitch-ratio being now known, *Fig. 3* could be used as before to find the diameter. To solve such an example as No. 3, p. 86, trial and error must be resorted to, and for this the Author's Table was preferable, even when the diagram was of large size. The threads would be each fixed to suit the case, and vertical lines dropped from their intersections with the lines of speed (in this case 20 knots) would be examined until two lines of efficiency and pitch-ratio, having the same value in each diagram, were found to intersect them. In example 3, this would be found to occur with 2·2 pitch-ratio and 68 per cent. efficiency. The diagram was drawn to too small a scale for very accurate measurements, but he hoped that the form into which he had put it might throw further light upon the problems involved. It would have been easy to give scales for I.HP. for two- and three-bladed propellers below the one on the diagram, which was calculated for four blades, but as the scale would have had to be still further reduced to get the diagram within the limits of space assigned, he had thought it better to omit them, so that allowance must be made as described on p. 87. The same corrections must also be made before using the diagrams as before using the Author's Table. It was interesting to observe that the lines of efficiency appeared to converge to a point in each Fig. This seemed to indicate that a simple formula could be constructed to express their co-relation completely, and he regretted he could not spare the time to pursue the subject further. Mr. Wingfield

Mr. J. I. Thornycroft observed that in considering the action of a screw-propeller, it appeared evident that near the boss it was not desirable to do much work, because the principal effect was to cause rotation; whereas near the end of the blade the water had what electricians might call a tendency to short-circuit the blade and allow water to go round to the wrong side, so that increasing the pitch towards the middle of the blade was decidedly advantageous. With regard to what the Author had said about the advantage of allowing the blades freedom to rotate, one the other, and so accommodating themselves to the Mr. Thornycroft.

Mr. Thornycroft.

varying velocities of the wake near the surface and below it, he was rather afraid that the application of such a thing was hardly worth the trouble. As the Author had pointed out, it might be considered in some vessels, particularly vessels of short proportions, liable to cause bad steering; whereas, in vessels of great length, perhaps the facility it would give in turning might be advantageous. There was one expedient for overcoming that difficulty that he had thought of, but had never yet ventured to try, namely, giving the shaft an inclination to the central line of the vessel when looked at in the plan, so that the shaft would not be parallel to the vessel's centre line. It was not a symmetrical arrangement, but he thought it might answer the purpose intended, of giving the blades the necessary change of pitch in the upper and lower positions, and have also the advantage of a firmer structure. The Author had referred to reasons that had led Mr. Thornycroft to criticize what Mr. Froude had done, or rather to differ from him, when he generalized on a Paper prepared for the meeting of the Institution of Naval Architects in 1889. Mr. Thornycroft had prepared diagrams to illustrate the effect of the rotation of the race of the screw, or the water coming to the screw, on the action of the propeller. Before referring to it, he wished to say that he believed that the demonstration given by Mr. Froude on the action of the surfaces of changing pressure on the water taking a particular phase of the action on the screw, was correct, and was a basis for further progress in the theory of the screw-propeller; but what he wished to show was the effect of rotation on the water that always took place in the screw-propeller, and the effect of combining rotation with the simple propulsive effect on the water which Mr. Froude had alone discussed. By *Figs.* 5 he intended to indicate a mass of water in the end section rotating. Assuming that the water composing this cylinder was all rotating about its axis, there would be a tendency for it to assume a different form; the cylinder would tend to enlarge and shorten, and if an angular motion was given to the water throughout the cylinder, then the distribution of pressure would take something like the form he had indicated by the curved thick lines bounding the ends, loss of pressure being shown by departure from the straight line indicating the end of the cylinder. Together with Mr. Froude's actuator—an instrument intended to change the minus pressure on one side to plus pressure on the other—he proposed to combine what he called a gyrator, consisting of radial arms not resisting the water passing through end-wise, but causing the water passing through the disk to

Mr. Thornycroft.



Mr. Thornycroft. rotate. If the gyrator were placed within a column of water, and rotated and travelled from one end to the other, all the water might be imagined set in motion in the cylinder of water. This produced a part of the rotating column which he proposed to consider. In *Fig. 6* it would be seen that the effect of Mr. Froude's actuator was that the water tended towards the disk, and diminished in area, having the motion continuously accelerated equally before arriving at, and after leaving, the instrument. What he wished to show was that this did not correctly represent the action of an ordinary propeller, and therefore could not be taken as always true for all propellers. That particular propeller, Mr. Froude's actuator, gave no rotation. Having considered the motion of the column of water influenced by the actuator, he would now consider that of the water which passed through his gyrator without being propelled, but simply rotated. The water at the centre of *Fig. 7* was rotated, the column arriving at this point was accelerated as it approached the disk, where it received rotation, and was retarded as it left the disk. The effect of rotating the water was illustrated in *Fig. 7*. The water would then be probably reduced to the same speed as it had originally. There was no permanent effect but a temporary acceleration in the rotating disk. In *Figs. 8* he intended to show the effect of superimposing the action of change of pressure, and that of rotation. Adding the effects of the minus pressure of Mr. Froude's actuator and the minus pressure due to the forward side of the gyrator, there was an increased acceleration before the combined instruments, while the sum of the minus and plus effects at the back was equal to no acceleration at the back, it appeared to him that what they would get was represented by the third or last part of *Figs. 8*, all the acceleration being forward of the instruments when combined so as to form one. Then the diagram, *Fig. 9*, corresponded in some sense to the diagram, *Fig. 6*, but in that case all the acceleration was in front of the propelling combination—the combination of the actuator and the gyrator. *Fig. 10* was an extreme case where the effect had been carried further. In this case the whole stream of water was supposed to be rotating in front of the propeller; the effect of the apparatus was merely to convert the rotating stream into pressure, the result of adding the two together was to get a propelling effect, but no acceleration. To illustrate a case which represented more nearly the effect met with in a screw-propeller, he had prepared *Figs. 12*. In the previous case the power of rotating the instrument was supposed to be such as completely to balance the plus pressure behind the actuator;

but the probability was that such an extreme case did not exist, and if a propeller could be imagined in which different parts were rotated at different speeds, so that all the parts had an angle of 45°, then perhaps such an effect would follow. But propellers were usually made with the pitch much shorter in proportion. In the case he was considering, the actuator gave a minus and plus pressure as before; the gyrator gave smaller pressures, and the result of combining the diagrams was that there was a small plus pressure remaining, so that the acceleration was principally before the propelling instrument, a small part of it being left behind. Mr. Thornycroft.

Professor A. G. Greenhill said that in considering any theory of the screw-propeller, the investigator was confronted with the difficulty of the large number of different quantities that must be taken into account, all of them apparently capable of independent variation. There was the speed of the ship as designed —the speed of the wake, the revolutions and pitch of the propeller, the thrust-power, the turning moment, the HP. required to turn the propeller, and so on. But in framing the theory, only what took place when those quantities varied one at a time could be considered. The Author's two coefficients C_A and C_B would, no doubt, introduce a notable simplification into the consideration of the question. Mr. R. E. Froude, in his Paper before the Institution of Naval Architects in 1886, formulated five propositions, which he imagined had received universal acceptation. In interpreting those propositions by the aid of the Author's two coefficients, Professor Greenhill found that the relation might be expressed by saying that the product of the coefficient C_A by the square of the coefficient C_B by the percentage of slip, or the slip ratio, ought to come out a constant. What the value of that constant was, of course would be determined ultimately by the experiments of Mr. Barnaby. He should be glad if Mr. Barnaby would kindly say whether that was approximately the case. He would also ask if he considered it possible to carry out his experiments on land in a current of water prepared for the purpose. Various experiments had been carried out with propellers working in a tank, but in all such cases that he had read of the propeller itself had produced the current, and consequently had been working with an inordinate amount of slip. Such experiments would thus be as valueless tests as, for instance, determining the efficiency of the propeller when the vessel was tied up to a wharf. Mr. Barnaby had concluded with some reference to the paradoxical result of negative slip. Early experimenters probably thought that they had caught a glimpse of perpetual motion in that apparent phenomenon. Mr. Isherwood of Professor Greenhill.

Mr. Stromeyer. starboard 52 square feet area. The average pitch of the port propeller was 23 feet 9 inches, and that of the starboard propeller was 16 feet 6 inches. The increased pitch towards the periphery was 2 feet with the port propeller, and 4 feet 4 inches with the starboard one. The revolutions were 52 with the port propeller and 58 with the starboard propeller. Unfortunately he could not give the HP. The only information which he had obtained on this point was that the total power was between 1,800 and 2,000 HP. and that the port engine, although it was making fewer revolutions, was indicating much more than the starboard one. He had applied his formula to both propeller-blades, and had marked the thrust, as calculated, for each square foot of the blade. This was shown in *Figs. 14* and *17*. The thrust-HP. of the starboard propeller amounted to 578 lbs., as against 615 lbs. in the port propeller, showing a difference of only about 6 per cent. That agreed with what the engineer had told him "that the helm did not indicate that there was any difference in the two powers." The turning powers, as calculated by him, *Figs. 14* and *17*, were 714 and 843, giving a ratio of about 5 to 6. Summing it up, the total HP. was about 1,550, and taking either 2,000 or 1,800 as the actual indicated HP. of the engine, that gave a very reasonable coefficient of efficiency. The efficiency obtained by dividing the thrust-HP. by the turning power at any point of the blade was given in *Figs. 15* and *18*. The total efficiency was 72·8 per cent. for the port propeller, and 81 per cent. for the starboard propeller. This result was obtained on the assumption of a certain amount of friction.[1] If it was doubled, the efficiency was reduced to 68 per cent. in the port propeller, and to 74 per cent. in the starboard propeller. He had assumed that the wake following the ship was travelling at a speed of 2 knots. This had been found by calculating the two thrusts for various speeds of the wake until the two were equal. This point was found to be where the wake was 2 knots, and the speed of the ship 10 knots. If he took into account the motion of the propeller in the wake, the actual efficiency would be 68·3 per cent. and 74 per cent., which was the same sort of efficiency as was shown in the curve of the Author, who arrived at 70 per cent. Mr. Stromeyer's highest was 74 per cent., so that there was a probability of both being correct. The remarks he had made with regard to the ratio between the

[1] Assumed coefficient of friction per foot of blade $F = v^2 \left(\frac{b}{400} + \frac{t^2}{1,200}\right)$; v = velocity in knots; b = width; t = thickness of blade in inches.

work done by the thrust and the turning power could also be applied to the case of Mr. Lels' screw, and if that was done, they could find out what was the friction of the propeller-engine, and subtract that from the rest of the work. He had carried out these calculations, and the results were given in the following Table:— Mr. Stromeyer.

No. of Experiment.	Indicated HP.	Friction of Engine ar
	HP.	HP.
	31·03	15·6
		·6
	260·32	37·8

From this Table the conclusion might be drawn that the friction of this engine and propeller was 12 HP. when running light, with an increase of 1 for every 20 indicated. He believed that that agreed fairly well with what was usually accepted. The Author's concluding remarks had reference to negative slip. Mr. Stromeyer did not see that any other explanation could be given, than that it was due to the spring of the blades: the normal pressure on a blade moving obliquely through the water had been shown to exist not at the centre, but at about one-third or one-fourth from the leading edge, and in working out the twisting moment of one blade of the port-propeller, he found it to be 22,000 inch-lbs., and he thought that was sufficient to give the tip of the blade about 3 or 4 inches increase of pitch. With lighter blades made of gun-metal, working at higher velocities and having greater thrusts, he believed that 1 foot increase of pitch would easily be obtained. But there was another thing that would help a blade of that sort in twisting, namely, the thick metal in the centre; that was sure to be in tension, and the outside in compression. Now it was well known that if the edges of a strip of thin metal were hammered, so as to put the centre line in a state of tension, it would have a natural tendency to be twisted one way or another. In fact as long as it was a thin plate it could not be made straight; but if it was thick like a propeller, the torsional strength of the central part would keep it straight, but the least twist would be increased by the latent spring that was in it.

Mr. ARTHUR RIGG said that many years ago he had made numerous experiments with screw-propellers. He exhibited a model of the Mr. Rigg.

Mr. Rigg. first turbine-propeller ever made and used. It went through many different forms, and it had been experimented upon by naval architects and others. He had designed and used it for slow-moving screws, for at the time to which he referred, about 1864, there was not much notion about high-speed screws, and experiments were made first on the model he had shown. The theory of the screw-propeller was one on which mathematicians had expended a great amount of energy, with surprisingly small results. Sir Francis Knowles, nineteen years ago, attempted to ascertain the best form of helix, but there was none to be found. He denied the existence of negative slip altogether. That was a good way of getting a theory to work—to deny the facts. Sir John Lubbock, at York, in 1881, at the meeting of the British Association, had referred to the number of theories implicitly believed in fifty years ago, but since discarded, and wondered how many pet theories would be believed in another fifty years hence. It almost appeared as if the screw theory would be no more heard of then. The Author now contended that negative slip was true, while Sir F. Knowles denied the fact, as his theories did not explain it; and finally the Author had given up theory in despair, and presented an empirical table of proportions, which did not fit it at all. Examining the theory, it would be found that the expression for the advance during 1 revolution $= 2\,r\,\pi \sin a$, where a was the inclination of the screw blade to the plane of rotation. Although that expression should really be $A = 2\,r\,\pi \tan a$, yet as he maintained the whole theory to be wrong from beginning to end, it did not matter whether the sine or the tangent were used. If the common theory was further investigated, it would be found that these facts ranged from screws with a coarse pitch giving positive slip, medium pitch giving no slip, and fine pitches giving negative slip, and herein lay a curious variation, which would naturally, to an ordinary mind, lead to the inference that the theory must be wrong; and although mathematicians had wrangled over it for half a century, their work in this direction had not been of the smallest practical use, and only accentuated the marvellous vitality of error. Indeed, it came to this, that the theory only taught designers how to make a bad screw, and thus warned them as to what they must, on no account, carry out. Referring to the Paper, the Author had mentioned Mr. Griffiths' jocular remark about flat blades. Having had the pleasure of making many experiments in conjunction with Mr. Griffiths, he might say that he simply meant that which everybody found who made screws by rule of thumb, namely, that an increasing pitch gave the best results. But nobody acquainted with the science of hydraulics would ever recommend a perfectly flat blade seriously. Reference was next made on p. 75, to the fact that the area of blades seemed unimportant. In connection with that he might mention that during one of his experiments a four-bladed screw, 3 feet in diameter, got aground in the middle of a run, and it was found on returning that three of the blades had been broken off, and nobody had noticed it. Indeed Mr. Griffiths remarked on this, that one of his screws had once brought a vessel home with all its blades broken off, only the roots remaining! Mr. Rigg.

The screw bore much analogy to a pump, and it was difficult to understand why the Author could suggest that the work done before the stream entered could be counted to increase the total; for it was impossible to take the "suction" of a pump and double it in an ordinary pump, and call that singular total the height through which it was to be raised. It was manifestly useless to maintain a theory which created bad screw-propellers, and he would try and illustrate some ideas which, whether right or wrong in themselves, made a good screw if properly carried out. The theory to which he referred was first published in 1867 and 1868 in Papers read before the Institution of Naval Architects, which were the outcome of experiments made during his invention of the guide blade or turbine propeller. The modes of propulsion through water might be divided into two general classes. One mode was the paddle, with its direction of motion exactly opposite to that of the vessel, and this was exemplified in the swimming of the frog, the duck, and quadrupeds. Another, and the commonest, had the direction of motion in the propeller more or less at an angle to that of the object driven—like the oar in sculling; the fish, the octopus, or a man swimming. Indeed, a man when swimming did not perform his work like the frog, but on the same principle as an octopus. He had no webbed feet to act as paddles; he had to spread his legs apart, and, closing them sharply together, he was propelled by the wedge of water-resistance caused thereby. That action was like a screw of a pitch increasing as his velocity increased. But the arms acted somewhat differently. When fully stretched above his head, or when closing against his sides, their action was like the action of his legs, but when widest apart, they acted as paddles. That simple illustration seemed to cover the whole mystery of screw propulsion; but in order to place the matter on a more intelligible basis, he had prepared a few diagrams, which would better illustrate his meaning. In *Fig. 19* the lines marked C F, D F, E F and H F represented veins of water moving with a given velocity

Mr. Rigg. through the air, and impinging against a plate indicated by the line A F B. These veins struck against the plate, and all flowed away horizontally upon it, so that the lines *c* F, *d* F, *e* F and H F represented vertical components of pressure due to whatever velocity was possessed by the stream, impinging at an angle of 30°, 45°, 60° or 90°. *Fig. 19*, therefore, contained the elements of the ordinary screw-propeller theory, as it was easy to conceive the plate, turned to corresponding angles, moving against the vein of water, and producing like results by impact against it. In *Figs. 20, 21, 22* and *23* were represented the elementary principles of his own theory of the screw-propeller, published in 1867 and 1868, and based upon the assumed behaviour of a vein as before, moving not in air, but in water, a condition which profoundly modified the results. Any one rowing could feel the difference between the resistance near the surface and in deep water. Taking the same vein moving with the same velocity, and at the same inclinations, as given in *Fig. 19*, the pressure due to impact remained as before; but in *Fig. 20* the stream C F was guided so as to have its angle of reflection equal to its angle of incidence, that was, C F represented pressure due to impact, as in *Fig. 19*, and F K represented pressure due to reaction, giving a total vertical-pressure L F, which was exactly double that shown by *c* F in *Fig. 19*. *Figs. 21, 22* and *23* gave the results of combined impact and reaction for 45°, 60° and 90°, all of which were double what was shown by *Fig. 19*, and it would be particularly noticed that this system of calculation showed that when the stream impinged vertically on the plate, and was reflected upwards to the same height, the pressure was also doubled. If now it were remembered that the screw and the paddle worked under water, and there was, or ought to be, no free vent for it to run horizontally along the blade, then there was no difficulty in considering that the behaviour of a vein within the water corresponded with the impact and reaction shown by *Figs. 20, 21, 22* and *23*, rather than with the impact alone which it possessed when flowing in a medium less dense, such as air. This system gave the value of the ship's progress added to the reverse current per revolution $= 2 r \pi \sin 2 a$, and the relation between progress and current depended on the proportion of area swept by the screw. If now the diagrams were turned to represent the blades of screw-propellers, so that C F B, (*Fig. 20*) became the angle *a*, or the inclination of the screw blade to its plane of rotation, then it required no very great effort of the imagination to understand the general effect of the theory on the operation of the screw-propeller. The last inquiry was, How did

ascertained facts accord with the proposition laid down? With a Mr. Rigg.
screw-propeller as with a paddle, the water was always driven off perpendicularly to the surface of the blade; never by any chance did it slide over the surface. If this were not so, how could sea-weed grow on the driving sides of screws and paddles? Then

Fig. 19.

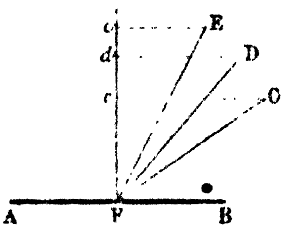


Fig. 20.

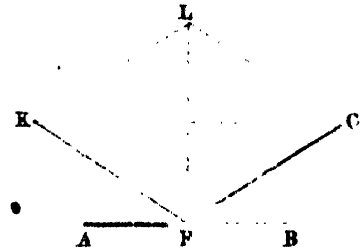


Fig. 21.

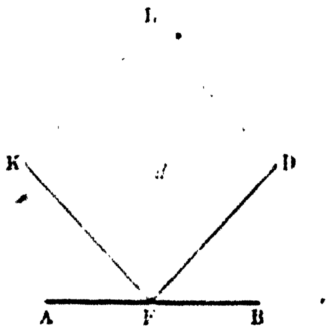


Fig. 22.

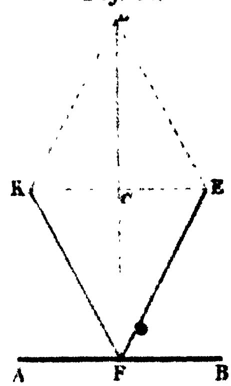
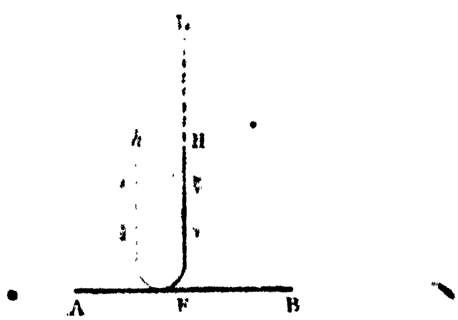


Fig. 23.



again, when a paddle struck under water, the pressure would be exactly double that which was due to its actual velocity, for its operation was like that shown by *Fig.* 23. That explained the total failure of such vessels as the "Waterwitch," where a stream driven backwards lost half the propelling power of a screw or paddle. It was impossible to tell a tenth part of what this theory

Mr. Rigg. implied in the limits of a short speech, or to combat difficulties so easily raised; but this much came out clearly, that it led directly to the design of a screw of varying pitch, and never countenanced such an absurdity as "Negative Pitch."

Mr. Reynolds. Mr. EDWARD REYNOLDS wished to ask a few questions, in order to get something more than formulas out of the Paper, which was evidently the result of a great deal of patient investigation, and no small degree of courage. He had been frequently urged by different institutions to undertake such a Paper himself; but he had been obliged to decline, because from an academical point of view he knew nothing about the subject. Nearly fifty years ago, when Mr. F. P. Smith was kind enough to give him free access to the "Archimedes" and the "Great Northern," he thought he knew all about propellers; but now, having made many hundreds for some of the most important ships in the world, he felt that he knew nothing about the matter. He feared designers were not likely to get much help from constants obtained by making experiments with models in smooth water. There were so many things affecting the question to be considered. The length of the ship affected the question abstractedly, because there would be less velocity of wake following a 200-foot ship going at 14 knots an hour, than following a 400-foot ship going at the same speed. The longer ship having a greater amount of skin friction would set in motion more wake; and some of the power lost in setting it in motion would be picked up by the propeller in reducing the slip. But there was another sense in which the size of the ship affected the question materially; it had been recently demonstrated that ships of a certain size could go practically at the same speed in all weathers. The splendid results got by the "Umbria" and "Etruria" might be taken as a proof of that fact; and the result seemed to be a disposition to reduce the surface of the blades in these large ships. In Atlantic ships it was formerly found necessary to make the propeller somewhat on the principle which the Author had described as being necessary for a tug in order to allow for a great deal of occasional slip, because when a ship was brought up by a heavy sea there was no longer any wake following it, and the propeller had to work in broken water. He had known of a case in which the "Russia" only made 285 miles in three days, the slip being 70 per cent. This did not happen with the later Atlantic ships, which, owing to their enormous weight and power and fineness of lines, were not so easily checked by a sea; and their height out of water made them safe where smaller vessels would be almost overwhelmed by the sea; therefore engineers would appear to be justified in trying a reduction of the effective area of the blades. This brought him to another part of the question. He wished to have some explanation of what he was about to mention. He had lately made new propeller blades for a large ship, the latest diagrams from which in his possession showed 10,658 indicated HP. at 61½ revolutions per minute, the pitch of the propeller being 32½ feet, the nominal total surface being 180 square feet; but the effective propelling surface of the four blades, namely, the proportion of the disk occupied as seen from abaft was 130 square feet. Taking for the sake of even figures the effective HP. as being 10,000, which would not be far wrong (although only from 55 to 60 per cent. of the total power was efficient in driving the ship; but that was because a great deal of the work of the propeller was exercised harmfully in aggravating the want of hydrostatic pressure against the stern of the ship, so that the propeller was thrusting against a self-created resistance to some extent) the pressure against the water in the direction of thrust must amount to no less than 8·825 lbs. per square inch on the blade, supposing the whole surface to be equally effective, which he would afterwards show could not possibly be the case. The velocity which would be imparted to water by this pressure, and therefore the theoretical slip due to it would be equal to 24 statute miles per hour. Part of this slip was taken up and hidden by the fact that the blades were working in the wake travelling with the ship, but a still greater part was avoided by the fact of having separate blades, each acting upon a comparatively large mass of unbroken water which required time to set it in motion—an analogous action to that of the widely separated floats on modern paddle-wheels. If that could be really explained, if any data or constants could be made available to show how much was to be obtained from a factor of that kind, engineers would be able to proceed with more certainty than they now could. The sort of knowledge which he wanted to get was such as enabled Mr. Thornycroft to produce his shallow-water propeller with its astonishing results. He would now explain his reason for saying that the whole surface of the propeller above referred to could not be considered as equally effective. There was a modern fashion, say for the last twenty years, of giving a bulge to the face of the blade near the root, so as to make the section approximately symmetrical there, this bulge dying away at about half the length of the blade (he might add that two direct experiments in substituting a flat face at this part had given unfavourable results); the result was that in some of the most Mr. Reynolds

Mr. Reynolds. successful ships of the present day, the leading edge of the blade adjoining the boss was at an infinite pitch, and therefore could not be doing anything in direct propulsion, but might still be doing useful work in what the late Mr. Griffiths would have called feeding the screw, by throwing some water outward, which if the outer portion of the blade had, as in the best modern practice, sufficient trail aft might be acted upon by the points of the blades, instead of their having to draw the water from the part of the ship's body next to them. The blade last introduced by Mr. Griffiths had the extreme point bent forward so as to have a disposition to pile water underneath the ship's counter, rather than to draw it away; and he was confident that the general idea conveyed by Mr. Griffiths was so far accurate, that he had ventured from the first to say that the Hirsch propellers, of which he had made considerable numbers, could do nothing but absolute harm by hooking the water inwards, because they would tend to aggravate the deficiency of hydrostatic pressure under the stern of the ship.

Mr. Cowper. Mr. E. A. Cowper desired to say, in confirmation of Mr. Thornycroft's statement about making the pitch of the screw near the boss at a less pitch than at the outside, that he had in 1855 made the speed of a screw less towards the centre than the outside, so that the arms might simply screw through the water, but not attempt to propel the ship, and the effective outside portions of the screw were made quicker so as to propel. This was in a ship called the "Prince Albert," but its name was almost immediately changed to the "Abundance," as although it was built to fetch timber from Norway and Sweden, it was bought by the Government, and filled with ovens to bake bread in the Black Sea, at the time of the Crimean War; it lay alongside a ship called the "Bruiser," by Fairbairn, which had a flour-mill on board, consisting of four pairs of stones. The "Abundance," when coming round from Sunderland, with upwards of 800 tons of coal on board, made a quick passage for those days, and gave great satisfaction, though the weather was very rough. The engines of the "Bruiser" could work up to ten times the power required for the flour-mill, and could not be controlled with any governor, till Mr. E. Humphrys took away the steam-pipe, and put a long 2-inch pipe for the steam to pass from the boilers to the engines; after this they were able to work the mill.

Mr. Barnaby. Mr. Sydney W. Barnaby said, in reply to the discussion, that Mr. Froude had made the subject of the Paper so peculiarly his own, that he had been much pleased to find that nothing seriously wrong had been pointed out by him. He thought there might be a relation between his constants C_A and C_B, as suggested by Professor Greenhill. The connection which Mr. Wingfield had established between them seemed to point to the possibility of Professor Greenhill's surmise proving to be correct. Experiments had been made with models in a small rotary canal, the velocity of the current being produced by a separate propeller or propellers, and not by the screw, the thrust of which it was desired to measure. It was not a very satisfactory arrangement, as it was difficult to obtain anything approaching to uniformity in velocity or direction of the currents in the canal. As to the challenge which had been thrown down by Mr. Isherwood, the late Chief of the Navy Department of the United States, he felt disposed to take it up in defence of the Admiralty. Mr. Isherwood had stated that negative slips existed nowhere but in the Admiralty Reports of the trials of British war vessels. Mr. Barnaby thought the reason was that it was only in Admiralty trials that there was the careful measurement of results so necessary to show such a small thing as apparent negative slip must always be. If Mr. Isherwood had said that reports of negative slip were confined to the trials of penny river-steamers it might have been discarded as a fallacy; but the fact that it was obtained in trials so carefully conducted as Admiralty trials were, made it clear that it was something to be met and dealt with. He had not met with Mr. Stromeyer's formula for calculating the thrust of the screw; in fact he did not even now know what it was; but he should be much interested in examining it, and he should like to apply it to Mr. Lels' thrust-curve, and find, if he could, why the measured thrust differed from the curve of indicated thrust calculated according to Professor Rankine's method. He did not agree with Mr. Stromeyer's view that negative slip might be the result of the blades twisting under pressure. Were this the case, it might be expected that the metal would soon give way from fatigue, as the fluctuations in pressure were very great and very rapid. Mr. Rigg could not understand how the work done upon the stream before it entered the propeller could be "counted to increase the total." Mr. Barnaby thought there would be very little total left to account for if the acceleration in front of a propeller were to be discarded, in view of the fact that open propellers produced nearly the whole of the acceleration in front; that was, they imparted velocity to the steam almost entirely by suction. He thought Mr. Rigg confused real slip and apparent slip. There was, of course, no such thing as real negative slip, and no one in these

Mr. Barnaby.

Mr. Barnaby. days would contend that there was. Mr. Reynolds had depreciated experiments with models. The trials made with the "Vlaardingen," described in the Paper, were not upon a small scale, but upon a vessel large enough to admit of trustworthy measurements being made, and when these were found to agree in such a marked manner with the results of the experiments with small models, it surely showed that there were good grounds for believing that these might be depended upon. What he said about the greater wake which would be produced by a long ship than by a short one was of course correct; but it only pointed to the necessity of exercising judgment in the selection of a wake correction to be used with the constants. The remarks of Mr. John about the large pitch-ratios and comparatively small disk-areas required with twin-screws completely accorded with his views, and the comparison of the effect of a sail upon a single screw and of one screw upon another in the case of twin-screws, was a very apt one. The constants in Table I provided for all those different conditions, and it was possible to design a screw from those constants for a single-screw ship or a twin-screw ship, the only difference in the treatment being that the wake factor in the two cases would not be the same. That point was well brought out in Plate 1, Fig. 2, of the Appendix, where ships were shown occupying different positions depending upon the velocity of the wake. The "Great Eastern" appeared in two positions, one with single- and one with twin-screws. The single-screw worked in a wake having a velocity equivalent to 27 per cent. of the ship's speed, whereas the twin-screws were in a wake having a velocity of 15 per cent. only. The effect of applying the correction for wake was to give a large diameter for single-screws as compared with twin-screws. He had pointed out that the best efficiency could only be obtained at one particular slip-ratio, and he had tried to show that in designing a screw for a tug, or for a ship which had to contend against head winds and seas, it was advisable to design it so that the slip should be small when the tug was running free, and when the sea-going vessel was steaming in smooth water; because, as soon as the abnormal resistance came into play, through the tow-rope in the one case and from the wind and sea in the other, the effect would be to increase the slip and to make it correspond more with the condition of maximum efficiency. It had long been known by practical men that a tug required a large propeller; but he did not think it had been shown before how large it should be. Mr. John asked whether the Author could account for the high efficiency which appeared from the Tables to extend over so large a range of pitch-ratio as from 0·8 to 2·5. He agreed that it was a matter of great surprise, and had expressed his doubts in the Paper as to whether there was justification for expecting 69 per cent. efficiency with 2·5 pitch-ratio. Mr. Froude's experiments extended to 2·2 pitch-ratio only, and it was a matter of opinion as to whether equally good results might be expected with ratios of 2·5. He did not agree with what Mr. John had said about apparent negative slip. He knew that Mr. W. Froude thought that the intermittent action of the screw as it passed in and out of the dead-water behind the stern-post of a full-formed ship tended to produce negative slip, but the "Collingwood" was not a full ship; it had a 10 per cent. wake only, and, moreover, the screws did not work behind a stern-post at all as it had twin-screws, and yet they showed 2½ per cent. apparent negative slip. As stated in the Paper, all the explanations of negative slip, based upon dead-water and following current, applied only to the case of screws of increasing pitch, and did not touch the case of a uniform pitch. The same thing was true of the theory based upon the circular motion of the particles of water in waves. He presumed that Mr. John referred to waves made by the ship: because it could not be contended that negative slip resulted from the screw working among waves. It was well known that the contrary effect was produced, that the slip was increased, and that the most favourable circumstance for the exhibition of apparent negative slip was perfectly smooth water. If a wave followed the ship, and its energy could be made use of in any way by the screw as suggested, that wave had previously been created by the ship, from which the energy had been robbed, and it could be only partially restored. Were it all restored, and were the whole of the energy of the frictional wake utilized by the screw without loss, there would still be no surplus of thrust to keep the vessel in motion. It was certain that there must be a stream of water left behind by the screw having sternward motion relative to still water; the question was, how did it come about that while this was so, apparent negative slip could be got? The reason seemed to be that the water flowed faster through the screw than was accounted for by multiplying the pitch into the number of revolutions, and that the speed of the race was not correctly estimated in this manner. The more rotation there was in the race the less the excess of water passing would be, and the less the probability of getting negative slip. This view appeared to be confirmed by the trials of the "Collingwood," where the pitch-ratio of the screws was very small, and where the negative slip

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r. Barnaby. was considerably increased by a reduction of pitch. He found, in a work by Robert Rawson on the Screw-Propeller, published in 1851, which was in the library of the Institution, the account of the trials of six of Her Majesty's ships. Of these one only exhibited negative slip, and that one, the "Plumper," had a pitch-ratio considerably less than either of the others, and the negative slip was afterwards increased by a reduction of pitch. Mr. Wingfield had pointed out that it was possible to plot the revolutions constants in straight lines. That was true; but they could not then be combined in one diagram with the disk-area constants, as was done in Fig. 1; but it would, no doubt, be useful to plot them in that manner if it was desired to interpolate or to extend the curves beyond the limits of experiment as suggested by Mr. Wingfield. He had studied Mr. Wingfield's diagrams carefully, and considered them very ingenious. The question of scale was of great importance in a diagram of this nature, and it was this difficulty which first prompted the Author to try and alter Mr. Froude's arrangement. Mr. Froude had given curves extending only to 200 revolutions per minute, and they were quite unsuitable on this account for the Author's use. Mr. Wingfield's diagrams covered a much wider range, but the I. HP. extended only to 6,000, and the scale was very crowded towards the high powers. The scale was more open at the small powers, and he suggested that it would be advisable to split up the diagrams into several parts, each including a small range of power, and in that form he thought they would be useful. One advantage of the table of constants was that it embraced an unlimited range of power, speed, and revolutions, and was independent of scale. Although it might take two or three minutes longer to work out a propeller from it, designers could well afford those two or three minutes for the purpose, especially if speed were only to be obtained at the expense of accuracy.

Correspondence.

Mr. Fitz-Gerald. Mr. MAURICE F. FITZGERALD noticed that the Paper contained a large amount of direct experimental evidence as to a matter in which mere calculation could give, even with much pains and labour, only unsatisfactory results; namely, the efficiency of and actual power consumed by, the same screw at different rates of revolution. The Author contrasted the opinions of Sir Francis Knowles and Mr. Griffiths as to the existence of some best possible form of helix, and Mr. FitzGerald agreed in the main with the

Author's conclusion, being of opinion that there was no inherently or essentially best propeller, apart from the engine and ship to which it belonged, or even apart from the trade and ports of call of the vessel, the financial position of her owners, and the engineers, stokers, captain, crew, and passengers. Any useful theoretical work must, therefore, be directed, not to finding an absolutely best screw, but towards enabling the designer to insure the absorption of a given IIP., and revolutions at a given speed of the vessel. The matter, from this point of view, was much on a par with the theoretical mechanics of girders and beams, the object not being the discovery of any absolutely best girder, but a girder whose strength was known in advance. The Author's remarks on the complication introduced in Mr. Thornycroft's experiments on a varied pitch by the manner in which the change of pitch was effected, fell in with Mr. FitzGerald's belief that the regular mode of treating the question theoretically on the basis of a propeller blade of small thickness and uniform pitch was unsound, or at any rate unpractical, in the sense that there was no reasonable probability that any ordinary screw could act like a thin plate whose pitch was that of the after face of the propeller blade. *Fig. 24* represented a circle near the boss of the screw of the "Vlaardingen" developed; from which it was evident that the motion of by far the largest part of the water passing through at this radius could not be expected to agree with the form of either the flat or the rounded face of the blade. It would, in fact, be much more natural to expect its average motion to follow the direction of the mean fibre or median line of the blade section, which at least had the merit of symmetry. The futility of supposing the general motion of the water to be altogether and absolutely derivable from the form of one face of the blade, chosen arbitrarily because it happened to be the one whose pitch was uniform, and therefore, most easily measured, and therefore used as a means for describing in words the general form of the blade, was sufficiently apparent. In another case, he found on examining the working-drawings of a screw of nominally 14 feet 9 inches mean pitch, that the pitch of the median line of section of the blades varied from nearly 17 feet at the tip (where it almost coincided with that of the face of the blade) to at least 25 feet at the after edge near the boss. At the leading edge the pitch was throughout less than the pitch of the after face, but did not vary much from 13 feet or thereabouts; and as the effect of a screw depended mainly on the condition in which the water was left behind it, that was, on terminal conditions, and not the average of

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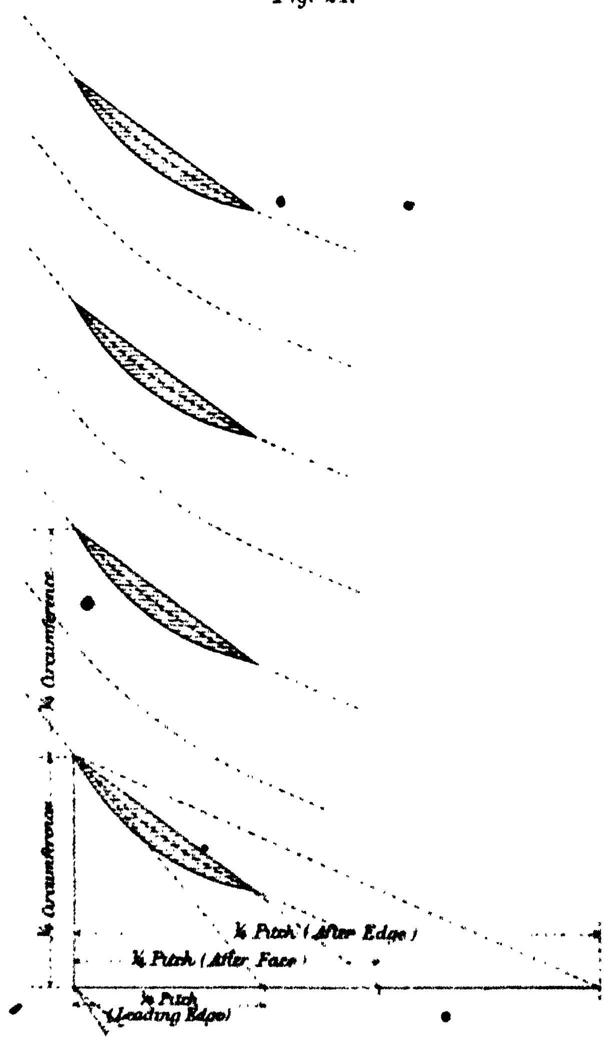
Mr. Fitz-Gerald. intermediate ones, no safe conclusion, but one most highly likely to be erroneous, could be drawn by assuming that the effective pitch might be taken where the two faces of the blade were parallel. The Author in his remarks upon Mr. R. E. Froude's explanation of Mr. W. Froude's conclusions as to the possible existence of negative slip, the correctness of which Mr. FitzGerald

Fig. 24.



saw no reason to doubt, might have proceeded much farther, as it appeared that no clear reason existed why the pitch of an arbitrarily chosen line (namely, that of the after face of the propeller at its mean radius) used as a measure of the ship's speed, should not occasionally lead to what would be called negative slip. He had no doubt that if any ordinary propeller were reversed on the shaft, so as to make the after face become the forward one, negative slip would become a very apparent and ordinary phenomenon, and the propeller would probably also be a very bad one, perhaps capable, under judicious management, of driving the ship backwards to a slight extent, without reversing the engine. Some years ago Professor A. G. Greenhill published a series of articles on the screw-propeller, from which it appeared that no mere geometrical resolution of velocities on the blade surface was possible unless one of them were given, and that the circumferential velocity of the water, in particular, could by no means be left out of account, in consequence of the centrifugal pressure produced where it existed. Mr. Froude, in explaining his conception of the "actuator," had guarded himself expressly against any absolutely certain pronouncement on the effect of these pressures in modifying the conditions of operation of the actuator, and from a perusal of Professor Greenhill's articles, Mr. FitzGerald had been led into an investigation of the problem of finding, apart from any particular form of blade, some compatible set of velocities, circumferential and longitudinal, which would make the resistance to rotation (due to the inertia of the water like that of a heavy frictionless nut on a screw), the thrust (due to inertia of the same nut), and the head or pressure in the stream lines, which depended on both the longitudinal and circumferential velocities, consistent with one another. Of course, an infinite number of such systems was possible, but he conceived that in order to design a propeller, the best thing would be to insure the results, by first ascertaining that the motion of the water, intended to be produced by the blade, could actually be produced, as, once the motion of the water was determined, there was no difficulty about making the blade to fit it. He had sent to the library of the Institution a note to a Paper on the "Theory of the Screw Propeller," read by him at a meeting of the Belfast Natural History and Philosophical Society, on March 4th of this year, in which the purely mathematical work of the investigation was given. This involved no special or extraordinary difficulty; the required consistency of motion and heads, or pressures, being arrived at by supposing a curve of heads drawn for each longitudinal stream line, and another curve of heads drawn for the radius of the screw disk where it was cut by the longitudinal stream line. The ordinate of the first curve depended on the velocity along the stream line, and that of the second on the centrifugal pressures due to circumferential motion; while the value of the ordinate at the point

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Mr. Fitz-Gerald. where they crossed was the hydrostatic pressure at that point, and consequently the same for both. Two forms of vortex were mentioned in the note which satisfied the mechanical and hydrodynamical conditions, and it was shown that, in an ordinary propeller, so long as the stream lines were "fair" and no violent twists or eddies were set up (as they must be when one part of it did not suit well with another), the vortex it produced must approach one, or indeed, both of these, as they were for a considerable portion of the screw disk practically the same. He had given in the note a Table of the HP. calculated on the assumption that one of these vortices was produced, and compared the results with some examples as below, to which some of the results given in the Paper under discussion were now added :—

—	HP.	
	Calculated.	Indicated.
Merchant steamer above mentioned, nominal mean pitch 14 feet 9 inches	470	518
H.M.S. "Camperdown," Minutes of Proceedings Inst. C.E., vol. xcv. p. 343. Speed 16·3 knots, revolutions 95; twin screws	8,480	8,622
No. 11 first-class torpedo boat, Minutes of Proceedings Inst. C.E., vol. lxvi. p. 176 :—		
Speed 18·843 knots; 380 revolutions .	314	390
„ 16·101 „	271	299
„ 12·995 „	112	131
Mr. Thornycroft's experimental screw, given in Paper by Mr. Barnaby :—	Foot-lbs. per minute.	
Speed 4·5 knots; 750 revolutions .	9,574	9,500
„ 4·5 „ 600 „ .	3,540	3,900
S.S. "		
Speed 9·6 knots; 100 revolutions .	36	38
„ 10·3 „ 150 „ .	138	138
„ 11·0 „ 180 „ .	277	255

He believed these examples showed a sufficient agreement between the calculated and realized results to justify the general correctness of the reasoning on which they were founded, when it was taken into consideration that none of these screws was intended by the maker to fit any particular vortex. The small scale of the drawing (Plate 1, Fig. 5, Appendix) also made the absence of any sufficient balance being left for friction in the case of the "Vlaardingen" screw not surprising, as it was not easy to make sure of what the rotation at the circumference of the wake, on which that at every other point depended, would be in it. The calculated results were also certainly higher than the exact theoretical results, owing to the Table in his note above mentioned having been calculated on the assumption that the longitudinal velocity was uniform over the whole disk area, whereas, though nearly so, it would not be exactly uniform; and the error made by this assumption would be always balanced, more or less, by friction. At almost all ordinarily practicable rates of rotation of open screws without guide-blades, the ordinary design of blade would cause somewhat less HP. to be absorbed than that required for the vortex assumed, the central velocities, both circumferential and longitudinal, being less than those calculated for in his Table. He believed that a competent man, by several years' labour, could arrive at a nearly exact estimate of the effect of a screw of given arbitrary form, in which several subsidiary effects would take place; but he also believed it would be much more practical to design the screw-blade so as to fit a simple system of longitudinal and circumferential velocities, such as was described in his note, especially as every screw must produce nearly these motions, whether it fitted them or not. The data required were the ratio of the speed of blade-tips to the speed of the ship, and the ratio of the rotational speed of the water at the circumference of the wake to that of the blade-tips. The latter ratio usually varied in practice from 2 to 4 per cent., and in a 10-foot screw, absorbing about 500 HP. at eighty revolutions, and 10 knots, the twist or rifling of the spiral path of water at the circumference of the wake would be about 1 turn in 300 feet of its length. The circumferential velocity at any other place on a radius of the screw disk was got by drawing a rectangular hyperbola with the radius and axis for asymptotes, through its value at the tip of the blade; so that in the above case, the twist of the inner part of the wake, behind a boss 2 feet 6 inches in diameter would be 1 turn in about 20 feet. The longitudinal velocity diminished slightly near the boss, when this was about one-fourth of the screw's diameter, but with very small bosses might vanish, or possibly be reversed locally. The form of the blade section was easily arranged, with the thickness usually required near the boss, so that the leading edge entered without slip (taking its median line as the effective blade), and the after edge had the requisite length of pitch, while retaining the practical convenience of a flat after face of uniform pitch. The resulting form of blade did not differ in any conspicuous way from ordinary forms. Mr. FitzGerald had long ago observed, though unable

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Mr. Fitz-Gerald. at the time to give any distinct account of its significance, the long twist of the wake of the outer pair of screws in one of the Russian circular ironclads, which were carried by conical projecting stern tubes a good way clear of the ship, so that the vortex produced was not influenced locally by stern-brackets, &c., or broken up immediately after its formation, by the stern-post and rudder. It was difficult to say, in his opinion, what was the correct inference to be drawn from the experiments mentioned by the Author on the "Antispire" of Messrs. Desgoffe and de Georges. A piece of vortex, something like a bit of a smoke ring, hung on along the after edge, and over the tip of a propeller-blade, which was of little, if any, use for propulsion; it was likely that a good deal of energy might be unprofitably expended on it, especially at the tip of the blade, where its axis lay tolerably parallel with that of the screw; so that if the circumstances of the experiment favoured the production of this curl, as he thought they would have been likely to do in the case mentioned, the "Antispire" might be useful. Mr. FitzGerald considered the effects of viscosity apt to be overrated by being confounded with the loss of power involved in producing the rotary momentum of the wake, which was no more avoidable than the loss through longitudinal momentum, being an absolutely necessary condition for the working of the screw, unless guide-blades were fitted. In ordinary large screws, however (not turbine propellers like Mr. Thornycroft's), this loss was small enough to be less than the probable friction of the guide-blades themselves, and, in comparing indicated thrust IHP. with that of the engine, was naturally included with other, more properly frictional, losses.

Mr. Hall-Brown. Mr. E. Hall-Brown said that one factor of propeller efficiency, as far as he could see, had been entirely left out of consideration in the Paper. He referred to "dead-water." With moderately fine ships, having a good run aft, the action of this might be inconsiderable, and might be safely left out of what after all was only an approximation unless experiments had been made with a model of the ship. With very full ships, however, the action of the dead-water must be considerable. The work upon the dead-water was shown by the late Mr. W. Froude to be absolutely lost, as far as propulsion was concerned, therefore the less the proportion of that work to the total work done by the propeller, other things being equal, the greater would the efficiency be. Now he thought the amount of work done upon dead-water would be proportionally larger with a small propeller than with a large one, as with a very bluff ship it was easy to suppose a propeller so small that it would work entirely in the dead-water. This, then, was a consideration which ought to be weighed against the reasons given by the Author why a small propeller should be more efficient than a large one. This action of the dead-water was probably greater than was generally supposed, and might, with ordinary steamers of, say 0·65 coefficient, and still more so with fuller boats, turn the scale in favour of the larger propeller. At any rate, there was a general tacit opinion among engineers that there was a certain diameter of propeller which would give the best results with any given ship. It was difficult to understand how this idea had arisen unless some influence of sufficient magnitude had not been considered by the Author. His attention had been for some years principally occupied with a class of ship as far removed from the "Phantom ship" as it was possible to conceive, namely, the ordinary 9-knot cargo boat. Here were the particulars of one:—Length B.P., 277 feet; beam, extreme, 37 feet 5 inches; draught moulded, 19 feet 11 inches; displacement, 4,670 tons; block coefficient, 0·792. All experience with this class of ships had been that they could not be economically driven by a propeller of small diameter. A ship having these dimensions would attain an average speed at sea of 9 knots, with about 825 indicated HP., the propeller being about 16 feet in diameter, and 16 feet pitch; or a pitch-ratio of 1·00. Taking the constants given in the Paper, this corresponded to an abscissa-value of slightly over 11; and the corresponding revolutions were 64·7, all of which agreed very well with ordinary practice. It was to be noted, however, that the value of the wake thus taken was only 10 per cent., corresponding to that given for a very fine vessel indeed; so that either the amount of wake with these bluff ships at 9 knots must be very small, or the propulsive coefficient must be lower than that taken by the Author. It would be interesting to know which was the case, and what were the causes. Taking, however, the same pitch-ratio as above, with an abscissa-value of 15, which ought to give an efficiency of 66 per cent., it would be found to require a propeller 12 feet in diameter, making about 98 revolutions per minute; now he was certain that such a propeller as this would never be fitted by any engineer experienced in these boats, as he would know that any such reduction in diameter would entail a very great loss of efficiency. Was it not probable that a low propulsive efficiency, caused by the action of dead-water, was the cause of the agreement in the first case mentioned, and that the same cause produced a still more diminished efficiency when a smaller propeller was applied? What now most required

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Mr. Hall-Brown. elucidation was the effect upon the action of the propeller of such very full ships as he had mentioned. The Author had given, in a very concise form, formulas which could readily be applied to all the finer types of ships, and which would, he thought, give results as nearly correct as it was possible to get without experiment upon each individual model.

r. Isherwood. Mr. B. F. Isherwood, Chief Engineer, United States Navy, observed that many persons interested in "The Screw as a Propeller for Vessels," seemed to have the belief that there was some particular kind of helicoid, some particular outline of blade, some particular number of blades and length of blade, some particular ratio of the pitch to the diameter, and some particular fraction used of the pitch, that could, under all circumstances, give the greatest economic efficiency, such efficiency varying inversely as the power required to give the same vessel the same speed; or, in other words, required to overcome the same resistance. Now the determination of the economic efficiencies of different screws, was not a matter either of imagination or of mathematics, although both had frequently been put in requisition for the purpose, with the result of conspicuous failure; it was a purely physical problem, and solvable, like all such problems, by experiment only. And there had been no lack of such solutions, for extensive comparative experiments had been made during the last half century by the naval authorities of Great Britain and France principally, not to include much subordinate experimenting made by the naval authorities of other countries, which, if accurately collated and intelligently interpreted, would decisively answer all the questions that could be asked in relation to the subject. Many of the experiments referred to were almost inaccessible, never having been published; and those which had been published were in many cases incomplete, important data having been omitted, but enough remained that was sufficiently extensive and sufficiently complete to form a solid basis for opinion, and a reliable guide for practice. The valuable results were those obtained from experiments with a number of different screws propelling the same vessel at the same speed, and varying gradually in some particular proportions, while the remaining proportions continued constant. Of course, such experiments were necessarily rare, owing to the time and cost involved; but sporadic experiments undertaken for the determination of some particular point of difference between two or more screws were valuable, at least qualitatively, if not quantitatively, even if incomplete, as they had generally proved to be. The problem was to ascertain the relative economic efficiency of different screws overcoming the same resistance. The latter was an indispensable condition. Without it the results were isolated, and could have no application to the purpose. If the same vessel were propelled at the same speed by the different screws, the resistance overcome by them would, of course, be equal; and if the vessel were propelled at different speeds, the results could be reduced for equality of resistance so long as the vessel's speed varied in the ratio of the square of the speed, which it would do for all speeds below a certain limit, differing for each model and size of vessel. Hence, the screw experiments of Mr. Thornycroft, cited in the Paper, were valueless, and determined exactly nothing, as the screws were not tried propulsively on a vessel, and did not overcome any constant resistance. Each screw overcame merely the resistance of the water to itself, being projected at the end of a pole from the bow of a vessel maintained at sensibly equal speed; and that resistance varied simply with the dimensions and proportions of the screws. The same results would have been obtained by dragging the submerged screws independently through the water without the intervention of a vessel, and did not in the least enable any comparison to be made of their relative economic efficiencies in overcoming a constant resistance. The greater the resistance of any of Mr. Thornycroft's screws, the greater would be the power applied to it, the resistance and power being necessarily in equilibrium; so that the efficiencies of all his screws properly measured in this manner would be equal. But such a case had no application to the problem of ascertaining the screw of greatest economic efficiency in propelling a given vessel, for in this latter case the whole power applied to the screw was not utilized in overcoming the resistance of the vessel, but a considerable portion was expended in the slip of the screw, and in overcoming the resistance of the helicoidal surface to the water, or the resistance of the wetted surface of the blades, and the comparison was between the fraction of the whole power which remained for the propulsion of the vessel after deduction of the fraction expended in slip, and in overcoming the resistance of the wetted helicoidal surface. Were there no slip, and no resistance of the wetted surface of the screw, one screw would be exactly as economically efficient as another, just as one wedge, or as any of what were called the mechanical powers, was as economically efficient as another; for a propelling screw was simply a wedge of indefinite length forced by the power between the fulcrum (the water in contact with the screw surface), and the object (the vessel) to be moved. The complication arose from the

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r. Isherwood. fact that the watery fulcrum moved as well as the object, and in the opposite direction, constituting the slip, and that the helicoidal surface experienced a resistance from the water in the direction of the helical movement of that surface. If the fulcrum did not recede, and if the helicoidal surface experienced no resistance from the adhesion of the water to it, the whole of the power applied to any propelling screw would be utilized in the propulsion of the vessel; consequently, the loss of useful effect accompanying any propelling screw, and inseparable from it, was the sum of the losses by slip and by surface resistance. And one screw could be economically better than another only in the degree in which it made this sum less. Now the losses of useful effect by the screw could be of only two kinds, namely:—1st, slip, or the recession of the watery fulcrum under the pressure of the screw, which slip was caused wholly by the mobility of the water, and could be lessened until it became insensible, by sufficiently increasing the virtual surface of the screw. The virtual surface was the actual or physical surface multiplied by the number of times it was used, or by the number of revolutions it made, while the vessel to which it was attached went a given distance through the water. The slip of the screw was diminished in a certain degree (vastly less than in the direct ratio) as the virtual surface was increased, and a screw could be so proportioned to any vessel that the slip would be insensible; it could never, however, be made nothing, though it might be continually diminished by additions to the virtual surface. The resistance which the water opposed to the pressure of the screw was that of the inertia of the mass acted on by the screw, the mass being in the direct ratio of the virtual surface of the screw, multiplied by the distance receded by the mass, or through which it was pushed back by the screw. Whatever might be the resistance of the vessel, it would always be exactly equilibrated by the inertia of the mass of water set in backward movement by the slip of the screw. The greater the virtual surface of the screw propelling a given vessel, the less backward movement would be given to the water, because, for the same resistance of vessel, the product of the virtual surface into the backward movement of that surface, or slip, would always be a constant. If a spring were interposed between the end of a free screw-shaft and the vessel, so that the thrust of the screw was measured by the compression of the spring, then the thrust was in common for both the vessel and the watery fulcrum of the screw, because action and reaction were equal, and in opposite directions. Under these conditions, the work done in propelling the vessel would be measured by the

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thrust of the screw into the speed of the vessel, and the work done in giving recession to the watery fulcrum (or in slip) would be measured by the thrust of the screw into the speed of the slip or distance receded by the watery fulcrum while the vessel was advancing a given distance. Hence, also, the power expended in the slip would compare with the power expended in the propulsion of the vessel, as the speed of the slip compared with the speed of the vessel. A clear idea might be formed of the preceding actions and reactions, by supposing the vessel to have its sternpost in contact with a wharf or any immovable inelastic solid. Now, between the stern-post and the wharf, let there be driven an inclined-plane shaped wedge, having the proportions of height to base that the pitch of the screw to be used with the vessel has to the mean circumference of the screw; this mean circumference being the circumference normal to the centre of pressure of the helicoidal surface. The pressure (supposed constant) to force forward the wedge would be applied in the direction of the base of the inclined plane; then the vessel would move through the height of the plane (corresponding with the pitch of the screw), while the base of the plane moved through its own length, and, as the immovable wharf did not recede under the pressure of the wedge, the only loss of useful effect would be the friction of the wedge. If, however, the wharf should be composed of elastic materials, they would yield under the given pressure of the wedge, and a slip of the latter would occur in the direction of the height of the inclined plane, and the vessel, instead of advancing the height of the plane while the base advanced its own length, would advance only the difference between the height of the plane and the recession of the base, the latter measuring, in addition to the friction of the wedge, the loss of useful effect. The second loss of useful effect, inseparable from the use of the screw, was in overcoming the resistance which the helicoidal surfaces experienced from the adhesion of the water to them during their passage through it, or, more briefly, the resistance of the wetted surface of the screw. This kind of resistance increased in the ratio of the squares of the helical speeds of the surfaces, and, for the same screw, in the ratio of the square of the number of revolutions made by it in equal times. Consequently, the power expended in overcoming this resistance would be, for the same screw, in the ratio of the cubes of the number of revolutions made by the screw in equal times, or, for any screw, in the ratio of the cubes of the helical speeds of its surface. When the dimensions of a screw were given, and the number of revolutions made by it in a given time, and the resist-

Mr. Isherwood. ance in lbs. or fractions of a lb. of a unit of surface per unit of speed were known, the second kind of loss of useful effect could be calculated, and expressed either in work or in HP. To make the calculation for an irregularly outlined blade, the latter must be divided into a reasonable number of what might be called "elements," or strips of equal breadth, say 3 or 6 inches, according to the size of the screw. The length of the helix, corresponding to the centre of each element for the entire pitch of the screw, must be taken for the speed of that element per revolution of the screw; and the fraction of the length of that helix contained by the aggregate blades, multiplied by the breadth of the element, would be the surface due to that helical speed. The aggregate surface of all the elements of the screw thus calculated, would, of course, be the entire helicoidal surface of the screw. The resistance of 1 square foot of helicoidal surface moving in its helical path, with a speed of, say, 10 feet per second, would vary with the roughness of the surface, and could only be determined by direct experiment. From the best determinations he had been able to obtain, the resistance of 1 square foot of cast metallic surface, moving in water with the velocity of 10 feet per second, was 0·45 lb., and for other speeds in the duplicate ratio of those speeds to the square of 10. The resistance of the wetted surface of screws having the proportions generally adopted in practice thus calculated, varied from 5 to 10 per cent., exclusive of extreme cases, of the net HP. developed by the engine. By net HP. was meant what was left of the indicated HP., after deducting the power required to work the unloaded engine. The net HP. was the power applied to the crank-pins, and from it were to be deducted, first, the friction of the load, which, for ordinary practice, might be taken at 7½ per cent. of the net power; then, from the remainder must be deducted the power absorbed in overcoming the resistance of the wetted surface of the screw, calculated as above described; and if from the resulting remainder there were deducted the percentage which the slip of the screw was of its speed, the final remainder would be the HP. applied to the propulsion of the vessel. The percentage of the net HP. applied to the propulsion of the vessel would vary with every screw, and with the different conditions of wind, wave, draught of water, foulness of immersed surface, &c., which caused the resistance of the same vessel to vary, and with the speed of the vessel, other things being equal, when the speed exceeded that at which the vessel changed trim by "squatting" at the stern. Within the limits of speed that "squatting" did not occur, all the different kinds of work done by the net HP.

increased or decreased, in the same ratio which that power did for different speed of vessel, namely, as the cubes of the speeds. Hence, within this limit, the power applied purely to the propulsion of the vessel would be in the ratio of the net HP. for the different speeds. If the HP. applied to the propulsion of the vessel, calculated as above described, were multiplied by 33,000, and the product divided by the speed of the vessel in feet per minute, the resistance of the vessel, corresponding to the horizontal thrust of the screw would be obtained in lbs. The thrust of a screw, as given by a spring interposed between the end of a free screw-shaft and the vessel, was not the resistance of the vessel unless the axis of the screw-shaft was horizontal, which was rarely the case. Even if horizontal when the vessel was at rest, it became inclined when the vessel was in motion with sufficient speed to alter the trim. Now it was almost impossible to ascertain the angle of inclination in the latter case; but if it could be obtained, then the thrust of the screw as given by the spring, which was indeed the true thrust upon the vessel in the direction of the screw's axis, must be diminished in the ratio of the radius to the secant of the angle. An allowance must also be made, and added to the observed thrust of the screw, for the pressure required to overcome the endwise friction of the screw-shaft, in order to have the true thrust on the water. The two kinds of losses of useful effect which had been described, namely, slip, and the resistance of the wetted surface, were the only losses experienced, or that ever could be experienced, by a propelling screw, and the evaluation of these losses could be closely approximated by experiment. Now, the peculiarity of these losses was that they were in opposite directions, and that as the one increased the other decreased, and *vice versâ*. Of course, the smoother the helicoidal surface, the less would be its wetted resistance; but that resistance would always exist, and, for the same surface, would increase as the slip was diminished, and decreased as the slip was increased. The blades of a screw had considerable bulk, and as they moved through the water in their helical paths with high velocity, they displaced bulks of water corresponding to their speed. Many persons supposed that a loss of useful effect resulted as a consequence, and that such loss would be lessened by making the blades thinner. This idea, however, was erroneous; no gain could be accomplished by making the blades thinner, because the blades being wholly submerged and tapering almost to a line from the centre to the edges, no power was expended in their displacement of water; the only resistance they opposed

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Isherwood. to movement was that of their wetted surface. The losses of useful effect due to inclination of the axis of the screw, to centrifugal action, and to all other causes except resistance of wetted surface of blades, were measured in the slip. The term "resistance of the screw" was often used, and generally without much understanding of what constituted it. The screw of itself, and irrespective of the resistance of its wetted surface, had no resistance, whatever its dimensions and proportions. The largest screw, and of any proportions, might be revolved freely in the water without experiencing any resistance except that due to its wetted surface, provided no load were attached to it. Consequently, the resistance which the propelling screw opposed to rotation, and obtained from the water, was measured simply by the load attached to it, and this resistance was due to the slip of the screw, or, in other words, to the mass of water pressed by the screw, and put in motion by that pressure with a speed equal to the speed of the slip. The screw could not possibly impart any thrust upon the vessel, except by virtue of its slip—that was, by virtue of the momentum of the water set in movement by the slip. The thrust exactly equilibrated that momentum. Any screw, large or small, could propel any vessel, large or small; the smaller the screw and the larger the vessel, the greater would be the slip of the screw to obtain the required resistance from the water. The economy of the power developed by the engine for propelling the vessel would, indeed, be greatly affected by the amount of the slip, but not the fact of the propulsion of the vessel. The utilization of the screw—that was to say, the proportion of the net power applied to the crank-pin of the engine, which was applied to the propulsion of the vessel—was a maximum when the sum of the losses of useful effect by slip and by the resistance of the wetted surface was a minimum. The object, therefore, in designing a screw for a vessel, was to so proportion the screw as to produce this minimum. Now, many screws of different dimensions and proportions might be applied to the same vessel with equal utilizations. Nothing could be more fallacious than the general supposition that there was some particular form of helicoidal surface, or proportions of screw, that would give the best utilizations in all cases. The slip of a screw attached to a given vessel could be varied within very wide limits, without sensibly affecting the utilization, because there was no possible way by which the loss by slip could be reduced without at the same time increasing the loss by the wetted surface, and *vice versâ;* and it so happened that these losses, for the ordinary conditions of practice, were so evenly balanced as quantities, that diminution of the one was inevitably accompanied by about equal increase in the other. Here, then, was the reason why, in practice, screws giving widely different slips when attached to the same vessel gave that vessel equal speeds with equal development of net HP. by its engine. In all that hereinafter followed in relation to slip, there would be meant by that term the difference in units of speed between the speed of the screw and the speed of the vessel. This method, now presented for the first time, of measuring the slip, instead of by the ratio which the difference of the speeds of the screw and vessel bore to the speed of the screw, was very important, and allowed very simple relations to be established between the slip and the dimensions of the screw when the latter propelled the same resistance, impossible when the slip was considered as a percentage. In the former case, absolute quantities were dealt with, while in the latter case only ratios were used. For want of this distinction, all the attempts heretofore made to connect the slip with the dimensions of the screw operating against a fixed resistance had been complete failures, leaving the results, which were clearly correlated by very simple mechanical laws, an unintelligible tangle. The question would now be asked, whether such an arrangement of a given virtual surface could not be made, that it would have, when propelling against a constant resistance, less slip than when otherwise arranged, while its wetted-surface resistance would, of course, remain unchanged. In other words, whether, for a given virtual surface, there was not some particular arrangement which would give the minimum of slip. The answer was, No. Suppose, as an illustration, a regular screw of given diameter, pitch and surface, the length being uniform from hub to periphery in the direction of the axis. The surface of this screw could be arranged in any number of blades required, from one blade upwards without in the slightest degree affecting the slip. The more numerous the blades the shorter would be the screw; but the action of the aggregate surface on the water would remain unaltered. If a given number of blades were arranged in two series instead of one series, on the same hub, thus doubling the length of the screw, the blades of the after series being placed immediately behind those of the forward series, as in the Mangin screw, the slip would not be changed; nor would it be affected by placing the given number of blades in three or more series similarly; the screw would be proportionally lengthened, but its slip would remain the same. Neither would the slip be affected by spacing the blades irregularly around the hub, some being separated by a narrow interval, and others by a wide

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If the pitch of the screw was lessened, the length being correspondingly reduced so that the projected area of the blades on a plane at right angles to the axis remained the same, all other things remaining unchanged, the slip would be lessened in the direct ratio of the new pitch to the old one. For example, if, with the old pitch and a speed of vessel of, say, 10 miles per hour, the slip of the screw was, say, 4 miles per hour, making the speed of the screw $(10 + 4 =)$ 14 miles per hour, then with a new pitch of one-half the old one, and the same speed of the same vessel, the slip of the screw would be just one-half the slip with the old pitch, or 2 miles per hour, making the speed of the screw 12 miles per hour. Halving the pitch halved the slip in miles per hour, but not in percentage of the screw's speed; for in the case of the old pitch the slip was $\left(\frac{4 \times 100}{14} =\right) 28\frac{1}{2}$ per cent., and in the case of the new pitch it was $\left(\frac{2 \times 100}{12} =\right) 16\frac{2}{3}$ per cent. Here appeared a considerable gain secured by so large a reduction of the loss by slip, but this gain had been bought by about as large an increase in the loss of useful effect due to the resistance of the wetted surface, so that the sum of the two losses (by slip and by wetted surface) remained about constant. The helicoidal surface of the small pitch screw would be less than that of the large pitch screw; but, for equal speeds of vessel, the screw of small pitch would have to make nearly double the revolutions of the screw of large pitch, and the HP. required to overcome the resistances of wetted surfaces was in the ratio of the products of the surfaces into the cubes of their velocities. If the diameter of the screw were increased, all its other dimensions remaining the same, the slip in miles per hour would be reduced in the inverse ratio of the cubes of the diameters. For example, in the case of two screws precisely the same, except that the diameter of the one was double the diameter of the other, let the slip of the small-diameter screw be 8 miles per hour, and let the speed of the vessel be 16 miles per hour, which would make the speed of the screw 24 miles per hour, then the slip of the large-diameter screw would be 1 mile per hour, and the speed of the vessel being as before 16 miles per hour, the speed of the large-diameter screw would be 17 miles per hour. The slip of the small-diameter screw would consequently be $\left(\frac{8 \times 100}{24} = \right)$ $33\frac{1}{3}$ per cent. of its speed, and the slip of the large-diameter screw would be $\left(\frac{1 \times 100}{17} = \right)$ 5·9 per cent. of its speed. This showed a very great reduction of the loss by slip; but the loss by the resistance of the wetted surface had been proportionally increased. The virtual surface of the large-diameter screw greatly exceeded that surface of the small-diameter screw; and the helical speed (entering into the computation for power in the ratio of the cube) of the virtual surface of the large-diameter screw also greatly exceeded the speed of the virtual surface of the small-diameter screw. The only net gain possible was the difference between the saving by the reduced slip and the loss by the increased resistance, due to the increased wetted surface. In any given vessel, all screws could be placed with the lowest point of their periphery in the same horizontal plane, consequently screws of smaller diameter could be placed at a greater depth below the water-surface than screws of large diameter. In the former case, therefore, there was a higher water column above the axis of the screw than in the latter case, and many persons had supposed that a unit of virtual surface with the higher water-column upon it, would obtain a greater reaction from the water than with a lower water-column upon it; so that the same unit of more deeply immersed surface would have a less slip than when less immersed. The supposition was erroneous; a unit of the same immersed surface moving at a constant speed in water, experienced exactly the same resistance at all depths, the water being considered incompressible. Against this might be brought the indisputable fact that a vessel propelled by a screw, and having its rudder immovably fixed in the line of the keel, always deflected from a straight course.

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Mr. Isherwood. As this deflection could be caused only by the screw's oblique surface above the axis, with its obliquity in one direction obtaining less reaction from the water than the same oblique surface below the axis, with its obliquity in the opposite direction; and, as the surface above the axis had indisputably a less height of water column upon it than the surface below the axis, the inference had been drawn that the deflection was due to the less reaction of the water nearer the surface. The defect in this reasoning consisted in the assumption that the water above the axis of the screw in the wake of a vessel was just as "solid" as the water below the axis, which was erroneous. The water which refilled the void left by the onward passage of a vessel, rose vertically by gravity from the horizontal plane of the bottom of the hull; and, as the vessel continuously advanced, the void was not as completely refilled by the rising water at the horizontal plane of the surface of the water as at the horizontal plane of the bottom of the hull; there was a gradual diminution of the "solidity of the filling" from the latter plane to the former one, so that the screw surface above the axis obtained really less resistance from the water than below the axis, and the deflection of the vessel from a straight course was the resultant of the difference. The screw, therefore, of small diameter, placed as low as practicable, would have to this extent less slip than in the inverse ratio of the cubes of the diameters, compared with the screw of large diameter. A last modification might be made by uniformly reducing the surface of the screw lengthwise. That was, there might be screws exactly the same in all respects except length. The shorter screw would have a greater slip than the longer one, but by no means in anything like the inverse proportion of the length of the screws. Here, then, a gain in useful effect was possible. The loss by the resistance of the wetted surface would be nearly in proportion to the lengths of the screws; but the loss by slip would be in a greatly less proportion, and it was owing to this fact that screws composed of a small fraction of their pitches had a greater utilization than screws composed of a large fraction of their pitch, until the slip had reached a quantity which overbalanced by its loss the gain by the lessening wetted surface. In practice, from one-fifth to one-third of the pitch was used; but the exact fraction for maximum utilization was determinable by experiment only in each case. As a general fact, though by no means invariable, and certainly depending on the accompanying conditions, the slip in miles per hour of exactly the same screws except length, propelling the same vessel at the same speed, was in the inverse ratio of the fourth root of the lengths. For example, a screw having a slip of, say, 4 miles per hour when propelling the vessel 12 miles per hour, would have, when its length was halved, a slip of $(4 \times \sqrt[4]{2} =)$ 4·76 miles per hour. In the first case the speed of the screw was $(12 + 4 =)$ 16 miles per hour, and its slip was $\left(\frac{4 \times 100}{16}\right) = 25$ per cent. of its speed. In the second case the speed of the screw was $(12 + 4 \cdot 76) = 16 \cdot 76$ miles per hour, and its slip was $\left(\frac{4 \cdot 76 \times 100}{16 \cdot 76}\right) = 28 \cdot 4$ per cent. of its speed. Here a slight increase (about one-seventh) in the loss by slip had been accompanied by a saving of nearly one-half of the loss by the resistance of the wetted surface. Various attempts had been made to increase the propelling efficiency of a given screw surface, that was, to reduce its slip, by giving irregular outlines to its blades as in the case of the Griffiths screw, and several others; or by giving the helicoidal surface a curved directrix gradually increasing the pitch from the front edge to the back edge of the blades; or by gradually increasing the pitch from the periphery to the hub; or by gradually increasing the pitch simultaneously in both directions, or by giving the surface a curved generatrix either alone, or in conjunction with an expanding pitch from the front to the back edge of the blades, the latter modification producing a spoon-shaped or concave blade. Raised edges had been given to the periphery of the blade, and they had also been placed at regular intervals from the periphery to the hub, with the view of holding the water in contact with the surface of the blade, and thus preventing its flying off by centrifugal action. Bands or drums had been used, connecting the peripheries of the blades, for the same purpose. Guide-plates had been introduced to project the water set in motion by the slip in a more aft direction, besides other numberless absurdities. So far from any benefit having been derived from these attempts, they had all, with the exception of the Griffiths form of blade, been disadvantageous, by simply adding to the wetted surface to be driven through the water by the power; while the slip, so far from being reduced, was increased by the resistance of the added surface. The Griffiths screw, in which the front and back edges of the blades tapered towards each other at the periphery, produced exactly the same economic effects as a regular screw with the front and back edges of the blades parallel, and having the same diameter, pitch and number of blades, and using the same fraction of the pitch in function of propelling efficiency. If the

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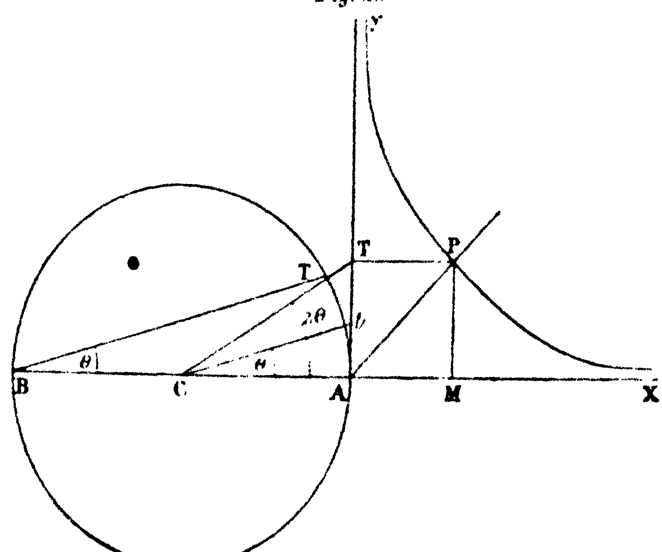
Mr. Isherwood. this idea, the screw's resistance was increased by the *vis viva* of the alleged current impinging upon it; so that although the screw might have a positive slip relative to this current, it had a negative slip relative to the speed of the vessel. But evidently the following current, supposing it to exist, which he denied, would act upon the stern of the vessel as efficiently as upon the screw, and thus the current effect would be exactly neutralized. The explanation also failed to account for this following current, producing so wonderful an effect, in the case of a few vessels only, and not in the case of all.

Sir Francis C. Knowles. Sir FRANCIS C. KNOWLES was afraid that his solution of the problem of maximum action had not been quite understood.[1] This solution had no special relation whatever to the mode of application of the power, whether impelling a ship through water, or raising water to a height, or blowing air through a pipe into a furnace, &c. No doubt a much larger screw of any form would do

Fig. 25



more work than a smaller one of any form. But it was implied in the conditions of the problem that the diameter of the blade to which it was to be compared should be the same. He had, he thought, omitted to point out in his Paper[1] that if the diameter was much increased in any given screw, the plane of the blade became more and more asymptotic to a plane perpendicular to the axis, and of course, at extreme points, would do little or no work. To gain power the screw itself must be of longer dimensions.

[1] Minutes of Proceedings Inst. C.E., vol. xxxii. p. 219.

Let

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$$a \tan 2\theta = y$$
$$v = x$$

that was $xy = a^2 \tan 2a$, the equation to a rectangular hyperbola, the co-ordinates being parallel to the asymptotes. The general equation was $xy = \frac{1}{4}(A^2 + B^2)$.

By the formula—

$$v \tan 2\theta = a \tan 2a.$$

The locus for the angle of the ordinary screw was $xy = a^2 \tan a$, by a different hyperbola.

The relation between the two kinds of screw was shown by *Fig. 25.* The angle ACT at the centre being double the angle ABT at the circumference, Ct was parallel to BT.

Mr. MURK LELS thought that a considerable advance had been made towards the correct determination of the best relation between the diameter, pitch, and revolutions of a propeller for a given speed of vessel. The rules which the Author had laid down, and the Tables which he had compiled, appeared to be of such a nature as to enable engineers to predict with considerable accuracy the performance of a given propeller. In the case of the s.s. "Vlaardingen," the Author had compared the results obtained from the trials with those which would have been anticipated from the Tables, and there was certainly a striking coincidence between them. As Mr. Lels had designed the machinery, and had conducted the trials of the vessel, he would make an explanation which he thought would render the coincidence still more complete. The Tables predicted an efficiency of 69 per cent., while the trials gave an efficiency of 70 per cent. It was just this 1 per cent. which he hoped to account for. There was one indicator fitted to each cylinder, and this was connected to the top and bottom ends of the cylinder by a $\frac{5}{8}$-inch copper pipe. Now, although this pipe was well lagged with yarn and canvas, it was almost certain that this arrangement would cause the diagrams to indicate less power than that actually developed, and would consequently give too high an efficiency to the propeller. He was inclined to think that 69 per cent. efficiency was more probably correct. Mr. Lels.

Mr. J. A. NORMAND noticed that the Author had alluded to his experiment of twin-screws with overlapping disks, turning in the same direction, on board the "Avant-Garde" torpedo-boat of 115 tons displacement. This boat attained 20·98 knots with 13 tons more weight on board than Mr. Thornycroft's "Coureur." However, the efficiency was less than that of Mr. Normand's Mr. Normand.

Mr. Normand. single-screw boats. Only one set of screws had been used, and these were too large. The loss of the vessel on the coast of Portugal prevented further experiments; but he was so well convinced of the excellency of the principle, that he was beginning a new boat with the same arrangement of screws. It was somewhat remarkable that the after screw gave less revolutions than the forward one, the reverse of what was observed with ordinary overlapping screws.

Mr. Vogt. Mr. H. C. VOGT noticed a statement in the Paper that twice as much power must be expended on propellers with flat blades as on those of ordinary form to obtain a particular speed. This was also true of a propeller in the air, where the blades on the active side, along which the fluid moved, should possess slight curvature, like that of a close-hauled sail, with the greatest curvature one-third from the leading edge. The mathematical screw-surface gave a very bad result. In regard to the number of blades the two-bladed propeller was found to have the greatest efficiency, because the interference of one blade with the other was less than when there were three or four blades. No comparison could properly be made between screws working in solid matter and propellers in fluids, because in one case the matter had sufficient cohesion to support the screw even when not revolving, whereas the cohesion of the fluid medium was insufficient to do so. The conception of absence of slip implied an amount of cohesion which fluids did not possess, and a screw-propeller could only draw a fluid in which it worked by producing a rarefaction in front of its blades. Centrifugal force was the principal agent in producing this rarefaction on the leeward or passive side, while on the active side the pressure decreased from the tips, where the velocity was greatest, towards the axis, and therefore the centrifugal force was opposed on the active side. In a well-shaped propeller the fluid was not sent radially outwards, but the rarefaction had even a tendency to draw the fluid from the sides towards the propeller, and the fluid thus drawn was sent behind the propeller by the following blade. Mr. Vogt had recently explained[1] that the rarefaction produced by centrifugal force was a function of the form $f\left(\frac{a v^3}{r}\right)$, where a was the size of the propeller, v the circumferential velocity, and r the radius. The centrifugal force producing the rarefaction was one function of the revolutions; the slip in its usual signification was another function of the revolutions, resistance, &c., but these two functions had nothing to do with each other, and the rarefaction

[1] *Engineering*, vol. xlix. (1890), p. 535.

produced by the centrifugal force, was totally independent of the slip, being positive or negative, or nil. Considerable negative slip occurred with an air-propeller, as soon as the resistance was comparatively independent of the forward speed of the propeller, as when it ascended into the air or drove a light wagon on rails. To construct the trajectory of a projectile the forces acting must be considered, and in the same manner the principal forces, namely, force of gravity and centrifugal force, must be considered in theories of propulsion with propellers; but apart from practical convenience the conception of slip might be excluded altogether, having nothing to do with the efficiency. Mr. Vogt.

The Author had been kind enough to allude to his propeller, which was shown in Fig. 4. He agreed perfectly with his remarks and criticisms upon it, and had only to add that since they were written he had introduced laminated springs, like carriage springs, in order to prevent a blade from feathering too much when the opposite blade was brought out of the water by the pitching of the ship. At the same time sufficient movement was allowed to enable them to adjust their pitch to suit the varying speeds of following current and thus avoid vibration. Propeller-blades were usually tapered towards the tips to reduce vibrations, and three or four blades were resorted to for the same reason, although a two-bladed propeller was the most efficient. With the feathering propeller the blades could be made broadest at the tips, and the diameter did not have to be so great. All propellers in nature possessed a high degree of elasticity to avoid shocks and vibrations; the fin whale, when chased, was said to attain a speed of 40 to 50 knots an hour, and even the small dolphin made a speed of about 30 knots, and the tails or propellers of both were highly elastic. It was known from daily experience that it was more economical to pull a certain weight on a wagon resting on springs than on one without, and the same economy should be effected when the blades of a propeller were permitted to feather in an elastic manner, because the irregularities of the resistance met with by a propeller-blade in its path through the different following-currents of a ship exceeded that encountered by a wagon on a bad road. When the spring was disconnected from the blades of the propeller the manœuvring power of the ship was increased in an enormous degree as described in the Paper.

Mr. S. W. Barnaby said, in reply to the correspondence, that he was of opinion that the virtual pitch of screws with blades much rounded at the back would be greater than the nominal pitch measured at the face of the blade, as Professor Fitz-Gerald Mr. Barnaby.

Mr. Barnaby. suggested; but not so much as a mean between the fore and aft faces of the blade. He thought *Fig.* 24 represented the channel which the water would have to follow if four screws were set one behind another on a shaft like a double Mangin screw, and did not correctly represent the conditions of a four-bladed screw when each blade entered fresh water, and when nothing existed, so far as he could see, resembling the grating, or series of guides represented in *Fig.* 24. Such guides would no doubt constrain the water to follow some such path as was indicated. It seemed to him that the suggestion that the motion of water through a screw should be treated as a form of vortex was a pregnant one, and was likely to throw light upon some obscure points. He hoped that the idea would be followed up. The Table of HP. calculated for a number of cases and compared with the indicated power showed sufficient grounds for believing that Professor FitzGerald's reasoning was well founded. He felt much indebted to Mr. Hall-Brown for making known his experience with the propellers of vessels of very full form, and he thought that Mr. Hall-Brown's views as to the unsuitability of small screws for very full ships were sound. In weighing the advantages of large and of small screws respectively, Mr. Barnaby had in his mind vessels of moderately fine form in which dead water as distinguished from frictional wake, was not a considerable element affecting propeller efficiency. Table II (Appendix) showed that the diameter of the screw required to be increased as the block-coefficient became fuller; but the fullest vessel which Mr. Froude had quoted in that Table was the "Inflexible," which was considerably finer in form than the cargo steamer referred to. If it was a fact that a 12-foot screw running at 98 revolutions per minute would not give a good result on a cargo steamer—and he would not dispute it for a moment, as no one knew better than Mr. Hall-Brown what the requirements of those vessels were—it certainly pointed to some such conclusion as Mr. Hall-Brown had arrived at, namely, that a small screw worked too much in the dead water, and that the propulsive coefficient was very small. He should himself be in favour of resorting to twin-screws for this type of vessel, and this for two reasons: the influence of the dead water upon the propellers would be less, and a higher rate of revolution would be obtained, which would permit of the use of faster running, lighter and more economical machinery, which he understood was a desideratum for this class of vessel. Mr. Isherwood expressed what was perhaps a popular, but was certainly in the Author's opinion, a very erroneous view, when he said that the best way to conduct experiments upon the efficiency of propellers was to try a number of screws varying gradually in some particular proportion, each screw propelling the same vessel at the same speed. Such a procedure mixed up in an inextricable manner the performance of the ship and of the propeller. It would be possible thus to ascertain what was the most suitable propeller for the particular vessel upon which the experiment was carried out; but it would be difficult to make much use of such information as might be obtained for the purpose of designing a screw for a vessel of a different form. The position of the screw with regard to the vessel, the form of the vessel, and the magnitude and velocity of the frictional wake would influence the performance of the screw to such an extent, that the results could only be applied with certainty in designing screws for vessels of similar form with the screws similarly situated. It appeared from Mr. Isherwood's remarks upon Mr. Thornycroft's experiments, that he had completely misapprehended the manner in which they were carried out. He seemed to be under the impression that the model screws were pushed through the water in front of the launch and allowed to revolve like a patent log. A reference to the description of the Chiswick trials on p. 78 of the Paper, and to Plate 1, Fig. 1, would show that the models were driven by a small engine and made to deliver a thrust in exactly the same manner as if they were propelling a vessel. The object had been to discover at what slip-ratio each model would give the best efficiency, and by placing the screws in front of the launch, not "at the end of a pole," but on a screw-shaft which could be rotated by an engine at any required speed, they worked in undisturbed water, and their speed of advance through the water could be exactly measured, as it was of course equal to the speed of the launch. Had they been placed behind the launch their speed of advance through the water would have been less than the speed of the launch, as they would have worked in a current produced by the friction of the vessel, having a forward velocity of unknown amount, and confusion would thereby have been introduced. Mr. Isherwood again quite misunderstood his views upon negative slip. Mr. Barnaby thought he could not have stated in plainer terms than he had done that there could be no propelling effect unless water were left with a sternward motion relative to still water, and he had supposed that it was almost axiomatic, and certainly undisputed, that the sternward momentum of the water in the race must equal the forward momentum of the ship under all circumstances. He discussed in the Paper the well-authenticated fact that the pitch of a screw Mr. Barnaby.

Mr. Barnaby. multiplied into the number of revolutions did not correctly measure the speed of the race, since while it was well known that the race must have some sternward velocity, it sometimes appeared, when its speed was calculated in this manner, to have a velocity in the opposite direction. He conceived that, in endeavouring to account for this, he had not laid himself open to the charge which Mr. Isherwood and others had attempted to fix upon him of believing in perpetual motion.

13 May, 1890.

Sir JOHN COODE, K.C.M.G., President, in the Chair.

The discussion upon the Paper by Mr. S. W. Barnaby, on "The Screw-Propeller," occupied the whole evening.

20 May, 1890.

SIR JOHN COODE, K.C.M.G., President,
in the Chair.

The following Associate Members have been transferred to the class of

Members.

Arthur Wilbraham Dillon Bell.
James Samuel Brown.
Malcolm Grant-Dalton.
Henry Beecroft Harvey.
Graham Rigby Lynn.
Henry Atwell Purdon.
William John Wilson, F.C.H.

The following Candidates have been admitted as

Students.

Norton Percy Anderson.
Harold Thomas Ashton.
Edward Saville Burrough.
Peter Valentine McMahon.
Reginald William Newman.
Henry Edward Newton.
Joseph Perez-Seoane-y-Villalobos.
Wilfrid John A[illegible]s Watkins.
Charles Ernest Wolff.

The following Candidates were balloted for and duly elected as

Members.

James Bingham Alliott.
Walter Philip von der Hörst.
Thomas Haines Wickes.

Associate Members.

George Edward Abrahams.
Percy Allan.
Oakeley Archer.
Walter Banks, Stud. Inst. C.E.
William Fitz-Gerald Barry.
Bertram Robert Beale, B.A., Stud. Inst. C.E.
George William Budd.
Herbert Alexander Caffin, Stud. Inst. C.E.
George Bickham Dunn.
Michael Elliot.
Herbert Taynton Foord, Stud. Inst. C.E.
Herbert Hinds, A.K.C., Stud. Inst. C.E.
George Henry Holden.
Arthur Henry Kingsley, B.A.
Thomas Elcoat Laing.
Charles Law-Green.

Associate Members—continued.

JOHN LEE, M.A.	HENRY WILLOCK RAVENSHAW.
THEOPHILUS SEPTIMUS McCALLUM.	ALEXANDER STEWART.
HERBERT WALTER PRINCE, Stud. Inst. C.E.	VSEVOLOD DE TIMONOFF.
	WILLIAM HENRY TODD.

(*Paper No. 2459.*)

"The Keswick Water-Power Electric-Light Station."

By WILLIAM PAUL JAMES FAWCUS and EDWARD WOODROWE COWAN, Assoc. MM. Inst. C.E.

THE Keswick Electric Light Station being the first attempt to utilize available water-power in this country for the purposes of a public supply of electric light, it has been thought that a short description of the works would be of interest to the members, if only in directing attention to a method of converting to a useful purpose a natural supply of energy now generally allowed to run to waste.

At a time when coal is dear, and the prospect of lower prices in the future is not promising, it is expedient to make use of all natural sources of power which may be found suitable.

Early in the year 1889 the Directors of the Keswick Electric Light Company instructed the Authors to prepare plans, and to procure tenders, for the erection of a central supply station in or near Keswick. Several sites were offered, of which two had water-power available, both being situated on the River Greta.

As the area proposed to be lighted was large and sparsely populated, and as many of the prospective consumers were gentlemen whose houses were at some distance apart, it was seen that the only feasible system to adopt was an overhead high-tension one. The alternating-current transformer system was finally selected.

Whatever difference of opinion there may be as to the best system for lighting large towns, there seems to be no doubt that, if at the present time any general scheme of lighting small towns and scattered suburbs with electricity is to be made a commercial success, a high-tension system, or some modification of it, must be adopted.

On account of the high price of coal at Keswick, it was considered desirable to utilize this water-power as far as possible in preference to steam. The saving effected is considerable. The rent paid for the water-power is 10*s.* per HP. per annum. Taking the number of HP. hours required per annum as one hundred thousand for the present output of the station from a 50-HP. turbine, the cost per HP. hour comes out as 0·06*d.* On the other hand, taking the price of steam-coal at 15*s.* per ton and the quantity burnt per HP. per hour as 6 lbs., the cost per HP. hour comes to 0·48*d.*, or eight times the cost of water-power. In addition to this, the attendance required for a turbine is, of course, less than that necessary for a steam-engine and boiler; the first cost, maintenance, and depreciation are also considerably less, and the chances of a breakdown much more unlikely. The Authors accordingly decided to recommend the Directors to obtain a site on the River Greta at the village of Forge, about ¾ mile from the town of Keswick, which had formerly been occupied by an old woollen mill, there being still in existence head- and tail-races, which, with repairs and some enlargement, could be made use of (Plate 2, Fig. 1). The head-race is about ¼ mile in length, the tail-race about 100 yards. The old tail-race extended down stream only some 70 yards, but by adding 30 yards to its length and increasing the depth about 4 feet, an extra head was obtained, which increases the total head now available to 20 feet.

The bed of the tail-race was rock, of which some 6,000 cubic feet had to be removed in order to deepen it.

The head-race was repaired and deepened, the cross-section below the water-level being made 21 square feet, the dimensions being in most places 7 feet wide by 3 feet deep.

As there was a possibility of partial failure of the water-supply during extreme drought in summer, it was decided to provide steam in addition to water-power. Figs. 2 and 3 represent the general arrangement of the station. A 50-HP. turbine is built into the end wall of the head-race, a portion of its casing and the wheel and guide vanes projecting into the race. Its speed is regulated by a hand-wheel in the station, which, by means of suitable shafts and gearing, opens and closes the guide passages. The turbine and draught tube are supported by the end wall of the head-race and a cast-iron girder built into the retaining-walls of the tail-race. Two similar girders carry the two pedestals of the main shaft, which latter can be put in or out of gear with the turbine by means of a claw-clutch. The stand-by engine, a 50-HP. Westinghouse, is fed by steam from a 20 nominal HP. Hyde duplex vertical boiler placed in a separate boiler-room. The engine is arranged to drive on to the main shaft (Fig. 3).

The driven pulley on the main shaft can be put in or out of gear by means of a friction-clutch actuated by a hand-lever. This arrangement permits of the alternator and exciting machine being driven by either the turbine or the engine, or by both should the shortness of water render it necessary to supplement the power of the former.

Provision has been made for the addition of another turbine and two 30-kilowatt alternators, when the demand for the light requires it, involving only a slight enlargement of the building. The installation would then have a total capacity of three thousand 8-candle-power glow-lamps.

The alternator at present erected is a Kapp 30-kilowatt machine.

It is intended to fix a fan in the boiler-room to produce a forced draught, the power for driving it being obtained from the turbine.

The belting, leather chain-link, is arched to suit the curvature of the pulleys.

The switch-board and electrical instruments are fixed on the north wall of the station, near the regulating-handle of the turbine. Additional regulation is obtained by varying the resistance in the exciting circuit, and so the magnetic field of the alternator.

The Turbine.

The turbine (Plate 2, Figs. 2 and 4) is of American design, and is called the "Victor." It is of a "mixed-flow" type, the wheel being 20 inches in diameter. This turbine was selected as being the one which seemed best suited to the work to be done, for the following reasons:—In the first place, its speed was 273 revolutions per minute, which is at least 70 per cent. greater than the speed of an "inward," "outward," or "parallel flow" turbine would have been working under a similar head of only 20 feet. The alternator having to run at 750 revolutions per minute, it was advisable that the speed of the turbine should be as high as possible to avoid the mechanical difficulties of speeding up. The regulation is effected by opening and closing a cylindrical sluice working between the guide-passages and the wheel.

As the turbine was 16 feet above the level of the tail-race, a draught-tube was necessary to give full effect to the head of 20 feet. This draught-tube is of wrought-iron 14 feet long and 3 feet in diameter. The maximum velocity of water flowing through it is a little over 4 feet per second.

The speed obtained, when running the turbine light at full gate, was 345 revolutions per minute, or an increase of only about 26 per cent. above the normal speed of 273 revolutions per minute. The volume of water passing through the turbine when running light at full gate was about three-quarters of that flowing when carrying its full load, the additional speed of revolution retarding its passage. Though there can be no doubt that automatic regulation, sufficiently sensitive for the purposes of an electric-light station, is difficult to obtain with water-motors, nevertheless, for hand-regulation, such as is used at Keswick, the method above described is simple and efficient.

The Engine.

The engine is a Westinghouse of simple type, having two single-acting cylinders 10 inches in diameter by 9 inches stroke. It is fitted with a sensitive governor. A test of the brake HP. developed at 80 lbs. steam-pressure gave 50·11 HP., the engine running at 350 revolutions per minute. Upon taking the load off the brake and allowing the engine to run light, the speed increased to 360 revolutions per minute, or less than 3 per cent.

This type of engine, on account of its compactness, is very suitable for providing reserve power. The floor space taken up by the engine described is 7 feet by 4 feet.

The Boiler.

The boiler is a 20 nominal HP. Hyde duplex made by Messrs. Tinker, Shenton and Company. It is 4 feet 6 inches in diameter and 11 feet 6 inches in height. The grate area is 13 square feet and the heating-surface 200 square feet. The heated gases pass twice diametrically across the boiler. The water evaporated per lb. of coal is about 11 lbs. The working-pressure is 120 lbs. to the square inch.

The Alternator.

The alternator, Plate 2, Fig. 5, which was designed by Mr. Gisbert Kapp and manufactured by Messrs. Johnson and Phillips, is a 30-kilowatt separately-excited machine, giving an output of 15 amperes at 2,000 volts. Its speed is 750 revolutions per minute and the frequency 75.

The armature has a cast-iron supporting-ring 28 inches in diameter and 2½ inches wide, provided with six arms. The armature-core is of charcoal-iron strip, 2½ inches wide, with paper insulation, and wound to a radial depth of 8 inches. There are nineteen coils, each containing 100 turns of 0·072-inch wire covered to 0·092-inch in two layers.

The resistance of the armature after working some hours was found to be 7 ohms. The magnetic field consists of twelve magnets on each side of the armature. The cores and pole-pieces are of wrought-iron, the yoke-rings of cast-iron. The former are cylindrical, $3\frac{3}{4}$ inches in diameter. The latter are 4 inches by $7\frac{1}{4}$ inches. Each core is wound with six layers of 58 turns per layer with 0·102-inch wire covered to 0·117 inch. The total resistance of the field after working some hours was 11·2 ohms. The curve (Fig. 6) shows the relation between the armature electro-motive force and the exciting ampere turns.

When working with an output of 15 amperes, the machine gives 2,000 volts at its terminals with an exciting current of 9 amperes. Therefore the energy of the field is 900 watts, or 3 per cent. of the output. The framework is of substantial construction, and the machine when running is remarkably free from vibration. Its open design admits of the ready passage of air to the armature, which will carry over 20 amperes without overheating. Should access to the armature be necessary, the field magnets can be racked aside in a short space of time. This provision has been found useful by the station attendant on at least one occasion.

The exciting dynamo is a small 1-kilowatt machine of the Gramme type, giving 10 amperes at 100 volts. The strength of the exciting current is varied for regulation purposes by altering the resistance in the field-magnet circuit. A Cardew voltmeter shows the electro-motive force of the secondary circuit, and an Evershed ammeter the high-tension current. A voltmeter and ammeter, placed on the switch-board in circuit with the exciting machine, are useful for indicating whether its brushes are working properly or need adjustment. The voltmeter in circuit with this machine also serves the purpose of a speed-indicator for the turbine.

Two circuits leave the station, both of which are double-pole, fused, and provided with double-pole switches and lightning-arresters. The switch-board is in a glass case. A platform, on oil insulators, is arranged for the floor under the switch-board and alternator.

The Overhead Mains.

There are some special features in the method of carrying out this part of the work, to which the Authors desire to invite attention. When the station was planned, there was a good deal of uncertainty as to the amount of light which would be required in different localities; and the consumers being widely spread, it became necessary, both on this account and on account of the intention to place a portion of the mains underground when the supply became more certain, to run the overhead mains as economically as possible.

If wire of the highest insulation had been used, the expenditure would have been considerable, and it does not appear that any great advantage, other than the increased durability of the mains, would have resulted. It was therefore determined to use a lower insulation for the mains, to rely upon the points of support for insulation, and to use special arrangements for cutting off all surface leakage where the wires enter the consumer's premises. The Authors are not aware that attention has been paid to this point before; yet it would seem that in wet weather, upon a long line of overhead mains, however well insulated the wire may be, the surface leakage, when high-tension currents are employed, would be considerable; and if devices are not adopted for cutting this off where the wires enter buildings, leakage to earth must result, which may be a source of danger, as well as of loss.

The overhead mains at Keswick are being insulated from earth, and from each other, by oil throughout the system, Messrs. Johnson and Phillips's well-known oil insulators being used; and where the wires enter a building they are provided with surface-leakage arresters. These leading-in arrangements are illustrated by Plate 2, Fig. 7.

The leading-in wires, which are insulated with vulcanized india-rubber of the highest quality, are threaded through a shackle oil insulator, the wire being cemented in with Chatterton's compound. Such an arrangement should effectually cut off surface leakage from the mains. The leading-in wires enter the roof through a stone-ware pipe, provided with a covering-piece to keep out rain and cover a reservoir of oil in the mouth of the pipe. A preliminary test, made on a very wet night, gave about 1 megohm as the total insulation-resistance of the mains. This is equivalent to about 3 megohms to the mile; but it should be pointed out, in connection with this result, that when the test was made the line-work was not finished, and the leading-in arrangements were incomplete. The test was made with 100 volts.

The sizes of the mains are fixed for a current density of 500 amperes to the square inch. The fall of potential between the generating station and the town is only slightly above 1 per cent. at full load. The result, from using wires of ample size, is that

TABLE.

Number of Experiment.	Revolutions of Turbine per Minute.	Head of Water, feet.	Height over Weir = h.	Cubic feet of Water Flowing per Second, $Q = L C \sqrt{2 g h^3}$.	Constant C.	HP. in Water.	Alternator.		Exciter.		Total Electrical HP.	Efficiency per cent.
							Volts (Secondary Circuit).	Amperes.	Volts.	Amperes.		
1	250	19·780	1·0500	23·480	0·4180	52·76	96·5	14·65	114	8·30	39·600	75·00
2	255	19·820	1·0330	22·920	0·4180	51·60	100·0	13·90	118	8·50	38·650	75·00
3	249	19·710	1·0420	23·180	0·4180	51·80	92·0	15·00	112	8·37	38·255	73·85
4	250	19·520	0·9370	19·750	0·4177	43·80	100·0	10·60	114	8·50	29·700	67·75
5	250	20·180	0·8630	17·400	0·4174	39·90	100·0	9·00	112	8·00	25·330	63·50
6	246	20·260	0·8200	16·135	0·4173	37·10	100·0	8·00	111	8·00	22·640	61·10
7	246	20·140	0·7785	14·830	0·4170	34·00	100·0	7·00	111	8·00	19·950	58·65
8	241	19·900	0·7625	14·460	0·4170	32·75	100·0	6·00	108	8·00	17·240	52·70
9	252	20·366	0·7165	13·150	0·4167	30·40	98·0	5·30	114	7·50	15·045	49·50
10	235	20·520	0·6460	11·290	0·4167	26·32	97·0	4·00	106	7·75	11·540	43·80
11	242	20·750	0·5830	9·680	0·4170	22·82	99·0	2·85	106	7·65	8·646	37·90

between the hours of 5 P.M. and 12 P.M. On account of the majority of the lamps being in hotels, it is probable that the maximum load will not be reached until the summer.

In connection with the arrangement of this central-station scheme, the Authors had occasion to make a comparison between the illuminating power of the glow-lamp and gas; the results showed that the relative values usually given are misleading, as they almost invariably deal with a standard London argand, a burner seldom used for ordinary lighting. This burner is generally taken as giving from 15 to 16-candle-power for 5 cubic feet of gas consumed per hour; whereas, out of a large number of ordinary burners taken hap-hazard, and tested where they were in use in Chester, Manchester, and Keswick at various times, it was found that the light given by 5 cubic feet of gas per hour was more frequently equal to 8 candles, or less. On the other hand, a number of Edison-Swan 16-candle-power lamps of various ages, from new lamps to those having been in use about fifteen hundred hours, were tested, and it was found that the difference between the new and the old lamps was in each case very slight. This would show that, in practice, one 16-candle-power glow-lamp gives approximately the same degree of light as two ordinary burners, each consuming 5 cubic feet of gas per hour.

This conclusion seems to be borne out by the result obtained by Dr. Hopkinson, who, experimenting upon some ordinary burners, found the average candle-power to be 1·76 per cubic foot of gas. As regards glow-lamps, Sir David Salomons found that 100 volt 16-candle-power Edison-Swan lamps average 17-candle-power at 100 volts.

The light has been received with great favour at Keswick, and already the demand is equal to the supply of the present plant. Supply was commenced at the beginning of the year, and the station has run without any hitch up to the present time; a man and a boy are sufficient for attending to the machinery.

The current is charged for by contract in most cases; but in a few instances meters are being fitted. A trial is being given to the new Ferranti-Borel-Wright alternating-current meter. These meters read direct, are compact, and comparatively cheap; if in practice they are found reliable, they should supply a much-felt want.

In conclusion, the Authors wish to express their thanks to Mr. Gisbert Kapp, Assoc. M. Inst. C.E., who has kindly placed at their disposal, for the purposes of this Paper, the particulars of

Mr. Kapp. two coils of insulated wire, served to transmit the electrical energy from one circuit to the other without there being anywhere contact between the coils. At the same time there might be a transformation in the form in which the energy was supplied to, and obtained from, the apparatus. If the coil receiving energy from the dynamo machine consisted of a few turns of thick wire, and the coil giving off energy to the lighting circuit of many turns of fine wire, energy supplied in the form of large currents flowing under small electric pressure would be transformed and given off in the form of small currents under high pressure; and conversely, if the receiving or primary coil consisted of many turns of fine wire, and the secondary coil of a few turns of thick wire, then energy supplied to the former in the form of small high-pressure currents would be given off by the secondary coil in the form of large currents flowing under small electric pressure. The energy was, so to speak, transformed by passing through the apparatus, and hence the name. The object of the transformer was to combine the safety and convenience of a low-pressure house-supply with the economy of a high-pressure long distance distribution. The type of transformer exhibited was not the only one used in electric lighting. In that type it was necessary to have an alternating current—a current which would make and unmake a magnet. In other types a continuous current was used; but in those cases there must be motion. If a current was sent through an ordinary dynamo machine it would revolve. If the same dynamo was coupled to another dynamo it would give motion to the second machine, and the second machine would give a current. It was feasible, and it had been recently done at the Chelsea Station, to have two dynamos for convenience placed together, with no belt between them, but on the same spindle; a high-tension current was sent through the motor part of the combination, and a low-tension current suitable for lighting incandescent lamps was obtained from the dynamo part of the combination. He would briefly describe the difference between the transformer exhibited and the previous pattern alluded to by Mr. Fawcus. Originally he made the transformer with the thin wire coil inside of the thick wire coil the whole length of the iron core. The iron core was in connection with the other pieces of iron which closed round the coils for the purpose of increasing the power of the apparatus. This arrangement, technically known under the term "closed magnetic circuit," was not absolutely necessary, but it was an advantage. Formerly—and many transformers were now so made—the thin wire coil was a long bobbin extending over the whole core, and on the top was wound a thick wire coil. He found this arrangement rather dangerous because there was a large surface of contact between the high-tension and the low-tension coil, and if the apparatus became hot there might be expansion, and the two wires might after a time get into contact. There would then be danger to persons touching the terminals. It was therefore necessary to separate the thin wire and the thick wire very thoroughly. It was astonishing that all who had made transformers had for so many years neglected to profit by the experience of the last generation. When the transformers were first introduced for the purpose of obtaining high-pressure currents by Ruhmkorff, Apps, and other electricians, the necessity of keeping the two coils as distinct as possible was recognized, and it could be seen in all the text-books how it was done. It was only within the last year or two that he personally had reverted to the construction which ought to have been adopted at first. When he first made the type mentioned he had three thin wire coils and two thick wire coils. A curious effect was produced which he had not foreseen, but which he might have foreseen by devoting a little thought to the subject. The ratio of transformation, that was, the ratio of the pressure between the primary and secondary currents, was approximately given by the ratio of the number of turns of the wires in the two sets of coils respectively. With a thousand turns in the thin-wire coil, and one hundred in the thick wire, there would be a ratio of transformation of 10 to 1; with 2,000 in the thick, and 100 in the thin, the ratio would be 20 to 1, but only if the transformer were working under a very light load or no load, there being a certain loss which increased with the current. In order to drive the current through the fine wire a certain pressure was required to overcome the electrical resistance of the wire; so that there was a loss of, say, 1 per cent. in the pressure of the primary current. The current in the thick wire before it could get out must overcome the electrical resistance of the thick wire, and thus another 1 per cent., and sometimes more, was lost. So that to obtain a transformer of the ratio of 20 to 1, which was the usual ratio, with a distribution of 2,000 volts from the central station, it might be expected at full load to get 98 volts out of the secondary; but curiously enough a great deal more was lost. There was an unexplained loss, or at any rate, a loss which had been until recently inexplicable to him. He had got the transformation ratio, 20 to 1, with a light load, but as soon as the load came on to the transformer, the secondary pressure fell sometimes as much Mr. Kapp.

Mr. Kapp. as 3 and 4 per cent. below what it ought to have been, after making full allowance for the resistance of the coils. That was a very inconvenient property of a transformer. In the Board of Trade regulations, it was obligatory to keep the pressure within 4 per cent., up or down, of a standard—what was called a declared standard pressure. There was already a loss of 1 per cent. in the mains, and 2 per cent. loss due to the copper resistance, or sometimes more; then there was the inexplicable loss, which brought the result dangerously near to the limit allowed by the Board of Trade. He need not say that if the pressures with glow-lamps were varied by 4 per cent. the light varied a great deal more than 4 per cent., possibly as much as 10 or 15 per cent. It was, therefore, important to avoid that loss as much as possible, and that was the reason why he had subdivided the transformer. It would be seen that there were eight coils instead of five as before. The reason for what he had called the inexplicable loss was, that the coils of thin and thick wire were coils acting in opposition. The thin-wire coils magnetized the core in one direction, and the thick-wire coils in the opposite direction; and consequently there was what was called magnetic leakage at the junctions between the coils, and the magnetism which leaked across had to be made by the thin wire, and it could not be utilized by the thick wire; that amount of magnetism, therefore, was lost. By subdividing the coils more, the magnetizing power of each coil was reduced to such a degree that the leakage became negligible; and in the new transformers the unexplained loss had been reduced to about ½ per cent. The Authors had mentioned in the Paper that the transformers could be loaded to 30 per cent. more than had been stated. That depended upon where the transformers were placed. If a transformer were placed in such a position that the heat could not get away it would get too hot, no matter how large it was made in the first instance; but if there was a reasonable amount of access of air to it, it was fairly easy to keep a transformer cool; in fact, the output of a transformer, as far as he had found, was not so much limited by its heating, as by its regulating power. It was inadmissible to have too great a difference between the lights when there were only a few burning, and when all were burning, and for that reason the loss of pressure in the transformer was the limit which should be kept in mind in designing it. In that connection he would suggest that makers of transformers should agree what loss of pressure they would allow. He had adopted the figure of 1¼ per cent. variation between the full load and the mean load, and 1¼ per cent. between no load and the mean load, as the minimum loss for reasonable loads, and $2\frac{3}{4}$ per cent. variation from the average as the maximum permissible loss for overloaded transformers. Mr. Kapp.

Mr. W. M. Mordey remarked that unfortunately there were not in this country many opportunities of applying water-power for electric lighting. The power available was generally very small, but no doubt where there was water-power in country places it would in a few years be utilized for electric lighting. The application was simple, and the working cost usually so small in comparison with other means of getting electric light that it was sure to come to the front. But it was a matter of surprise that so little had been done towards utilizing very small water powers for the lighting of country houses. He wished to draw the attention of those who were acquainted with such sources of power to the fact that a very small water-wheel and dynamo could safely be left to slowly charge an accumulator without more than one visit a day from an attendant, and that such an accumulator could be used for lighting in the evening. For instance, a stream capable of working a turbine at 2 HP. regularly all day and night, would in this way suffice for a house requiring fifty to sixty lamps for three or four hours daily. Simple automatic appliances were available for the control of a plant of this kind. There were one or two details in the Paper to which he should like to be allowed to refer. The stone-ware suspenders appeared to him to be a great improvement on the suspenders generally used—untanned leather, and so on, which were useless for insulating purposes. The Board of Trade now insisted that electric-lighting wires carried overhead should be borne by suspenders. He had known cases in which the suspenders were borne by the electric-light wires. He did not think that any description was given of the lightning-arrester used in connection with the switch. All electricians were interested in lightning-arresters, and he should be glad if some account could be given of the one mentioned. It was very difficult to get a good lightning-arrester to work in connection with high-tension currents. The difficulty was not usually with the lightning, at least in this country, but with the current of the dynamo, which leaped across the arc, following the lightning spark and, perhaps, short-circuiting the machine. That was a difficulty not experienced, he believed, in telegraph work, because in that case the electro-motive force of the battery was not sufficient to set up an arc, and its internal resistance was high enough to prevent the passage of dangerous currents. A safety fuse was shown by the Authors, but he thought it should rather be called an unsafety fuse. He had had a good Mr. Mord.

Mr. Mordey. deal of experience of high-tension safety fuses, and he would undertake to set a house on fire with the fuse on the table. It was very difficult to get a safety fuse of anything like reasonable size that would break a short-circuit across 2,000-volt mains without forming a dangerous arc. He had seen very bad arcs formed with every kind of fuse that he had been able to obtain—sometimes over 18 inches between the terminals—arcs that were alarming and dangerous. He might perhaps be allowed to describe a simple form of fuse that had been invented quite recently by one of his fellow-officials at the Brush Company, Mr. Watson, which, he thought, was absolutely safe. A glass tube, which might be only 2 inches long—though 5 inches was a better length—had an airtight brass cap at each end, and a copper wire was drawn through and soldered on the two ends. So far that was like many other fuses; and it required an addition before it could be relied upon to break the arc under all circumstances; Mr. Watson got over the difficulty by filling the tube about one-third full of water, which was practically a non-conductor. On the wire fusing, the water immediately quenched the arc. He had short-circuited dynamos giving 50 electrical HP. at 2,000 volts with a fuse of that sort, 2 inches long, without any difficulty. The fuse wire simply disappeared; a little steam was formed, but the strength of the tube was sufficient to prevent fracture.

He agreed with almost everything that Mr. Kapp said on electrical questions, but according to his own experience with transformers the heat did not depend much upon the load; often when the transformer was running with no load on the secondary the heat was almost as great as when the full load was on. The loss in the transformer was, or should be, practically independent of load, and that was due to the fact that the magnetization with no load was greater than with a full load, otherwise with a full load no current could be generated. It was a reduction of the electro-motive force due to the lowering of the magnetization of the iron that allowed the greater primary current to go through, and the greater secondary current to be generated. With the two currents flowing in a perfect transformer there were equal ampere turns in opposite directions almost at the same time, so that in such a case there would be only a small magnetization. This condition was, of course, not reached in practice, but the magnetization was considerably greater with the secondary open than with the secondary closed, and the result was that in one case the loss was mainly in the iron, and in the other case it was partly due to that cause and partly to the loss in the copper conductor itself.

With reference to the alternator of Mr. Kapp, as to which some figures were given, he wished to ask whether there was not a mistake. The diameter of the armature-core was said to be 44 inches. It was a core made of thin iron strips rolled up into a spiral, with paper or some insulating substance between them. It ran at 750 revolutions per minute, corresponding to a peripheral speed of 9,600 feet per minute. He wished to ask if that figure was right. A speed of 9,600 feet per minute for an armature of the Gramme type, overwound with insulated copper wire—an armature necessarily rather unmechanical in construction—was a very high speed indeed. Although the Brush Company had for many years been making dynamos of exactly the same general type, with flat disk Gramme armatures, it had never ventured to drive them at that speed. Alternators with iron cores were satisfactory from some points of view, but from the point of view of efficiency he did not think they were very satisfactory. He should like to have some information with regard to the power taken to drive the machine when no work was being done outside, when the full electro-motive force was being maintained but no current was going out. Drs. J. and E. Hopkinson in 1886,[1] and Professor Ewing[2] about the same time, determined the loss in iron with given densities of magnetization. Some time afterwards Mr. Mordey made some practical tests as to the HP. lost under the same conditions, and it was satisfactory to find that his workshop tests came out almost exactly in accordance with the results obtained in laboratory experiments by those gentlemen. The result he obtained was that with a magnetization of about 12,000 C. G. S. lines the loss from hysteresis per complete period was 9,600 ergs per cubic centimetre; that made the loss from magnetic friction alone about 1½ watt per cubic inch at 100 periods per second. Working out the data given with that alternator he found, on the assumption that Mr. Kapp was only working at half the magnetic density mentioned above, and also that the loss from hysteresis was half what it was at the higher density, then there must be 1½ HP. lost in magnetic friction alone, and in eddy currents there must be a loss which might be perhaps three times as much. He should be glad to know what was the loss with machines of that kind running on open circuit at full speed and full electro-motive force. Mr. Mord

[1] Phil. Trans. Royal Society of London, vol. clxxvii. (1886), p. 331.
[2] *Ibid.*, p. 361.

r. Mordey. An interesting comparison had been given between gas and electric light. He might mention as a thing easy to remember, a rule of Mr. Raworth's as to the comparative price of the two. He had found that electric light at 1*d*. per Board of Trade unit, was equal to gas at 1*s*. per 1,000 feet. It was arrived at in this way. Taking as standards a sixty-watt lamp, giving 16 candle-power for the electric light; and a 5-foot Argand burner giving 16 candle-power, then one electric unit, 1,000 watt-hours, gave 265 candle-hours, and one gas unit gave 3,200 candles. The ratio was 12 to 1. Most of those who used gas found that they only got about half the candles that an Argand burner gave, so that the figure was more favourable than 1*d*. for electric light to 1*s*. for gas. The Board of Trade limited the price to be charged for electricity to 8*d*. per unit; that, on the Argand basis, would be equal to gas at 8*s*. per 1,000. Now, if gas only gave ordinarily half this amount of light in practice, then the ratio was twice as favourable to electricity. Electricity at 8*d*., a very usual price, was equal to gas at 4*s*. per thousand feet. Thus electricity was getting very close indeed to gas.

He might be allowed briefly to describe the Lynton water-power installation. It differed from the Keswick installation in one particular. The turbine was run at a higher speed, and was coupled directly to the alternators, this being rendered possible by the large fall obtained. The installation was extremely simple, owing to the absence of belting, counter-shafts, and gearing. The credit of the installation was due to Mr. Geen, an engineer of Okehampton, who had found at Lynton, as many had found, a very interesting water-power in the River Lyn. He obtained rights from the riparian owners, and carried out the installation entirely at his own risk. The amount of water available was about 1,000 cubic feet per minute in the driest season, but was usually considerably more. The turbine was capable of working up to 200 HP., requiring about 1,500 cubic feet of water. At present it was driving electric generators having a maximum output of 100 electrical HP. An open leet 6 feet by 3 feet 6 inches, and about 1,650 feet of 30-inch iron pipe conveyed the water to the turbine at an available head of 95 feet. A good deal of blasting and excavating had to be done. Fig. 1, Plate 3, was a perspective view of the station. Fig. 2 showed the arrangement of the machinery in the station, one half in elevation, the other half in section. The only part not shown in Fig. 2 was the exciter which was driven by the pulley on the extreme right. This exciter, which was similar to that shown on the extreme left, and was seen in end elevation in Fig. 4, was omitted for the sake of clearness. Fig. 3 showed one of the alternators in end elevation, partly in section. Fig. 4 showed an end view of the turbine, of which Mr. Hett, of Brigg, was the maker, and he had to thank him for a description of it. It was a double scroll turbine of the type that he believed the Americans called the "Little Giant." The shaft was horizontal. It had two disks 14 inches in diameter, made of a specially tough mixture of cast-iron, and cast in one piece. There was a division plate in the centre of the case, and one-half of the turbine might be run without admitting water to the other half. The discharge water flowed away down the bends, to which were attached some 7 feet of draft pipe dipping into the tail water. To prevent air being drawn into the draft tubes through the stuffing-boxes, a water passage was provided at the top of the bend which admitted the head-water to a chamber behind the stuffing-box; any leakage at the stuffing-box would therefore be outwards. The regulating was done by a slide-valve worked by a hand-wheel, by means of which the quantity of water consumed might be adjusted to suit the requirements as to power. The turbine spindle was of steel, and ran in long cast-iron bearings provided with lubrication. The casing and discharge bends of the turbine were bolted to strong cast-iron bearers which rested on rolled joists. These also carried the alternators, which were coupled direct to the turbine shaft by means of couplings designed by Mr. Raworth, which combined the features of a Hook's joint and an Oldham coupling, and gave a sufficient amount of flexibility to allow slight differences of level between the coupled shafts. One side of the coupling was secured to the shaft by a frictional grip. The large pulley shown in section was put on to enable any tools or a third machine to be driven if necessary. The alternators were of his own design. The armatures were stationary. There was no iron in the armature cores. The revolving field-magnets were of cast-iron. The diameter was 2 feet 11 inches, speed, 650 revolutions per minute. The field exciting-current was led in through two collecting rings, from a small direct-current dynamo run by a belt at the extreme end of the shaft in each case. The exciters ran at the same speed as the alternators, and usually were driven direct; but in this case there was not room for such an arrangement. Each alternator was capable of running continuously at 37,500 watts (50 electrical HP.). The pressure was 2,000 volts; the excitation, 30 amperes and 15 volts on full load, or 1·2 per cent. of full output. There were eighteen armature coils in each armature; the resistance was 4·5 ohms. As illus-

Mr. Morde

Mr. Mordey. trating the smooth and silent working of the machinery, he might mention that the greatest noise in the station, when the plant was running at full speed, was made by the brushes of the little exciters on the commutators. A boy could turn the regulating wheel, control the station, and keep everything going without any trouble. The mains (primary) which distributed current in Lynmouth and Lynton were Callender's bitumen cables, lead-sheathed, laid underground, principally in grooved wood casing, with grooves well flooded with bitumen compound. Some parts, however, were laid direct in the ground, fine earth being sifted on before filling. Mr. Geen took great pains with the cables, and had experienced no trouble. The joints were boiled in pitch *in sitû*, and were then protected by soldering a lead sleeve over all.

Mr. Kapp. Mr. GISBERT KAPP said he had been asked a question as to the circumferential speed of the armature. The figure, as given in the Paper, 9,000 feet, was right. The armature was exceedingly strong; the coefficient of safety was about 10. He was not satisfied with the theoretical safety; but in some large machines of 200 HP. which had been built for him, he specified that, before the machines would be accepted, they must be tested at a circumferential speed of 16,000 feet per minute; and that had been done with perfect safety. He might mention that, in regard to hysteresis, magnetic friction, and windage (which was an important item), he had tested the machine described in the Paper, and Mr. Mordey would be pleased to hear that he had used one of his dynamos as the motor, and the power required varied from 1 to 1½ HP. That disposed of the objection to the use of iron in armatures.

Mr. Hedges. Mr. KILLINGWORTH HEDGES thought that the Paper did not go sufficiently into detail. The commercial element, for example, was entirely absent; it was important to know the cost of producing the light, and what was obtained by selling it. With regard to water-power, although more economical than steam, the difficulty was the first cost of applying it. Some details on that subject would be very interesting. Wherever he had gone into the application of water-power, he had found that the first cost counterbalanced the subsequent gain, as it was always necessary to have a steam-engine in reserve in the summer. Lynton station would probably be an exception. It was stated that a light insulation was used at Keswick. He supposed that the Board of Trade had not been there, because it condemned a light insulation and insisted on a heavy one, which was a rather important factor as regards cost when overhead mains were used. The surface leakage was another point referred to by the Authors.

Mr. Hedge

He had never heard of its being a great detriment, and he could not see the good of all the ingenious devices described. There were many systems of overhead mains working in England and on the Continent, but he was not aware that any preventive devices were used. Messrs. Lowrie and Hall, the engineers of the House to House Company, used the surface leakage to find out whether the mains were in good condition or not by the statical charge which passed through a vacuum tube. One end of the tube was connected with the outside of the cable, and the other connection to earth was made through the operator. If the cable was in order there would be surface leakage, and the leakage would be carried to the operator and would cause a glow in the tube, but if there was a fault in the cable there would be no glow. The method was found to work efficiently, and there was no necessity to insulate in the manner described by the Authors so as to stop the leakage which would not pass the transformer. The Board of Trade insisted on a transformer being placed where it could not be inadvertently touched, and he thought that that was sufficient reason why electricians should not be hampered in their already complicated details of electrical construction by any device that they could possibly do without. With regard to the question of cut-outs, he did not quite understand whether the Authors meant double cut-outs on one frame, or single cut-outs alongside one another. If they were too close together he thought that they were objectionable, and the sooner the so-called double pole cut-outs were done away with the better. He had recently had an unpleasant reminder by touching one of these, and found a severe shock could be obtained from the leakage current which passed across the china insulator. The Authors stated that they had tested cables at 100 volts. That was a most important matter, and the sooner engineers saw that the only way to test an installation in a house was by the working-pressure, the sooner they would find no break-downs. Very often in testing an installation with the working-pressure a fault was found, which a small battery with a delicate instrument failed to discover. He congratulated the Authors on using the high-tension system. Many discussions had taken place on the subject, but he was convinced that the only way of serving a scattered neighbourhood like that described was by means of high-tension currents. If there was a break-down or any disaster, it would probably be due to the neglect of details and not to the use of the high-tension current. When those details were worked out it would be as easy to utilize the high-tension as the low-tension current. The fuse

Mr. Hedges. described was an ingenious one. He had also designed a fuse for use with high-tension currents which immediately extinguished an arc. In that described by Mr. Mordey, he would like to ask what happened if gas was formed when the fuse melted. He tried a fuse of this description with a continuous current, and the tube was shattered and the water was decomposed directly an arc started.

Mr. Segundo. Mr. EDWARD C. DE SEGUNDO said it was acknowledged that, owing to the uncertainty of the water-supply, a stand-by steam-engine was necessary. But in estimating the cost per HP. per hour, the interest on the cost of the stand-by engine and boiler had not been considered. Taking the interest at 5 per cent. as about £25 per annum on this outlay, it worked out to about 0·06*d.* per HP. per hour, making a total of 0·12*d.* per HP. per hour. The estimation of the cost by steam-power alone was also incomplete. An amount of 6 lbs. of coal per HP. per hour was far in excess of the performance of even a phenomenally uneconomical electric-light engine. For a 50-HP. engine of the Westinghouse type 3½ lbs. was an ample allowance, and on this basis the coal consumption at 15*s.* per ton would come to 0·28*d.* per HP. per hour. Hence the ratio $\frac{\text{cost of steam-power}}{\text{cost of water-power}}$ was about 2·3, and not 8 as suggested by the Authors. In regard to the question of overhead mains, he thought that members not conversant with electrical matters might be misled by some of the statements in the Paper. The Authors considered that if "wire of the highest insulation had been used, the expenditure would have been considerable, and it does not appear that any great advantage, other than increased durability of the mains would have resulted." Now increased durability of the mains was so important a matter, and under usual circumstances so desirable an object, that it would be expected that the difference in price of highly insulated wire and wire of inferior insulation must be very great indeed to have induced the Authors to adopt the inferior quality for so small a net-work of mains. It would therefore be of interest to compare the prices of some cables of high and low insulation resistance. Judging by the size of the plant put down, one thousand 8-candle-power lamps could be supplied simultaneously at full load. This would mean about 18 amperes in the primaries, and, as there were two sets of mains, about 9 amperes in each. At 500 amperes per square inch a conductor of 0·18 square inch sectional area would be required. It might therefore be assumed that the mains were each composed of seven strands of No. 16 wire. The price of this cable of a quality offering an insulation resistance of 5,000 megohms per mile was £91 5s. per statute mile. For a cable of 600 megohms per mile the price was £78 5s. The first cable was 730 per cent. better in point of insulation than the second, and only about 16 per cent. dearer. The total actual saving in using wire of the latter class (and it was not likely that wire less heavily insulated was used), instead of wire of the first-named quality, would be £39 for the 3 miles of cable. Now, even if the Keswick Electric Light Company contemplated an indefinite extension of the system in the near future, it would hardly be wise to economize in this direction; but when the greatest capacity of the station hoped for by the Authors was only about three thousand 8-candle-power lamps, the reason for drawing attention to economy effected in this way was difficult to understand. Another matter which should not pass unnoticed was the way in which the mains were tested. It was stated that the mains, which were to carry electricity at 2,000 units of pressure, were tested at 100 units of pressure. Such a method of testing, though in general use among electricians, needed no comment in the presence of engineers. In regard to the abnormally high efficiencies, another column, giving the brake HP. of the turbine under various conditions, would have added to the interest of the Table, and would have afforded a rough means of checking the formula from which the values in column V were derived. He agreed with the Authors in their mode of estimating the comparative of gas and electric light. In the course of his connection with London Electric Supply Companies, he had always taken an 8-candle-power lamp to give an equivalent in light to an ordinary 5-feet gas burner. He congratulated the Authors upon having produced a Paper on an interesting subject, but he should have been glad had they entered more into commercial details. At present the cost and the efficiency could only be roughly conjectured. Mr. Segundo.

Mr. Ll. B. Atkinson congratulated the Authors on the simple and effective methods adopted for utilizing the water-power of the River Greta for the electric lighting of Keswick. Several points in the Paper were somewhat open to criticism. The chief point in dealing with electric-lighting machinery driven by water-power was to secure a regular speed when running at various loads. This would appear to be best attained without the use of special hand or automatic regulation by the employment of the inward flow or vortex turbine, in which the varying centripetal action with variations of speed regulated the pressure on the blades. The efficiency, too, of such a turbine with varying loads was more Mr. Atkinson.

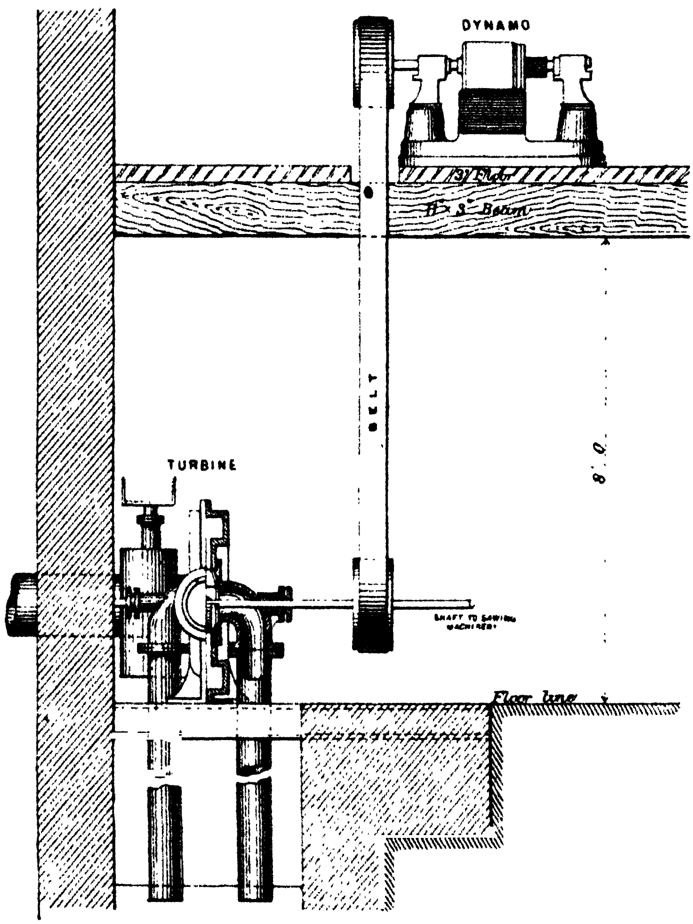
Mr. Atkinson. constant. The dynamo of the "Kapp" type embodied several improvements originally introduced into this form of machine by Messrs. W. T. Goolden and Co., who were the first makers of Kapp alternators. Important among these, from a practical point of view, was the arrangement of collecting rings, one on each side, carried on ebonite insulating pillars with steel or bronze centres, giving a very high insulation, whilst from their position it was physically impossible for the two collectors to be accidentally touched at one time. The tests of the turbine and electric generators were open to considerable criticism, both as to the results obtained and the methods of calculating them. In estimating the electrical output the energy expended in magnetizing the alternator was added to the electrical HP., whereas this of course was all wasted, and if this waste quantity was to be added, the waste in the alternator armature, and field, and armature of the exciter must be considered. Taking the first test on the list, the deduction on this account amounted to 3 per cent. of the assumed total, reducing the efficiency to 71 per cent. This was on the assumption that the actual power given out was measured by the product of $(20 \times 96 \cdot 5)$ volts multiplied by 14·65 amperes. This was only true if the current and electromotive force were in the same phase. But as these tests were made with the alternator supplying current to transformers, there would certainly be a difference of phase, though it was difficult to say how much from the data given in the Paper. As an example of an electric installation worked by water-power, he would mention one recently erected by the firm of W. T. Goolden and Co., on the estate of Mr. James Farrer, at Clapham, in Yorkshire. The water-power was obtained from a reservoir made by throwing a dam across a valley, and the supply was continuous all the year through. The turbine was a vortex-turbine made by Messrs. Gilkes and Co., of Kendal, and was supplied by a pipe; the effective head, including the fall through the draught-pipe, was, at full gate and full load, about 60 feet, the actual difference of level being about 68 feet. The turbine would develop 20 HP. at about 650 revolutions per minute, taking then about 240 cubic feet of water per minute, being an efficiency for the turbine of 73 per cent. The turbine had adjustable guide-blades, by which it was regulated, for working at present below its normal speed and power the self-regulation was not good, though very effective for charging secondary batteries, the tendency being for the speed to vary so as to maintain a constant current notwithstanding the variation in electromotive force as the charging proceeded. The line was an overhead line composed of bare copper

No. 6 wire B.W.G. on poles and porcelain insulators. There were on the line, including end shackles, sixteen points of support, and on a dry day the line tested as follows, measured with 100 volts:— Mr. Atkinson.

+ to −, over 10 megohms; + and − to earth, 3 megohms.

The pressure was regulated by accumulators at the end of the line

Fig. 1.



Goolden $\frac{O}{D}$ Dynamo coupled to Vortex Turbine.

Scale ¼ inch = 1 foot.

near to the point where the maximum current was taken off. At present about one hundred and fifty lights, some 8-candle, some 16-candle power were installed, provision being made for future extensions. The section, *Fig. 1*, showed the arrangement of dynamo and turbine. It would be noticed that the turbine discharged on each side, thus leaving the wheel perfectly balanced as regarded thrust on the bearings.

Mr. Pearsall. Mr. H. D. PEARSALL thought it strange that the Authors had neglected to consider the velocity of approach, particularly after they had measured it and found that it amounted to the considerable quantity of 1½ foot per second, which would make from 7 to 9 per cent. difference in the quantity of the water; 9 per cent. according to the coefficients obtained by Messrs. Fteley and Stearns, on whose experiments the Authors relied. He also thought that figures should be given showing the actual net efficiency at the town. The efficiency was given for the first transformation, but after that the power was transmitted and re-transformed. Very little information was given as to the loss at the transformers. The result did not appear to be very good. Making the deduction due to the velocity of approach, the maximum efficiency of the first transformation came to only 69 per cent. Running at half power it was something like 35 per cent.; so that with a variation of only one-half in the power, the mean efficiency would be only 50 per cent.; and if the range was taken still lower, it would be something less than 50 per cent. It was forty years since a Paper had been read before this Institution, giving an account of any kind of water-power machinery; and no Paper on the subject of water-power generally, and the best ways of utilizing it, had ever come before the Institution. This was a remarkable neglect of a very important branch of engineering, and he hoped that other Papers on the subject would be presented, say in the next session. Reference had been made to the number of water-powers unused. The United States was, he believed, the only country where statistics on the subjects had been published. The unused power was 200,000,000 HP. as against 1,500,000 at present in operation.

Mr. Preece. Mr. W. H. PREECE said that the relative cost of gas and electricity should be clearly understood. In 1883 Mr. A. G. Vernon Harcourt of Oxford, a great authority, and himself made a series of careful measurements for the City of London and the Post Office on the relative lighting of gas and electricity; and they found that a 5 feet burner, which was supposed to give a light of 15 candles, practically only gave a light of 10 candles. At that time, the efficiency of the glow-lamps being rather low, electricity at 6*d*. per unit was equivalent to gas at 4*s*. 6*d*. per 1,000 cubic feet. Within the last three months he had occasion, at Taunton, to go through the same measurements again, and it now appeared that the glow-lamps of the present day gave an efficiency considerably greater than they did eight years ago, the 6*d*. Board of Trade unit being equivalent to gas at 3*s*. per 1,000 cubic feet.

Mr. Bodmer. Mr. G. R. BODMER thought it was a pity that the Authors had not given more particulars as to water-measurements, the length of weir, the width of the approach, and the section of the weir crest. They had stated that their measurements and conditions were the same as those which existed when Messrs. Fteley and Stearns obtained their coefficients, which the Authors had used; but it would have made the Authors' experiments more valuable if those particulars had been given, as the members could then have formed a judgment for themselves as to the accuracy of the results. He did not think that the effect of the velocity of approach would be great. Some speakers appeared to imagine that it was proportional to the velocity, but of course that was not the case. The quantity of water passing over the weir was not increased in proportion to the velocity of approach, the influence of the latter, within certain limits, being partly included in the experimental coefficients. Seeing also that there was some controversy as to the total efficiency of the installation, it was a pity that the Authors had not measured the brake HP. of the turbine, which was an American one. Mr. Kapp had told him that the mechanical efficiency of the alternator was 90 per cent. At that rate the efficiency of the turbine would be about 83·3 per cent., which was of course very good, but not better than that of some European turbines. The Authors appeared to be surprised at being able to obtain so much power with so small a diameter of wheel; but there was no mystery about it. With a smaller diameter the depth must be greater in proportion, to get the same area of flow. Every one who had given attention to turbines must have noticed that in American turbine-wheels the depth (or width) of the orifices was very great in proportion to the diameter. Mr. Bodmer.

Mr. W. W. BEAUMONT said he observed that the brake HP. of the engine was 50, and the boiler placed in the station to drive it was 20 nominal HP., the heating-surface being 200 feet. It seemed, without further information, rather puzzling to know how a vertical boiler with 200 feet heating-surface could drive an engine of the kind of 50 brake HP. Perhaps the Authors could say at what pressure they had evaporated 11 lbs. of water per lb. of coal, and it might be useful to put the result of any experiments, and some further particulars of the boiler, in the Paper. Mr. Beaumont.

The AUTHORS, in reply, said they were glad Mr. Mordey had given a description of the Lynton Water-Power Station, where the limit of simplicity seemed to have been reached, as it formed an interesting example of the best method of applying water-power when the fall exceeded 50 feet. Mr. Mordey had regretted the scarcity of water-power in this country; but they had been The Authors.

The Authors. surprised to find how much was at present running to waste in places where it could be well applied to electric lighting. The lightning arrester in the main switch possessed no novel features, consisting only of an air gap between serrated discharge combs, one being connected to the cast-iron case which was earthed. There could be no danger of fire from the safety fuze exhibited; it had been repeatedly tested by themselves and the manufacturers, and the arc was immediately quenched, being chilled by the narrow-grooved slate base. Mr. Killingworth Hedges and others had expressed a wish that some commercial particulars should be given. The total capital employed in the undertaking was at present about £3,700. The total annual expenditure of the Company, including depreciations, rent, salaries, &c., would amount to about £360, and the income from the lamps installed was estimated at about £600—leaving a balance of £240, or nearly 6½ per cent. on the capital employed. It was, however, intended to double the out-put of the station at an additional cost of about £1,500, and it was estimated that the profit would then amount to over 13 per cent. on the total capital. Mr. Hedges considered that the surface leakage amounted to an inappreciable amount, yet telegraph engineers had found it necessary to make provisions against it. The leakage in wet weather along the soddened outer braiding of electric light cable would be, in their opinion, with 2,000 volts electromotive force, considerable, and well worth cutting off from the earth by means of some such contrivances as those described in the Paper. The leakage would take place before the transformer was reached. The cut-out for each pole was in a separate grooved base. Mr. E. C. de Segundo's calculation respecting the economy of the use of water-power would not apply to the conditions at Keswick, the boiler being in use for other purposes during the day; but if it had been idle, the cost would have come out 0·12*d.* not 0·16*d.* In the practical running of electric-light machinery at central stations, a consumption of 12 or 15 lbs. of coal per Board of Trade unit was not unusual. They were acquainted with a very large station which was burning 9 lbs. per indicated HP. per hour. Of course it was the variation in load which increased the consumption of fuel. Mr. Segundo had made a calculation as to the extra cost of using highest insulated Silvertown cable, and found that a saving of only £39 had been gained. The actual saving effected was £210. Explosions in joint-boxes were not unknown in England—a man-hole door had been destroyed from this cause near Albert Gate. Mr. Atkinson had criticised their method of measuring the electrical out-put;

but they had no means of measuring the electromotive force of the primary circuit directly. They had taken care to state exactly how the measurements were made, and left members to correct their results if they thought the method of making those measurements required it. They were inclined to think that the self-regulation of the "mixed-flow" turbine was as good as the "inward-flow" type; centrifugal action scarcely came into play. The test described was made with the turbine running light, without shafting, &c. In reply to Mr. Pearsall, the reason why they had not made any correction for the velocity of approach was made apparent by the disagreement between Mr. Bodmer and himself as to its influence on the result; they had left members to make the correction themselves. Mr. Pearsall seemed to think that a maximum efficiency of 69 per cent. was not good, but the Authors would have been satisfied with anything over 60 per cent. They quite agreed with Mr. Bodmer that a brake HP. test would have added to the interest of their experiments, but they had not time to make it. The length of the weir was 6 feet 6 inches, and the width of approach the same. The 20 nominal HP. Hyde duplex-boiler had been found to be quite equal to the supply of steam for a 50 indicated HP. engine with a good draught. The Autho.

Correspondence.

Mr. Bernard Drake furnished some particulars of the hydraulic plant at Cragside, where his firm had carried out a considerable amount of electrical work for Lord Armstrong, who was one of the first to use water-power for electric lighting, and had made a large number of experiments to arrive at the best practical results under all working conditions. It was only during the past year that Lord Armstrong considered a complete solution of the problem had been arrived at both mechanically and electrically. The final arrangement was briefly as followed:—The principal plant consisted of a turbine having a fall of 385 feet, the water being conveyed in a 7-inch pipe through a distance of 1,200 yards; the speed of the turbine was 1,300 revolutions per minute. The HP. obtained was 27, which was utilized for driving two dynamos coupled tandem on the same axis, much after the manner since adopted by the Brush Company. The distance from the house was about ½ mile; the current was conveyed partly overhead in the ordinary way and partly by bare copper conductors laid in a long wooden trough and carried by flat pottery supports, fixed in slots formed Mr. Drake.

Mr. Drake. in the inside of the trough. This arrangement, which had been in use several years, was found to answer every practical requirement as regarded insulation, and afforded a simple solution of the problem of carrying electric conductors up to a private house where the overhead wires would be unsightly. One of the dynamos was compound-wound, and was used for the direct supply of lamps in the building, which were all required to be used together, or, if necessary, the supply of water was reduced for the lighting of a fixed portion of these lamps. As switching off a portion of the lights would cause the remainder to be overworked unless the turbine were checked instantly, an electrical system had been worked out to control the turbine automatically. This was effected in the following manner:—The main ring contact switch placed in the house carried a small separate switch, so arranged that before the main circuit was altered, a current was passed through one or other of a pair of magnets fixed near the turbine. These magnets gave a pull of 30 lbs., which was used to open or close a cock leading to the main piston which opened or shut the blades of the turbine. A system of starting and stopping gear worked from the house had also been developed, and had never failed to act. It was merely necessary to touch a button, and the whole of the necessary movements were effected electrically, the main action being somewhat similar to the regulating gear above described. The second dynamo was used for charging the accumulators, which supplied the lights after the turbine had been stopped, and also such circuits as were required intermittently. A distributing switch-board afforded facilities for putting any circuit on to either source of supply as desired. Another smaller plant was chiefly used for the electrical transmission of power. The turbine in this case gave 10 HP. with a fall of 29 feet; the generating dynamo was driven by a belt, and the current was conveyed to the workshops, a distance of 750 yards, by bare overhead conductors. A continuation of this circuit had been made a further distance of 750 yards to the house, by means of which the current could be utilized for electric lighting in case of emergency. The electrical motor which received the current drove, by means of belting, a large circular saw, which was in constant and daily use for purposes of the estate, and a number of other tools and lathes. The motor was compound-wound in a special manner, which enabled the work to be removed suddenly without danger. The type of turbine used was that of Professor James Thomson, made by Gilkes and Co., in which the water was taken in at the circumference and discharged at the centre, the speed being controlled by the alteration of the angle of the guide-blades. Another of these turbines had recently been erected for the Duke of Northumberland in connection with the lighting of Alnwick Castle, where the fall was very low and the HP. over 30. He could not speak too highly of their working. Other water-power installations were in course of construction, and there was every sign of this branch of electric lighting increasing rapidly during the next few years. Mr. Drake.

Mr. C. L. HETT was afraid that the experiments given in the Table, p. 162, might lead to a very false impression as to the efficiency of turbines when working with a short supply of water. In these experiments, when the supply of water was reduced rather more than one-half, the efficiency was reduced nearly one-half, the power being reduced to about one-quarter of that obtained with the full supply. The greater portion of this loss of efficiency might be assumed to be in the turbine. The regulating-gate of the turbine was described as cylindrical. This was rather misleading; the gate was not cylindrical as in the old Fourneyron, but might be termed a cylindrical gridiron valve. This form was an old one which had been employed by many turbine builders in the United States, where it was known as an inside register gate. This gate never gave a good result when the supply of water was short. Its advantages were simplicity and easy working. The inside register gate was inferior to the cylindrical gate of Fourneyron, which was adapted to many types of mixed-flow turbines, and to the swinging-gates of Professor James Thomson's vortex wheel, and its modification called the Leffel wheel. A 21-inch turbine with a sliding-gate would have run only 10 per cent. faster than the turbine employed. Had the use of any particular turbine enabled the Authors to drive their alternators direct there would have been a good reason for selecting a turbine the efficiency of which with short water was its weakest part. In the case of Keswick belt-driving was employed; hence it was rather difficult to understand the selection of this turbine. Mr. Hett.

Mr. REGINALD J. JONES stated that in 1885 Messrs. Woodhouse and Rawson installed a turbine plant for the purpose of driving the dynamo supplying the electric light at Arborfield Hall, near Reading (Plate 3, Figs. 5, 6, and 7). This was a 44-inch "Trent" turbine, made by Mr. C. L. Hett, of Brigg, Yorkshire. The head of water was only about 4 feet, and was taken from a stream running through the grounds. There was the usual large sluice, the admission of water through which was regulated at the first start by winding up by hand. A supplementary regulator, which worked on the guide-vanes of the turbine, was controlled by a Porte-Manville Mr. Jones.

Mr. Jones. electrical governor which acted thus:—A wheel had two sets of ratchet-teeth cut in it in opposite directions. An oscillating arm, by means of an eccentric driven off the first-motion shaft, gave a reciprocating action to the two pawls, which were capable of being drawn down by electro-magnets underneath them. The pawl on the one side, when pulled down, tended to turn the wheel in one direction, and when the other pawl was put in connection, the wheel was turned in the opposite direction, causing the guide-vanes to open and close, thereby reducing or increasing the amount of water admitted to the turbine, so that variation of speed was obtained. These pawl magnets were controlled from the house electrically. The machine used was an ordinary shunt-dynamo, and the mains were connected to a relay, situated as near as possible to the centre of the points of distribution. This relay consisted of a long hollow magnet placed horizontally, inside which was a balanced armature in the form of a lever pivoted in the centre. One end of the armature carried an adjustable weight, and on the other were two platinum contacts for making the circuit through two stops, connected respectively with the opening and shutting magnets which controlled the pawls. When the electromotive force of the circuit was normal, the armature or tongue rested in mid air between two stops, and the reciprocating arm with the two pawls simply oscillated without making any movement on the wheel which governed the opening and shutting of the guide-vanes; but if the electromotive force fell, the armature fell on the bottom stop and put the pawl in circuit, which tended to open the guide-vanes, so as to give a greater supply of water. On the electromotive force rising the opposite action took place, the armature or tongue coming in contact with the top stop. This plant had been working for nearly five years; the governing had given the greatest satisfaction, and there had been practically no repairs to the water-wheel and the electrical plant. In order to stop the turbine, a two-way switch had been provided in the house to put in circuit the closing-pawl of the electrical regulator, and shut the vanes until the turbine stopped, thereby saving the trouble of keeping a man to watch the machinery during all the hours that the lighting was required. It might be pointed out to those who had a water-supply, that with a governor of this description, the necessity of accumulators was to some extent done away with, and consequently the cost of the installation was greatly reduced.

Sir David Salomons. Sir DAVID SALOMONS observed that, his name having been mentioned in connection with the light given by the Edison-

Swan glow-lamps, it might prove of interest to give the results which he had found from practical tests and experience. The tests had been made both with direct and alternating currents, the normal pressure being 100 volts, and, facilities existing for varying the voltage above and below the normal. Dr. Hopkinson might be right in finding that an 8-candle-power lamp produced about the same light as a good gas-burner intended to pass 5 cubic feet per hour, the gas being at such a pressure as to enable this quantity to be consumed in the given time. From this statement, it might well be imagined that an 8-candle-power lamp should, with equal effect, replace a gas-burner in a dwelling-house; but the inference was not true. A little practical experience with domestics would convince anybody, in the face of the most severe scientific investigation. The reason was, that the nature of the light was different. A clear globe lamp did not diffuse the light, whereas an obscured one did. Consequently, although the obscuring involved a loss of light, yet in practice a better illumination was produced for daily requirements. The illuminating surface was considerably enlarged, and the glare of the filament was removed. With these modifications the light more nearly resembled a gas-flame. At the same time, whatever might be said to the contrary, it was impossible to see at night-time, with equal effect, unless obscured 16 candle-power lamps replace a 5 cubic feet gas-burner. It was for this reason he started the simple method of comparing the price of gas with that of electricity, namely, by multiplying the cost of the electrical energy per unit by ten, and considering the result as the equivalent of gas per 1,000 cubic feet. The economy of working lamps above and below normal pressure he found to be equal under the following conditions:—(1) When employing an electromotive force 1 per cent. below the normal, whereby less light was obtained, but the life of the lamp was greatly increased; and (2) When working at an electromotive force 2 per cent. above normal, thus greatly increasing the brilliancy of the light, but shortening the lamp-life. He had found that the alternating current blackened the globes far more than the direct, also that the direct current was much in favour of increased lamp-life. From a series of tests made with a direct current upon a number of 100 volt 16-candle-power lamps, the average of the light given for different electromotive forces was, in round numbers, as followed:—For 102 volts the candle-power was 19; 101 volts, 18; 100 volts, 16½ to 17; 99 volts, 13½; 97 volts, 12; 93 volts, 8. Obscured lamps gave a loss of light varying from 16 to 17 per cent.; but the diffusion was far more than

Sir David Salomons.

Sir David Salomons. correspondingly increased. These tests were upon lamps of recent make. Those manufactured two years ago gave nearly 10 per cent. more light, when rendered incandescent at the voltage for which they were made; and, as far as he had been able to judge, their life duration was as good as those of more recent manufacture. The practical bearing of this observation was that the more recent lamps had a lower efficiency than the earlier ones, with no apparent compensating advantages.

Mr. Snell. Mr. ALBION T. SNELL had recently erected several overhead lines for transmitting electricity for power purposes. The tensions used varied from 200 to 750 volts. The cables were practically bare, being only covered by a braiding of hemp soaked in ozokerite, and then coated with wood-tar. For insulation he depended entirely on "fluid insulators" made by Messrs. Johnson and Philipps. For leading in and out of dynamo and motor houses, special precautions were taken to avoid damp. A vulcanized rubber insulated cable was jointed on near the outside of the buildings, and then carried on insulators to the insides, where it was protected by wood casing. The cables were protected from lightning by comb-dischargers at each end and near the middle of the line. In addition to this, a No. 12 B.W.G. galvanized-iron wire was run about 1 foot above the two copper cables. This iron wire was carried on insulators when the posts were of wood, but with iron posts it might be run on the top direct. It was attached at each end, and at suitable intermediate places, if necessary, to copper plates surrounded by coke in damp soil, and had also a few copper discharging-rods attached to it at some of the post-tops. During last summer a severe thunderstorm took place in a district in which he had erected a copper cable about 2·5 miles long. It was protected substantially, as described above. The workmen stated that the lightning visibly played along the wires again and again; but no damage was done to the dynamo, motor, line or instruments. The lightning arresters and discharging-rods seemed to have been perfectly successful.

The Authors. The AUTHORS, in reply, thought that the regulation effected in Lord Armstrong's installation, which only regulated for a definite number of lights switched off or on at once, could not find any general application. The method of regulation described by Mr. Jones, though somewhat complicated, apparently fulfilled its purpose. Mr. Jones did not say within what percentage it controlled the electromotive force. Mr. Hett had arrived at the conclusion that the greater part of the loss of efficiency at half-load was due to the inefficiency of the turbine. This was not so; it was to be accounted for chiefly by the mechanical, exciting, and other electrical losses being nearly the same at light load as at full load; no doubt there was an appreciable loss due to the regulating gate, but they thought that Mr. Hett rather over-estimated the advantages of the other methods of regulation he had mentioned. At the same time, high efficiency was wanted at full load, and it did not much matter what it was at light load. Sir David Salomons had called attention to an interesting point in artificial illumination; but their experience differed from his; they found an equal inconvenience in working with a naked flame as with a clear-globe glow-lamp, which was due to a want of light in the shadows, and too sharp a gradation from light to shadow. Both the flame and the incandescent filament needed a frosted globe, or its equivalent, to diffuse the light, and this was especially the case in rooms with dark-coloured surroundings. They would like to know whether the electromotive force was equally steady in the case of the alternating and direct current in Sir David Salomon's experiments on the blackening of globes and the life of lamps before accepting his results as proving what he contended. They were glad Mr. Snell had found that reliance for insulation upon the points of support of the wires was quite satisfactory. They thought that in every case the points of support deserved special attention in the insulating a line, on account of the durability of an oil insulation as compared with the insulating covering of the wire. The Authors

27 May, 1890.

This being the Tuesday in Whitsun week, there was no meeting.

ANNUAL GENERAL MEETING.

3 June, 1890.

SIR JOHN COODE, K.C.M.G., President, in the Chair.

The Notice convening the Meeting was read, and the Minutes of the Annual General Meeting of the 28th of May, 1889, having been read and confirmed,

It was moved, seconded, and resolved,—That Messrs. W. Fox, A. C. Hurtzig, Wm. Matthews, Charles S. T. Molecey, R. Jno. G. Read, Ed. C. de Segundo, Wilfrid Stokes, Alfred W. Szlumper, J. M. Wood, and L. S. Zachariasen, be requested to act as Scrutineers for the election of a President, of four Vice-Presidents, and of fifteen Other Members of Council for the ensuing year; and that, in order to facilitate their labours, the Balloting-papers be removed for examination at intervals during the period of balloting.

The Ballot having been declared open, the Secretary read the Report of the Council upon the Proceedings of the Institution during the Session 1889–90 (p. 200), the Statement of Accounts being taken as read. After discussion it was

Resolved,—That the Report of the Council be received and approved, and that it be printed in the "Minutes of Proceedings."

Resolved,—That the members present desire to express indebtedness to the Vice-Presidents and to the other Members of Council for the manner in which they have advanced the interests of the Institution.

Mr. Berkley, the senior Vice-President, replied on behalf of himself and his colleagues.

Resolved unanimously,—That the hearty thanks of the members be tendered to Sir John Coode, K.C.M.G., the President, for the very efficient way in which he has conducted the duties of his office.

Sir John Coode thanked the members for the Resolution which had been so cordially received.

The Ballot was then declared to be closed, having been open more than one hour.

Resolved,—That the thanks of the Institution be presented to

Messrs. Alex. McKerrow and Robert White, the Auditors, for the Statement of Accounts which they had submitted; and that Messrs. Robert White and Wm. Matthews (of London) be requested to act as Auditors for the ensuing year.

Resolved,—That the thanks of the Institution be given to Dr. Pole, Honorary Secretary, to Mr. Forrest, the Secretary, and to the members of the staff, for the very satisfactory performance of their duties during the past year.

Dr. Pole and Mr. Forrest returned thanks.

The Scrutineers then announced that the following gentlemen had been duly elected:

Sir JOHN COODE, K.C.M.G.

Vice-Presidents.

George Berkley.
Harrison Hayter.
Alfred Giles, M.P.
Sir Robert Rawlinson, K.C.B.

r *Members of Council.*

William Anderson (of Erith), D.C.L.
Sir Benjamin Baker, K.C.M.G., LL.D., F.R.S.
John Wolfe Barry.
Edward Alfred Cowper.
Sir James Nicholas Douglass, F.R.S.
Sir Douglas Fox.
J. Clarke Hawkshaw, M.A.
Charles Hawksley.
Sir Bradford Leslie, K.C.I.E.
George Fosbery Lyster.
James Mansergh.
William Henry Preece, F.R.S.
Sir Edward James Reed, K.C.B., F.R.S., M.P.
William Shelford.
Francis William Webb.

Resolved,—That the thanks of the meeting be given to the Scrutineers, and that the Ballot-Papers be destroyed.

REPORT OF THE COUNCIL, Session 1889–90.

This Meeting is held on the sixty-second anniversary of the Incorporation of the Institution by Royal Charter which was granted in the ninth year of the reign of King George IV. At that time the number of members was 156, and the gross receipts were £446 16*s.* 0*d.*; at the close of the past Financial Year, ended on the 31st of March, the number on the books was 5,872, and the gross receipts for the twelve months amounted to £22,477 14*s.* 7*d.*

This increase—thirty-seven-fold in numbers and fifty-fold in revenue—will sufficiently indicate the position which, in the course of these sixty-two years, the Institution has taken in connection with the profession it was designed to promote.

But it is well the Council should not only make the comparison with such small beginnings, so long ago, but also should enquire what has been done in recent years, in order to see whether that progress has been maintained at a date more nearly corresponding to the present time.

For this purpose, it may be convenient to take the last five years, this being the period during which the Revised By-laws have been in operation. In these statutes, it will be remembered, the change was made by which the Annual General Meeting is held at the close of the Session, in May or in June, instead of, as formerly, near the end of the Calendar Year.

The Abstract of Receipts and Expenditure presented in 1885 included only the four months ending on the 31st of March in that year, and therefore does not form a good basis for comparison; but in the following Session, 1885–86, the Council thought it advisable to provide a new standpoint by preparing, with some care, an historical notice of the Institution from its commencement, together with a full explanation of its objects and modes of working, and a complete account of its statistical and financial positions. The Notice was printed in vol. lxxxvi. of the Minutes of Proceedings, and will serve as a basis for comparison of the modern progress of the Institution, either now or at any future time.

The strict annual income then was £15,691 8*s.* 6*d.*, and in the last twelve months it has amounted to £17,677 13*s.* 10*d.*

The Capital Receipts (*i.e.*, admission-fees and life-compositions) then were £3,813 12*s.*, against £3,794 14*s.*, and at the former date the Trust-Funds produced £440 15*s.* 3*d.*, while last year the dividends thereon only amounted to £405 6*s.*, the diminution being due to the conversion of Government Stocks from Three-per-cent. to Two-and-three-quarters-per-cent.

The Summary of Investments at the two periods stands as follows:—Institution Investments four years ago £57,000, Trust-Funds £14,642 13*s.* 10*d.*, together £71,642 13*s.* 10*d.* At present the Institution Investments in Consols, Metropolitan Board of Works Stock, and Railway Debenture Stocks aggregate £43,500, the freeholds of the three contiguous houses in Great George Street £40,000, Whitworth Legacy £5,400, Trust-Funds £15,286 0*s.* 10*d.*, making a total of £104,186 0*s.* 10*d.*

Comparing the numerical statistics of the two periods, it is found that there were—

——	In 1885.	In 1890.	Increase.	Decrease.
Honorary Members . . .	20	19	..	1
Members	1,485	1,684	199	..
Associate Members . . .	1,932	2,768	836	..
Associates	507	432	..	75
Students	843	969	126	..
	4,787	5,872	1,161	76

representing an effective increase of 1,085.

This comparison shows that, during the period in question, the progress of the Institution has been well maintained.

It should always be borne in mind that a large rate of increase is by no means desirable. There is no object in limiting the numbers, as is the custom in some exclusive bodies; for the Institution always has opened—and it is to be hoped will always open—its doors to all professional men who have an honest title to be entered on its register; but it refrains from augmenting its numbers by the admission of persons who are merely attracted to it for their own advantage; and the Council, above all things, desires to make it understood that membership in the Institution is a real guarantee of the professional standing, and (as far as possible) also of the personal character, of those on whom it is conferred.

For this reason the Council desires to repeat the recommendation often made before, that every member will take care not to attach his signature to any proposition paper, unless he is fully satisfied as to the truth of the representations it contains, and as to the general eligibility of the candidate, both on professional and personal grounds.

The Institution is now so large and far-reaching, that it is often difficult for the Council, notwithstanding the utmost care, to exercise the close control it formerly did as to the selection of candidates; and as the ever-increasing magnitude of the Society demands the utmost caution as to its future management and welfare, the Council appeals with confidence to the general body to aid in this and in all other measures which may tend to ensure its continued good working and prosperity.

Work of the Session.

From the foregoing details as to the position of the Institution it may be well to turn to the way in which its scientific objects have been carried out. Constructive Engineering has occupied a large share of attention at the Ordinary Meetings, Papers having been read and discussed on "Dock Extensions at Liverpool," "Barry Dock Works," "Bars at the Mouths of Tidal Estuaries," "Water-Works in China and in Japan," "Railway Bridges involving Deep Foundations in India and in Australia," and "Lough Erne Drainage Works." Mechanical Engineering has been dealt with in Papers on "Water-Tube Steam-Boilers for Marine Engines," "Triple-Expansion Engines and Engine-Trials at Owens College, Manchester," and on "The Screw-Propeller"; while the Applications of Electricity have been treated in "Welding by Electricity," and "The Keswick Water-Power Electric-Light Station." It was hoped that during the past Session some branch of Metallurgy might have been brought forward, but in that hope the Council has been disappointed. It is, however, confidently believed that the omission will be made good next Session.

For two of the Papers above enumerated the Institution is indebted to Mr. Lyster, Member of Council, and to Sir Frederick Bramwell, Bart., Past President. In conformity with long-established usage these communications, emanating from Members of Council, were not taken into consideration in the adjudication of the Premiums.

Telford Medals and Telford Premiums have been awarded, for Papers read and discussed at the Meetings, to Messrs. John Robinson, C. O. Burge, and F. T. G. Walton; Telford Premiums to Messrs. S. W. Barnaby, W. H. Wheeler and James Price, jun., and the Manby Premium to Messrs. W. P. James Fawcus and E. W. Cowan.

For Papers printed in the Proceedings without being discussed Telford Premiums have been given to Messrs. C. Hopkinson, H. G. Sheppard and W. Airy.

Of the twelve Papers read and discussed at Supplemental Meetings of Students, one was contributed by a Student who had attained the age of twenty-five, and who was, therefore, according to previous ruling, ineligible to compete for a Miller Prize. For the remainder a Miller Scholarship has been awarded to Mr. C. F. Jenkin and Miller Prizes to Messrs. C. H. Wordingham, A. E. Young, L. A. Legros, F. P. Reynolds, J. Hale, and G. H. Sheffield.

It has been determined to print in the Proceedings, either in whole or in part, three of the Papers contributed by Students, viz., those by Messrs. Jenkin, Wordingham, and Young.

Associations of Students for holding meetings, for visits to works, and for promoting the growth of professional knowledge and acquaintanceship, are in existence, to the great benefit of all concerned, at Birmingham, Liverpool, Manchester, and Glasgow. They serve as centres of local activity, and indirectly as a bond of union between the Corporate Members residing in those towns.

The Roll of the Institution.

During the year ending the 31st of March, there were elected 3 Honorary Members (Sir Henry Bessemer, Sir William Thomson, and General Edward Frome, R.E.), 32 Members, 263 Associate Members, and 3 Associates, while the name of 1 Member was restored to the list. On the other hand 138 names have been removed from the Register, 87 of which were losses by death. Among the latter, the Council records with regret, the names of 3 Honorary Members, H.M. Dom Luis I., King of Portugal, Dr. John Percy, F.R.S., and General Edward Frome, R.E., who died shortly after his election. The Roll of the Institution therefore shows a net increase of 164, the number of members of all classes (irrespective of Students) on the 31st of March, 1889, and on the same date, in 1890, being 4,739 and 4,903 respectively. This represents an increase at the rate of about 3½ per cent.

per annum, or somewhat less than that of the previous twelve months.[1]

Admission of Students.

In the last Report of the Council, reference was made to the fact that more stringent regulations as to the admission of Students had as was foreseen, resulted in diminishing the numbers of that class. The total number of Students on the 31st of March, 1889, was 989; on the same date in this year it was 969, or 20 less. During the year 156 Students were admitted and 1 was restored to the list, while 73 were elected Associate Members and 104 ceased to be attached to the Institution. Since the last Annual Meeting the Regulations of the Council as to the admission of Students, and a list of the Public Examining Bodies whose certificates are accepted as evidence of proficiency, in the subjects of general education, have been printed and circulated to the members of all classes. The Council can only repeat its conviction that the imposition of a high standard of proficiency on candidates for admission into this class must be conducive to the future welfare of the profession and to the best interests of the Institution.

[1] The actual changes during the Sessions 1888–89 and 1889–90 are shown in the following Table:—

Changes from 1 April, 1888, to 31 March, 1890.

—	April 1, 1888, to March 31, 1889.					April 1, 1889, to March 31, 1890.				
	Honorary Members.	Members.	Associate Members.	Associates.	Totals.	Honorary Members.	Members.	Associate Members.	Associates.	Totals.
Numbers at commencement	20	1,617	2,458	461	4,556	19	1,657	2,613	450	4,739
Transferred to Members	..	..	45	..		..	..	46		
Do. to Associate Members	..	..	..	..		..	..	..	1	
Elections	1	42	245	12	300	3	32	263	3	302
Restored to Register	..	..	..	..		..	1	..	..	
Elected Honorary Members	..	..	..	..		..	2	..	1	
Associate elected Member	..	..	..	1		..	..	..	..	−138
Deaths	2	42	23	13	−117	3	44	26	14	
Resignations	..	2	12	7		..	2	17	4	
Erased	..	3	10	2	—— 183	..	4	20	1	—— 164
Numbers at termination	19	1,657	2,613	450	4,739	19	1,684	2,768	432	4,930

Publications.

Since the last Annual Meeting four volumes of Minutes of Proceedings have been issued. The Council trusts that the members will continue to contribute to this part of the work of the Institution, as being that which is of the greatest permanent importance.

In 1870 the Council issued a volume entitled "The Education and Status of Civil Engineers in the United Kingdom and in Foreign Countries," the first part of which contained information as to the Educational Institutions in Great Britain and Ireland where instruction was given bearing on the profession. During the time which has since elapsed, the number of these institutions has so much increased that it has been determined to issue shortly a pamphlet of about 60 pages, enumerating those public educational establishments in the British Dominions which include special preparation for the engineering profession. Prefixed to this pamphlet will be found the present Regulations as to the admission of Students.

Library and Reading Room.

The Council has to state that the additions to the Library number about eight hundred volumes annually. It is gratifying to find that it is largely attended, a sure proof that the efforts made to keep the collection abreast of Engineering progress are fairly successful. The Reading-room has always been highly appreciated. It is believed to contain every journal of repute relating to Engineering and Architecture, as well as the leading daily newspapers.

The Council regrets to announce the resignation, on account of ill-health, of Mr. Henry Storks Eaton, who has satisfactorily filled the office of Librarian for the last twenty-six years. The Council has appointed Mr. George J. Burch to succeed Mr. Eaton.

Dr. Percy's Treatise on Metallurgy.

The executors of the late Dr. Percy, F.R.S., Hon. M. Inst. C.E., having presented to the Institution the original manuscript of his "Treatise on Metallurgy," the Council has had the autograph MS. suitably bound and placed in the Library as an interesting record of this important work.

The Council takes this opportunity of stating that autograph reports of important engineering works by deceased members will be gladly received, as these would in time constitute a small library of special interest.

TREVITHICK MEMORIAL.

A communication was received from Lieut.-Col. Davis, the Honorary Secretary of the Trevithick Memorial Committee, thanking the Council for having taken such a warm interest in the labours of the Committee, and asking it to accept in trust, on behalf of the Institution, the balance of the Fund collected for the purposes of the memorial, viz., £100 0*s.* 9*d.*, the interest to be devoted to the presentation periodically of a premium to be called after Richard Trevithick. The Council gladly accepted this trust on behalf of itself and of its successors. It is a matter for congratulation that this action of the Committee affords an additional opportunity of perpetuating the memory of a great natural genius, and an eminent and skilful engineer.

WESTMINSTER (PARLIAMENT STREET, &C.) IMPROVEMENTS.

The powers of the Act, which received the Royal Assent on the 23rd of August, 1887, having been allowed to expire, a new Bill for the same object is now in Parliament, and has passed the House of Commons. One of the conditions, to be imposed upon the promoters, is to the effect that the Act shall lapse if the capital be not raised within six months after it has been obtained. The saving provisions of the Act of 1887, and the agreements then made, including the special clauses for the protection of the Institution,[1] remain in full force and effect.

INTERNATIONAL CONGRESS ON INLAND NAVIGATION.

The Fourth International Congress on Inland Navigation will be held in Manchester on the 28th of July and following days. The three previous Congresses were held respectively in Brussels, Vienna, and Frankfort-on-Maine. The object of these gatherings is the study of questions relating to Inland Navigable Waterways. The subjects to be discussed will comprise the present condition of some of the principal Inland Canals and Canalized Rivers in this country, including Ship Canals and the improvement of Tidal Rivers. It is intended to have an exhibition of plans, maps, and models relating to inland navigation. The Council ventures to express the hope that some of the members of the Institution will be ready to afford assistance to the Executive Committee in forwarding the objects, and in promoting the success, of the Congress.

VISIT OF AMERICAN ENGINEERS.

The visit of American Engineers to Europe, immediately after the close of the Session 1888–89, to which allusion was made in

[1] Minutes of Proceedings Inst. C.E., vol. xciv., p. 137.

the last Annual Report, afforded the members of the Institution an opportunity of welcoming their professional brethren from the other side of the Atlantic. The primary object of this visit was to attend the Paris Exhibition. On becoming aware of this intention, the Council sought to induce the visitors to make a short stay in this country before proceeding to the Continent. The party comprised members of the American Societies of Civil, Mining, Mechanical, and Electrical Engineers, and came over in two divisions, arriving in Liverpool within twenty-four hours of one another. There, on the 6th of June, the visitors were met by a deputation of the Council, and spent the succeeding week, it being the period of Whitsuntide, in visiting various places of historical interest. On the 13th the party was formally received at the house of the Institution by the President, Council, and members, when an Address of Welcome was presented, which was eloquently responded to by Professor Thurston—a name well-known to all engineers. On the evening of the same day the Reception Committee was, by the express sanction of the Lord Mayor, Aldermen, and Court of Common Council of the City of London, enabled to entertain the visitors at a Banquet in the Guildhall.

In gracious response to an application to the Queen, Her Majesty was pleased to direct that special facilities should be afforded for visits to Windsor Castle, including the private apartments; and to St. James's and Buckingham Palaces.

The Archbishop of Canterbury personally showed and explained the objects of interest at Lambeth Palace; while the Dean of Westminster delivered in the Abbey an Address on the Historical Associations of that building.

Among the purely social entertainments offered were a garden party by the Baroness Burdett-Coutts, a reception by Lord Brassey, K.C.B., Assoc. Inst. C.E., and a Dramatic Performance in the grounds of Copped Hall by invitation of Mr. S. B. Boulton, Assoc. Inst. C.E.: while those members who had facilities for doing so vied with one another in their efforts to afford the visitors amusement and recreation during the six days of their stay in London as an organized party. There were also visits to various engineering works and places of interest in and around London. Special trains were granted by the principal railway companies, and the entire party was escorted to Dover by a deputation of the Council, when leaving for Paris on the 20th of June. On the whole, the visit may be considered to have been a great success, and was one full of pleasant memories for the hosts.

Copies of various addresses relative to the occasion will be found in an Appendix to this Report.

[ABSTRACT OF RECEIPTS AND EXPENDITURE.

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS.

Dr.	£.	*s.*	*d.*	£.	*s.*	*d.*	£.	*s.*	*d.*
To Balance, March 31st, 1889, viz. :—									
On Deposit				3,000	0	0			
Cash in the hands of Treasurer				2,265	13	10			
„ „ Secretary				44	14	8			
							5,310	8	6
INCOME.									
— Subscriptions :—									
Arrears	460	15	6						
Current	13,560	18	0						
Advance	613	18	0						
				14,635	11	6			
— Library-Fund				134	13	6			
— Minutes of Proceedings:—Repayment for Binding, &c.				242	12	6			
— Miscellaneous				1	2	3			
— Dividends: 1 year on									
£ *Institution Dividends.*									
6,000 $2\frac{3}{4}\%$ Consols . . .	164	10	6						
6,000 Metropolitan Board of Works $3\frac{1}{2}\%$ Stock .	204	15	0						
3,000 Great Eastern Railway 4% Debenture Stock .	117	0	0						
3,000 Great Northern Ditto .	117	0	0						
3,000 Great Western Ditto .	117	0	0						
3,000 Lancs. and Yorks. Ditto	117	0	0						
8,000 London & N. W. Ditto .	312	0	0						
3,000 North Eastern Ditto .	117	0	0						
4,000 Midland Ry. 3% Ditto .	117	0	0						
NEW PURCHASES.									
3,000 Great Northern Railway 4% Debenture Stock .	0	0	0						
1,500 Great Western Ditto .	0	0	0						
				1,383	5	6			
£43,500 Total nominal or par value.									
— Ditto: 1 year on									
Whitworth Legacy.									
£1,400 5% Debenture Stock in Sir Joseph Whitworth & Co., Ltd.	68	5	0						
4,000 Four hundred £10 shares in Ditto	400	0	0						
				468	5	0			
£5,400									
— Rents				771	7	6			
— Interest on Deposit				40	16	1			
							17,677	13	10
CAPITAL.									
— Admission-Fees				3,062	17	0			
— Life-Compositions				731	17	0			
							3,794	14	0
Carried forward							£26,782	16	4

from the 1ST APRIL, 1889, *to the* 31ST MARCH, 1890.

EXPENDITURE.

Cr. GENERAL EXPENDITURE.

	£.	s.	d.	£.	s.	d.	£.	s.	d.
By House and Establishment Charges:—									
Repairs:— No. 24 Gt. George St.	18	11	2						
No. 25 Gt. George St.	319	0	7						
No. 26 Gt. George St.	138	19	9						
				476	11	6			
Rates and Taxes:—									
No. 24 Gt. George St.	263	7	1						
No. 25 Gt. George St.	393	19	7						
No. 26 Gt. George St.	166	2	1						
				823	8	9			
Insurance:—No. 24 Gt. George St.	10	10	3						
No. 25 Gt. George St.	36	9	3						
No. 26 Gt. George St.	5	1	6						
				52	1	0			
Rent of Telephone				23	13	0			
Fixtures and Furniture				232	9	6			
Lighting and Warming:—									
No. 24 Gt. George St.	10	16	6						
No. 25 Gt. George St.	145	0	7						
No. 26 Gt. George St.	18	0	6						
				173	17	7			
Refreshments at Meetings				59	10	5			
Assistance at Meetings				46	7	9			
Students' Meetings				47	15	3			
Household Expenses				217	8	2			
							2,153	2	11
— Postages, Telegrams, and Parcels				299	15	0			
— Stationery and Printing				667	16	2			
— Watt Medals				7	2	6			
— George Stephenson Medal				2	7	6			
— Diplomas				36	14	1			
— Annual Dinner (1889 and part 1890)				350	14	4			
							1,364	9	7
— Salaries				2,375	0	0			
— Clerks, Messengers, and Housekeeper				857	2	6			
— Donation to late Housekeeper				30	0	0			
— Donation to late Messenger				52	0	0			
							3,314	2	6
— Library:—Books				367	4	6			
Periodicals				62	1	5			
Binding				152	0	7			
							581	6	6
— Publications:—									
"Minutes of Proceedings," Vols. xcvi., xcvii., xcviii. and xcix.				6,573	13	3			
Charter, By-Laws, and Lists of Members . .				215	2	6			
							6,788	15	9
— Expenses, *Re* Corporation Duty							350	0	0
— Illuminated Addresses to American Engineering Societies . .							144	9	0
							£14,696	6	3

CAPITAL.

	£.	s.	d.	£.	s.	d.
— Purchase of £3,000 G. N. Ry. 4 % Debenture Stock	4,060	10	0			
— Ditto £1,500 G. W. Ry. Ditto	2,030	9	0			
£4,500 nominal or par value.				6,090	19	0
Carried forward . .				£20,787	5	3

ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS—*continued.*

Dr.

		£.	s.	d.
Brought forward		26,782	16	4

£. s. d.	*Telford Fund.*	£. s. d.	£. s. d.	£. s. d.
	To Dividends:—1 year on			
5,439 11 0	2¾% Consols (one quarter at 3%)	148 17 9		
3,299 2 0	Ditto (Unexpended Dividends) . . .	90 5 7		
£8,738 13 0			239 3 4	
	Manby Donation.			
£250 0 0	Great Eastern Ry. 4 % Debenture Stock		9 15 0	
	· *Fund.*			
3,125 0 0	2¾% Consols (one quarter at 3%) .			
2,004 17 5	Ditto (Unexpended Dividends). . . .			
£5,129 17 5			140 11 3	
	Howard Bequest.			
£551 14 6	2¾ % Consols (one quarter at 3%) .		15 2 8	
	Trevithick Memorial.			
£103 0 0	2¾ % Consols (three months) . . .		0 13 9	
				405 6 0
	— Crampton Bequest			500 0 0
	— Trevithick Memorial			100 0 9
				£27,788 3 1

CAPITAL RECEIPTS—EXTRAORDINARY.

	£. s. d.
To Balance from Yearly Receipts, viz.:—	55 10 0
— Rent of Stables in Tufton Street	64 10 0
	£120 0 0

:Y OF INVESTMENTS.

	£. s. d.	£. s. d.
INSTITUTION INVESTMENTS		43,500 0 0
FREEHOLDS OF NOS. 24, 25 & 26 GREAT GEORGE STREET.		40,000 0 0
WHITWORTH LEGACY;—400 SHARES OF £10, AND £1,400 5 % DEBENTURE STOCK IN THE FIRM OF SIR JOSEPH WHITWORTH AND CO., Ltd.		5,400 0 0
; INVESTMENTS:—		
Telford Fund	8,738 13 0	
Manby Donation	250 0 0	
Miller Fund	5,129 17 5	
Howard Bequest	551 14 6	
Crampton Bequest	512 15 11	
Trevithick Memorial	103 0 0	
		15,286 0 10
		£104,186 0 10

from the 1ST APRIL, 1889, *to the* 31ST MARCH, 1890.

EXPENDITURE—*continued.*

Cr.			£. s. d.
Brought forward			20,787 5 3
TRUST FUNDS.			
By Telford Premiums	268 16 1		
— Telford Medals	3 0 0		
— Purchase of £13 19s. 3d. 2¾% Consols	13 11 3		
— Ditto £8 9s. ditto	8 4 6		
		293 11 10	
— Miller Scholarships	80 0 0		
— Miller Prizes	70 9 9		
— Purchase of £5 2s. 10d. 2¾% Consols	5 0 0		
		155 9 9	
— Crampton Bequest—Purchase of £512 15s. 11d. 2¾% Consols		500 0 0	
— Trevithick Memorial—Purchase of £103 2¾% Consols		100 0 9	
			1,049 2 4
— Balance, March 31st, 1890:—			
On deposit		3,000 0 0	
Cash in the hands of the Treasurer		2,791 15 3	
" " Secretary		40 0 3	
			5,831 15 6
			27,668 3 1
— Transferred to Credit of Capital Expenditure—Extraordinary			120 0 0
			£27,788 3 1

CAPITAL EXPENDITURE—EXTRAORDINARY.

	£. s. d.
— Rent of Stables	120 0 0
	£120 0 0

Examined with the Books and found correct.

(Signed) A. McKERROW, ROBERT WHITE, } *Auditors.*

JAMES FORREST, *Secretary.*
5th *May*, 1890.

PREMIUMS AWARDED.

Session 1889–90.

The Council of The Institution of Civil Engineers has awarded the following Premiums:—

For Papers Read and Discussed at the Ordinary Meetings.

1. A Telford Medal and a Telford Premium to John Robinson, M. Inst. C.E., for his Paper on "The Barry Dock Works, including the Hydraulic Machinery and the Mode of Tipping Coal."
2. A Telford Medal and a Telford Premium to Charles Ormsby Burge, M. Inst. C.E., for his account of "The Hawkesbury Bridge, New South Wales."
3. A Telford Medal and a Telford Premium to Frederick Thomas Granville Walton, C.I.E., M. Inst. C.E., for his description of "The Construction of the Dufferin Bridge over the Ganges, at Benares."
4. A Telford Premium to Sydney Walker Barnaby,[1] M. Inst. C.E., for his Paper on "The Screw-Propeller."
5. A Telford Premium to William Henry Wheeler,[2] M. Inst. C.E., for his Paper on "Bars at the Mouths of Tidal Estuaries."
6. A Telford Premium to James Price, jun., B.E., M. Inst. C.E., for his account of "Lough Erne Drainage Works."
7. The Manby Premium to William Paul James Fawcus, and to Edward Woodrowe Cowan, Assoc. MM. Inst. C.E., for their joint Paper descriptive of "The Keswick Water-Power Electric-Light Station."

For Papers Printed in the Proceedings without being Discussed.

1. A Telford Premium to Charles Hopkinson, B.Sc., M. Inst. C.E., for his Paper on "Hydraulic Packing-Presses."
2. A Telford Premium to Herbert Gurney Sheppard, Assoc. M. Inst. C.E., for his Paper on "The Reclamation of Lake Aboukir, near Alexandria, Egypt."

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[1] Has previously received a Watt Medal and a Telford Premium.
[2] Has previously received Telford Premiums.

3. A Telford Premium to Wilfrid Airy, B.A.,[1] M. Inst. C.E., for his Papers, "On the Action of Quicksands," and on "The Probable Errors of Surveying by Vertical Angles."

For Papers read at the Supplemental Meetings of Students.

1. The Miller Scholarship to Charles Frewen Jenkin, B.A., Stud. Inst. C.E., for his Paper on "Some Applications of Electricity in Engineering Workshops."
2. A Miller Prize to Charles Henry Wordingham, A.K.C., Stud. Inst. C.E., for his Paper on "Telephonic Switching."
3. A Miller Prize to Alfred Ernest Young, Stud. Inst. C.E., for his account of "The Deflection of Spiral Springs."
4. A Miller Prize to Lucien Alphonse Legros, Stud. Inst. C.E., for his Paper on "Economy Trials of a Compound Mill-Engine and Lancashire Boilers."
5. A Miller Prize to Frank Paul Reynolds, A.K.C., Stud. Inst. C.E., for his description of the "Roof over the Carlisle Markets."
6. A Miller Prize to John Hale, Stud. Inst. C.E., for his description of the "Hydraulic Station and Machinery of the North London Railway at Poplar."
7. A Miller Prize to George Harrison Sheffield, Stud. Inst. C.E, for his Paper on the "Principles of Iron-foundry Practice."

*** It has been determined to print the first three Students' Papers, either in whole or in part, in the Minutes of Proceedings.

[1] Has already received Telford and Manby Premiums.

SUBJECTS FOR PAPERS.

SESSION 1890–91.

THE COUNCIL of The Institution of Civil Engineers invites Original Communications on the Subjects included in the following List, as well as on any other questions of professional interest. This list is to be taken merely as suggestive, and not in any sense as exhaustive. For approved Papers the Council has the power to award Premiums, arising out of Special Funds bequeathed for the purpose, the particulars of which are as under:—

1. The TELFORD FUND, left "in trust, the Interest to be expended in Annual Premiums, under the direction of the Council." This bequest (with accumulations of dividends) produces £260 annually.

2. The MANBY DONATION, of the value of about £10 a year, given "to form a Fund for an Annual Premium or Premiums for Papers read at the meetings."

3. The MILLER FUND, bequeathed by the testator "for the purpose of forming a Fund for providing Premiums or Prizes for the Students of the said Institution, upon the principle of the 'Telford Fund.'" This Fund (with accumulations of dividends) realises £150 per annum. Out of this Fund the Council has established a Scholarship,—called "The Miller Scholarship of The Institution of Civil Engineers,"—and is prepared to award one such Scholarship, not exceeding £40 in value, each year, and tenable for three years.

4. The HOWARD BEQUEST, directed by the testator to be applied "for the purpose of presenting periodically a Prize or Medal to the author of a treatise on any of the Uses or Properties of Iron or to the inventor of some new and valuable process relating thereto, such author or inventor being a Member, Graduate, or Associate of the said Institution." The annual income amounts to nearly £16. It has been arranged to award this prize every five years, commencing from 1877. The next award will therefore be made in 1892.

5. The CRAMPTON BEQUEST of £500, free of legacy duty, has been invested in the purchase of £512 15*s.* 11*d.* 2¾ per cent. consols, and the income arising therefrom is now £13 15*s.* This trust is for the purpose of founding "a Prize to be called the 'Crampton Prize,' so that the interest of the said legacy shall be annually expended in a medal or books, or otherwise . . . . for presentation to the Author of the best Paper on 'The Construction, Ventilation and Working of Tunnels of Considerable Length,' or, failing that, then on any other subject that may be selected."

6. The balance of the TREVITHICK MEMORIAL FUND, amounting to £100 0*s.* 9*d.*, has been accepted for a periodical Premium to be called after Richard Trevithick. This sum has been placed in £103 2¾ per cent. consols, upon which the interest is £2 15*s.* a year.

The Council will not make any award unless a communication of adequate merit is received, but will give more than one Premium if there are several deserving memoirs on the same subject. In the adjudication of the Premiums no distinction will be made between essays received from members of the Institution or strangers, whether Natives or Foreigners, except in the cases of the Miller and the Howard bequests, which are limited by the donors.

LIST.

1. The Effect of Internal Stresses in Materials on their Powers of Endurance.
2. The Influence of Wear and Oxidation on the Safety and Durability of Metallic Bridges; with estimates of the value, in these respects, of (*a*) increase in the weight of the structure, by the choice of other than the lightest design; (*b*) increase in the dead-load, by the adoption of a heavy description of flooring.
3. A scheme of Statistical Returns, in uniform headings of general application, on the Cost of Maintenance and Renewal of the Permanent-way of Railways, with examples of the mode of application.
4. The Design and Construction of Railway Passenger-carriages, having reference to (*a*) strength and safety; (*b*) ease and smoothness of motion; (*c*) durability; (*d*) moderate dead weight in proportion to the number carried; (*e*) facility for entrance and exit; (*f*) accommodation and comfort to

passengers of both sexes, particularly in long runs; (*g*) provisions for refreshments to avoid long stoppages; (*h*) sleeping arrangements.

5. The Lighting of Railway-carriages by Oil, Gas, and Electricity compared.
6. Electrical Traction for Roads and Railways.
7. The Design and Construction of Ship-Railways.
8. Description of any new or peculiar types or applications of Mountain Railways, for very steep gradients, or other local peculiarities.
9. The present condition, advantages, and prospects of development, of Inland Navigation at home and abroad.
10. The setting out, boring, and ventilation of long Tunnels through Rock.
11. Ship-Canals.
12. The laying out and equipment of River-Ports, such as Frankfort-on-Main, with reference to improved methods of transshipping merchandise.
13. The comparative Resistance of Ships of various size and form, and at varying speeds.
14. The Comparative Efficiency of different types of Marine Engines, or the final work done in propulsion, in proportion to the fuel consumed.
15. The most recent types of (*a*) Passenger and Mail-Steamers; (*b*) Cargo-steamers, and (*c*) War-ships.
16. The Relative Merits of Single and Twin Screws for Passenger-steamers, Cargo-boats and Battle-ships.
17. Mechanical Propulsion for Lifeboats.
18. The cleaning and deepening of Drainage- and Irrigation-Canals by mechanical means.
19. The Flow of Water, from land areas of differing character, during long-continued drought, and the Floods produced thereon by heavy falls of rain in short periods.
20. Subterranean Water in the Valley of the Thames, and its relation to the Supply of London.
21. Forms and Construction of Masonry-dams for Reservoirs.
22. Water Meters, and the Sale of Water by Measure.
23. The Manurial Value of Sewage-sludge, and the best mode of applying it to the land.
24. The effects produced by Mixing Crude Sewage with Sea, or brackish, water.
25. Means and Appliances, other than Sewers, for dealing with the Refuse of Towns.

26. The Design, and Construction of large Gas-holders.
27. Mechanical Stoking in Gas-Works.
28. The Design and Arrangement of Electric supply-stations, and of Electric Distributing-Apparatus, for domestic, trade and general service in towns, particularly as to economy and safety.
29. The Comparative Advantages of Gas and of Electricity for Lighting-purposes.
30. The Application of Electricity to Bleaching.
31. Appliances and buildings for Refrigerating-purposes.
32. Recent Researches into the Molecular Properties of Steel.
33. The Effect of Sea-water on Structures of Steel, both stationary and floating.
34. The production of Aluminium and its alloys, and their use for engineering purposes.
35. Gold-quartz Reduction and Amalgamation: description of the various machines, and of their method of working.
36. Electric Mining-Machinery for Pumping, Hauling, and Coal-Cutting in Mines and Collieries.
37. The application of Electricity to Smelting and Metallurgical Operations.
38. The Electro-deposition of Copper.
39. The laying out of Engineering Workshops.
40. The comparative merits of Triple- and Quadruple-Expansion engines.
41. Friction at different velocities, and the comparative value of different Lubricants.
42. The Utilization and Distribution of Water-Power.
43. Windmills for Raising Water and for general Power-Purposes.
44. The Design, Construction and Capacity of Blowing Fans, with experimental results.
45. Liquid-Fuel Motors, and their applications.
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Queen's College and University, Kingston, Canada.
Queen's College, Cork.
Queensland Branch of the Royal Geographical Society of Australasia.
Quinette de Rochemont, Baron E. T.

R.

Radcliffe Library, Oxford University Museum.
Raddi, A.
Raffard, N. J.
"Railroad and Engineering Journal."
"Railway Engineer, The."
"Railway Master Mechanic."
Reade, T. M.
Reale Accademia dei Lincei.
Reale Istituto Lombardo.
Rebolledo, J. A.
Regio Istituto Tecnico Superiore di Milano.
Rensselaer Society of Engineers.
Reuleaux, Prof. F.
"Revista de Engenharia."
"Revista de Obras Publicas," Lisbon.
"Revista de Obras Públicas," Madrid.
"Revista dos Constructores."
"Revue générale des Chemins de Fer."
"Revue Industrielle."
"Revue Universelle des Mines."
Richards, Admiral Sir G. H., K.C.B., F.R.S.
Richards, R. W.
Rinecker, F.
Robert, Lieut.-Col. H. M.
Roberts-Austen, W. C., F.R.S.
Robertson, F. E.
Robins, E.
Rotheram, T. F.
Rouse, H. J.
Rowe, J. A.
Royal Agricultural Society of England.

Royal College of Science for Ireland.
Royal Colonial Institute.
Royal Cornwall Polytechnic Society.
Royal Dublin Society.
Royal Engineers Institute.
Royal Geographical Society of Australasia.
Royal Historical and Archæological Association of Ireland, The.
Royal Institute of British Architects, The.
Royal Irish Academy.
Royal Meteorological Society.
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Royal Society of Queensland.
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Royal Statistical Society.
Royal United Service Institution.
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Rozario, L. C. do.
Rust, A.
Ržiha, Prof. F. v.

S.

St. David's College, Lampeter.
St. George, P. W.
Sala, P. P. de la.
Salomon, L. A. M.
Sandberg, C. P.
Sanders, L.
"Sanitary Engineering."
Saxby and Farmer.
Schermerhorn, L. J.
Schrabetz, E.
Schreiber, C.
Schröter, Prof. M.
Scott, Maj.-Gen. A. de C., late R.E.
Scott, J.
Scottish Society of Literature and Art.
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Sears, J. E.
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Seismological Society of Japan.
Simmance, J. F.
Sinigaglia, F.
Slaby, Prof. Dr. A.
Smith, C. W.
Smith, Prof. R. H., Wh.Sc.
Smithsonian Institution.
Snell, A. T.
Sociedad Científica Argentina.
Società degli Ingegneri e degli Industriali di Torino.
Société des Ingénieurs civils de Paris.
Société industrielle de Mulhouse.
Société scientifique industrielle de Marseille.
Société technique de l'Industrie du Gaz en France.
Society for the Encouragement of the Fine Arts.
Society of Architects, The.
Society of Engineers.
Sormani, E. B.
South Australian Railway Commissioners.

South Staffordshire and East Worcestershire Institute of Mining Engineers.
Spon, E. and F. N.
State Board of Health of Massachusetts.
State Board of Health of New York.
State Board of Health of Wisconsin.
"Stevens Indicator, The."
Stevens Institute of Techno-

Stoney, B. B., LL.D., F.R.S.
Streckert, W.
"Street Railway Journal."
Stretton, C. E.
Sugg, W. & Co.
Surgeon-General, U.S. Army.
Surveyor of India Department.
"Surveyor, The."
Surveyors' Institution.
Sydney Survey Club.
Sydney Technical College.
Symons, G. J., F.R.S.

T.

Technical Society of the Pacific Coast.
Technische Staatslehranstalten zu Chemnitz.
"Telegraphic Journal and Electrical Review."
Tetmajer, Prof. L.
Thayer, J. B.
Thomason Civil Engineering College.
Thropp, J.
Thurston, Prof. R. H.
Thwaite, B. H.
Tiers and Co.
Timmins, A.
Timonoff, V. E. de.
Tiplady, R.
Tomlinson, S.
Tonge, L.
Tower Company, Limited.
Traill, T. W.
Tratman, E. E. R.
Trautwine, J. C., Jun.
"Travellers' Official Guide of the Railway and Steam Navigation Lines in United States and Canada."
Trélat, Prof. E.
Tresca, A.
Trigonometrical Branch Office, Survey of India.
Tripp, W. B.

U.

Union Bridge Company.
Unione Tipografico - Editrice Torinese.
United States Coast and Geodetic Survey.
United States Department of Agriculture.
United States Engineer Office.
United States Geological Survey.
United States Legation.
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University of Calcutta.
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Vacher and Sons.
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Vétillart, H.
Victoria University, Manchester.
Victorian Institute of ... neers.
Victorian Railways ... sioners.

W.

Waddell, J. A. L.
War Department, U.S.A.
War Office.
Waring, F. J.
Warren, Prof. W. H., Wh.Sc.
Wassmuth, Prof. Dr. A.
Water Commissioners, City of Taunton, Mass., U.S.A.
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White, W. H., F.R.S.
Widmer, M.
Willcocks, W.
Williams, M. J. M., M.A.
Villis, W.
...n, J. B., J.P.
Wilson, J. M.
"Wiltshire Rainfall."
Witz, Dr. A.
"Wochenblatt für Baukunde."
Wynne-Williams, B. R.

Y.

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Yorkshire College, Leeds.

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Willox, W.	1	1	0
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	£134	13	6

APPENDIX A.

TO THE PRESIDENTS OF THE AMERICAN SOCIETIES OF CIVIL, MINING, MECHANICAL AND ELECTRICAL ENGINEERS.

We, the President, Vice-Presidents, Council, and Members of the Institution of Civil Engineers, acting, on this occasion, both for ourselves and the various bodies of Engineers of the United Kingdom, hereby tender to you, as representatives of the Members of the several Engineering Societies of America, a sincere and cordial welcome to this country, and gladly avail ourselves of the opportunity of publicly acknowledging, and as far as possible reciprocating, the manifold courtesies which, for many years past, have been lavished on British Engineers visiting the great Republic.

It is a source of peculiar satisfaction to receive you within this building, because we are here in the home of the parent of all the duly constituted Engineering Societies of this kingdom.

The association of Engineers, in England, into one body, for their common advantage, originated with Smeaton, one of the fathers of the profession; it was not, however, until twenty-five years after his death, viz., in 1817—well nigh three-quarters of a century ago—that the present Institution was actually formed.

Telford became its President in 1820, and in 1828 it received the Royal Charter, under which it has ever since flourished. In regard to magnitude, it is sufficient to state that our Institution now comprises (including the class of Students) upwards of 5,700 members, and is largely adding to its numbers every year.

Although the Civil Engineers act as hosts in your reception, the several Engineering bodies of the country are associated with us, and others outside our Profession join in the welcome, and have rendered valuable aid in our endeavours to secure your comfort and gratification.

Foremost of all must be mentioned the special permission, given by Her Most Gracious Majesty, the Queen, for you to visit and inspect her Royal Palaces and Domains, at Windsor, and in the Metropolis. Nor must we omit to place on record the very exceptional and gratifying fact that the Lord Mayor, Aldermen, and Common Council of the City of London have been pleased to place at the disposal of the Reception Committee the use of their ancient and noble Guildhall, in order that we may entertain you in accordance with old English custom at a Festival Dinner therein.

The leading Railway, Dock, Gas and Water Companies have vied with each other in exercising hospitality; nor have private individuals been lacking in the earnest desire to add to your gratification whilst in our midst.

It would be superfluous and presumptuous to enlarge on the professional merits of American Engineers. Their great works and clever inventions have passed far beyond the sphere of mere technical appreciation, and have become of world-wide celebrity. We feel justified in regarding the influence of you and your predecessors as one of the principal factors which have raised, with unexampled rapidity, the modest Republic of George Washington to one of the foremost nations on earth.

The problem of dealing with great difficulties presented by Nature, and, until recently, with comparatively limited means and limited appliances, has been solved by the American Engineer, and the solution has left its mark upon the character of the nation.

With a population about double our own, and a territory stretching between ocean and ocean, more than 3,000 miles from east to west, not to speak of its extent from north to south, distances have been conquered by your vast system of Railways on a scale of magnitude of which we have no experience.

We trust that all the arrangements made for your visits to some of the most important Public Works in this Kingdom will be successful and acceptable, and we hope you may carry back pleasant recollections of your visit to this country.

Witness our hands and seal at Westminster this 13th day of June, 1889.

(L. S.)

JNO. COODE, *President.*
JAMES FORREST, *Secretary.*

APPENDIX B.

TO THE ADDRESS PROFESSOR R. H. THURSTON REPLIED AS FOLLOWS:

Mr. President and Gentlemen:—In behalf of the Societies of American Engineers, now enjoying the unexampled hospitality of the British Institution of Civil Engineers, and its many friends, official and unofficial, I am desired by my colleagues in these Societies to attempt to make a fitting response to the eloquent and friendly, the impressive and hearty, address of welcome, to which we have listened with such pleasure and interest, as presented by the able and honoured President of the Institution.

A reply fitting and worthy this remarkable occasion and that generous greeting is far beyond my powers of thought or tongue; but it is the hope of my fellows and my own desire that such feeble expression of appreciation and acknowledgment as I may be able to frame may at least convince you, Mr. President, and you, Gentlemen, our hosts, that what we lack in rhetoric and oratory may be compensated in some degree by sincerity and earnestness, and by the warmth of those feelings which lend quickness and fulness to the pulsations of our hearts to-day.

The accident of having been honoured by selection for the first Presidency of one of these great American organizations, and of having also been admitted to membership in the others, has determined the appointment of the respondent at this time; but it is needless to say that the eloquence of our noblest orator and the brilliancy of our cleverest rhetorician would have failed to express suitably our sense of the obligations which, through your kindness to your wandering—and wondering—kinsmen, are so rapidly, and intimidatingly, accumulating. We despair of being able ever to requite them.

But, on an occasion like the present, we may perhaps be justified in our conviction that we may entrust even the least eloquent and most insignificant of our members with the duty of giving expression to our appreciation of those fraternal and generous impulses which have prompted so unprecedented a reception of the representatives of those great bodies of professional brethren and of cousins of the blood residing in the younger Britain, in the newer England across the rapidly narrowing Atlantic. They are coming daily nearer in heart and thought; as, through the labours of British Engineers, they are continually being brought nearer in space and in time by ties of electric wire, and by those giant shuttles, plying to and fro across the sea, weaving a bond of closer and closer texture as the years go by. At such a time simple words are best.

We do not come to you as strangers nor as aliens; for we cannot forget that we have a common ancestry and a common fatherland. We are rather returning to our old home, and we look upon the scenes about us, upon the friends who greet us, upon the people amongst whom we for the time sojourn, as does the long-absent, returning traveller upon the sights that meet his entranced vision, the half-strangers giving him welcome back again, the half-forgotten, yet not unfamiliar, faces and form, voices and costumes, of the land of his nativity. Some of us are but one generation removed from fatherland, more of us are grandsons of migrating Britons, and a very large proportion of our members trace their family lines across the ocean long subsequent to the times of Cromwell and the Jameses. The minority still have a claim upon us through our cousinship with that noble Teutonic stock which, born to the Vikings and the Berserkirs, has ever been great of soul and mighty of deed.

Are we not indeed justified in claiming a hearty welcome, and heart-to-heart reception, the touch of hand to hand? Yes, truly; but we are freely given even more than we should dare to claim! Thus we, younger sons in the noble family of English-speaking nations, come to you from the land of the setting sun, sailing across the seas that our Viking fathers teased with their driving prows, vexed with their rhythmic oars, over the site of lost Atlantis; from the coast revealed to the sons and brothers of the hero of a thousand years of fame, of old Thorstein—ancestor of noble memory; from the continent of mighty rivers and broad plains, of irresistible floods and magnificent distances; from the midst of a nation of recent but tremendous growth, to visit the sons of the older nation to which we all owe, still, patriotic allegiance and blood-cemented friendship.

We who have played our little parts in giving strength and stability to the government of sixty-five millions of people, by that people, for that people, who have seen the growth of 150,000 miles of railway, the spanning of 4,000 miles of continent by the magic wire, the building of the workshops of a great nation above the relics of what was but a little time ago an unmeasured expanse of trackless forests sparsely peopled by rude tribes of savages, a people who have made safe the integrity of their government by the most tremendous war known to chronology, and by the creation, in a few short months, of navy and army and of all the material of war for two great armies aggregating two millions of men, we, whose task it is to convert wildernesses into abodes fitted for civilized men, we now come home to see what the later work of the older nation has been. We come to see the Liverpool Docks and Manchester Ship Canal, the bridge over the Forth, the workshops on the Clyde where are built the greatest of steamships, the locomotive building of Crewe and of Horwich where are constructed those marvels of concentrated energy which annihilate space and time to the confusion of all the older prophets of our race. We come, also, reverently to bow before the tombs of the older masters of our craft, so largely the authors of the present prosperity and greatness of the British Empire as well as of the American Republic, to make a pilgrimage which has been the, until now, unrealized dream of many years.

What wonder that we should feel more strongly than we can find words to express, and more deeply than you, our friends, can possibly imagine!

This occasion, as has been so often remarked, is truly memorable. It cannot fail to become historical. For the first time, we see here a great body of associated Engineers in all branches of the profession coming across the seas, hand in hand and with a common object, greeted with words of welcome by the oldest and greatest association of their brethren, not only in Great Britain, but in the world. How extraordinary, how significant of progress, how suggestive of great thought is such a scene! A convention of the whole constructing profession of the English-speaking race is a meeting of the advance guard of that army of peace which is revolutionizing and civilizing and promoting, in a thousand ways, the best interests of all mankind; it is the forerunner of that millennium which shall surely come, when the arts of peace shall have conquered the arts of war, and when the industrial interests of all peoples shall dictate the direction of all political movements, and shall guide all statecraft towards the permanent establishment of international brotherhood and of civil relations, in the presence of which hostile diplomacy and selfish policies shall wholly disappear, when political boundaries shall no longer separate us, slowly, perhaps, but none the less certainly, fading out of view. This meeting is an assurance that, in time, when the Engineer shall have advanced material civilization a little further, we shall see, in all nations, peoples governed by patriotic statesmen, and legislatures looking solely to the best permanent interests of their constituents, building all industries on stable foundations, as the basis, the only safe basis, of permanent and always progressive advancement in intellectual and in moral life.

To-day, for the first time in history, the men of the profession in the New have come to accept the hospitality of their colleagues in the Old World, to grasp them by the hand, and, face to face, heart to heart, to exchange fraternal greetings. They come to learn by observation and daily intercourse what the more mature and more experienced of the brotherhood have to teach their younger relatives. They visit the land of Watt and of Stephenson, of Smeaton and of Telford, of Rennie and Brunel; the old home of Russell and of Siemens; they seek the monuments of Fairbairn, of Rankine, of Elder, and of many other of the great men whose names are famed and revered by us and all the world over.

They come to compare the works of Baker with those of Roebling, those of Nasmyth and Napier and Whitworth and Maudslay with those of their disciples in America; to describe to Bessemer the fruits of his genius, now rising from seed planted by Holley on the other continent, watered by Hunt, and brought to marvellous ripeness by Jones and Forsyth, while we study the best British practice in the home of the great inventor.

These guests have traversed the hemisphere to learn by what means the Scottish shipbuilder has hit upon the secret of giving his engines the power of many thousand horses, and to his ships a speed that makes the crossing of the Atlantic but a seven days' pleasure trip; to find out the methods by which English railways are made to transport their passengers with such celerity and safety; to see your locomotives constructed; to visit your public works; to inspect your mighty war-vessels and all the apparatus that make your nation the mistress of the seas in peace or in war, and preserve that system of home and colonial polity which gives the Empire of Great Britain continuity in time and extension in space co-terminous with the reach of the rays of the rising and the setting sun.

All this had we planned, all this had we anticipated with that pleasure which so exceptional a prospect might naturally yield; but, prepared as we were for a season rich in all those incidents that seem to us most delightful, the no less regal hospitality of our reception passes quite beyond anything that we could have imagined or looked for. The unexpected and unprecedented experiences of this one day will live in our memories as worthily typical of the whole, and throughout the remainder of our lives we shall all look back upon this grand reception and prolonged hospitality, these unimagined courtesies, as a period of intensest interest, and pleasure without parallel.

This hospitality, warming our hearts, as it cheers our lives, is quite beyond adequate acknowledgment. It is simply commensurate with the resources of your country, and with the extent of the realm governed by your noble Queen —God bless her!

The glance into the future is illuminated by such reunions as are this and those which we may now confidently expect will follow. It was long the dream of our beloved and never-to-be-forgotten Holley that the time might come when we should have in America an Institute of Engineers of all departments, to which each of the great Societies should send delegates to meet at stated intervals, and for specified periods, to study those greater problems, and to formulate those grander schemes of further conquest of the forces of Nature that a congress of the greatest men of all branches of our great profession might best discuss, and most effectively carry to a conclusion. The enormous importance of such a congress and of such union of talent and power, leading and guiding in all those movements that constitute human progress in the arts, and in all advances that are based upon them, may be at once seen; but what are we not here and to-day encouraged to anticipate later?

It will not now be considered chimerical to look for and confidently to expect the extension of this plan until it shall comprehend the union of the Engineering Profession throughout all Christendom into one great brotherhood, extending over both hemispheres, and, through its wisest and greatest leaders, foreseeing, directing, planning and executing, effecting with most perfect method and promptest execution the development of every resource, and all the best work of that world, to be yet created by our successors, the wonders of which are to-day barely foreshadowed. Taking the lessons from Nature's methods of transformation of energy, the marvels of steam and electricity, of the trans-Atlantic liners and of the trans-continental railway, of the telegraph and the telephone, of the electric light, all these wonders of our day will, by that time and through such means, be far outdone. Nature transmutes chemical energy into manual power without elevating temperature, changes it into heat without waste, evades Carnot's law, produces light without heat, and electricity from caloric and without machinery. Why may we not believe that these problems are to be solved by our successors, even if not by ourselves, and that the challenge of Nature to solve the riddles of the animal structure, of the heat-engine taking energy from food, of the illumination of the glowworm, of the electric system of the gymnotus, may yet be successfully met and these problems completely solved?

The Watts and the Corlisses, the Morses and the Wheatstones, the Stephensons and the Jervises, the Fultons and the Stevenses and Fitches, the Ericssons and Smiths and Elders, the Bells and Edisons and Thomsons, will have greater disciples possibly, and fit successors of our greatest predecessors and contemporaries will have grander problems to study and mightier works to accomplish, and, in the midst of all their victories, they may not improbably look back to this day as marking an era in the history of our profession, an era which introduced the possibility of acquiring that highest power which can only come with universal fraternity, and thus of gaining their grandest opportunities.

We of America strike hands with you of the fatherland, and gladly unite in this first movement towards perfect unity of our profession, and through that unity towards the real fraternity of all the nations.

Mr. President and Gentlemen :—I have detained you already far too long, but I have not said half enough, if the fulness of our hearts were gauged by words. On behalf of my colleagues, here and at home, in these to-day united Societies of American Engineers, in behalf of the whole profession in America, I tender to you, sir, and the British Institution of Civil Engineers, heartiest thanks for this generous reception, and for the more than royal hospitality of which we are the gratified and grateful recipients.

APPENDIX C.

TO THE PRESIDENT, COUNCIL AND OTHER MEMBERS OF THE INSTITUTION OF CIVIL ENGINEERS.

THE joint party of American Engineers visiting Europe, comprising Members of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Mining Engineers and the American Institute of Electrical Engineers, to their hosts in London, the President, Council and other Members of the Institution of Civil Engineers,

A GREETING.

The members of the visiting party, almost overwhelmed by the cordiality of the reception accorded to them by their brother engineers of the United Kingdom, deeply cognizant of the personal obligation under which the hospitalities so widely and so cordially extended have placed them, appreciating most warmly the professional welcome which those hospitalities imply, and realizing above all the sentiments of international friendship and goodwill on which they rest, tender this greeting in return as a slight token of their appreciation and esteem.

They recognize especially the promptness with which all arrangements for their reception were conceived, the thoroughness with which all plans were matured, and the efficiency with which every detail was carried out. The foresight and care thus exercised contributed greatly to their enjoyment of the various visits and excursions, deepened the obligations of the visitors to their hosts, and will ever command their admiration as exemplifying to an unusual degree the ability to organize and to execute.

Foremost amongst the many acts of welcome for which they desire to express their thanks must be mentioned the special permission given by

HER MOST GRACIOUS MAJESTY THE QUEEN,

for the inspection of Her Royal Palaces and Domains at Windsor and in the Metropolis, an act consistent with a long series of others from the same source indicative of that cordiality and goodwill between the two branches of the Anglo-

Saxon race, which it is equally the interest and the desire of both to see maintained and made secure.

They desire also to thus record their sense of obligation to

THE LORD MAYOR AND COURT OF COMMON COUNCIL,

for the high compliment implied in their sanction of the use of the Guildhall for the dinner given to the Visitors by the Institution of Civil Engineers on the 13th June, 1889.

To their hosts on that occasion, the President, Council and other Members of the Institution of Civil Engineers, they desire to express their most cordial and hearty thanks for the magnificent hospitality then extended to them, on a scale and amidst surroundings without precedent in the long record of fraternal gatherings of Engineers, and constituting an event which will not only be remembered by those who had the privilege and honour of participating in it, but which will also be ever memorable in the annals of the Societies whose Members were the guests of the occasion.

They beg also to convey through the Institution of Civil Engineers their hearty thanks, to the Trustees of Public Works and the Officers of the numerous Corporations and Firms whose works were opened to the Visitors for their inspection tendered by all of them, and the courtesies and attentions received from those whose hospitality it was impossible to accept.

Finally, the Joint Party of American Engineers visiting Europe individually, and as Members of the several organizations to which they belong, unite, with more cordiality than they can find words to fittingly express, in the wish that the Members of the Institution of Civil Engineers, and of the engineering fraternity of the United Kingdom should reciprocate the present visit, by coming to America, either collectively or individually, assuring all who may so come of a warm welcome and of every facility for visiting such places of engineering or other interest as they may desire to visit, and recording here the earnest hope that this suggestion may be generally and speedily accepted.

On behalf of the Joint American Societies:

D. J. WHITTEMORE, *Past President.*
CHAS. E. EMERY, *Chairman, Committee*
AM. SOC. CIVIL ENGINEERS.

ALFRED E. HUNT, *Vice President.*
C. KIRCHHOFF, JUN.,
AM. INST. MINING ENGINEERS.

HENRY R. TOWNE, *President.*
F. R. HUTTON, *Secretary*
AM. SOC. MECH. ENGINEERS.

JESSE M. SMITH,
ELIHU THOMSON, *President,*
AM. INST. ELECTRICAL ENGINEERS.

LONDON, *June*, 1889.

APPENDIX D.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS,

127 East 23rd Street, New York,

TO THE

PRESIDENT, PAST PRESIDENTS, COUNCIL AND MEMBERS OF THE INSTITUTION OF CIVIL ENGINEERS,

25 Great George Street, Westminster, London, England.

Gentlemen:

The American Society of Civil Engineers acknowledges with great pleasure the receipt of a copy of the Illuminated Address of Welcome to the representatives of American Engineers who visited the United Kingdom during the past season, kindly tendered for the acceptance of this Society with the confident hope that the sentiments therein expressed may prove of interest not only to those who listened to the words of welcome when uttered by Sir John Coode, K.C.M.G., the President of the Institution, but also to the other members of this Society.

The Officers and Members of the American Society of Civil Engineers desire to thank the Officers and Members of the Institution of Civil Engineers for the unequalled welcome and entertainment given to the visiting members of this Society, and particularly for the words of welcome and the information contained in the address of the President, Sir John Coode, and more than all for the evidences of good feeling, and brotherly and professional fellowship shown by the terms of the said address, and the receptions, excursions, and various entertainments given to members visiting the United Kingdom as a body in 1889, and to individual members who have visited the United Kingdom from time to time. It gives pleasure to this Society that its representatives were received in "the home of the parent of all the duly constituted engineering Societies" of the United Kingdom, a home we may say equally dear to this Society, which in its organization, aims and purposes must be considered in heart and feeling if not in reality a child of the parent society in the United Kingdom, the British Institution of Civil Engineers as well as a descendant of all the representatives of engineering progress throughout the world. We are gratified to know that the Institution of Civil Engineers, though acting as hosts, were associated with the several other engineering bodies of the United Kingdom, and others outside the profession in the reception of our members.

Long live her most gracious Majesty the Queen, beloved and respected throughout the world, who gave special permission to the visitors to visit the Royal Palace and domains. We tender our sincere thanks to the Lord Mayor, Aldermen and Common Council of the City of London, for having placed at the disposal of the reception committee their ancient and noble Guildhall, that our members might be entertained in accordance with the old English custom at a festival dinner therein. Finally we tender our thanks through you to the leading railway, gas and water companies, to the various members of the reception committee, to the members of the Institution, and to various others who so kindly and hospitably united in entertaining our members and making them feel that they had left their own homes to come to a joyous greeting in the homes of their fathers. We feel especially complimented at the kindly words of reference to the great works and inventions of American origin, to the expression of the feeling that the engineers were "one of the principal factors" in the progress of this great Republic and are greatly pleased by the recognition and appreciation that the engineers of this country have until recently with comparatively limited means and limited appliances, dealt with the "great difficulties presented by Nature," and developed our country by a system of railroads and internal improvements which have received your commendation. The visiting engineers have brought back pleasant recollections of the visit to your country, and there is a general expression of regret from those who were not able to go and see for themselves.

In the history of the land of our common ancestors, where peoples and tribes of various language, in turn warred and united with each other, finally giving birth to the English people, we feel that we trace the development of those elements of character and self-reliance, which in modern times handle great mercantile enterprises, cross the seas with ever-increasing speed, build towers and temples, bridge streams and pierce mountains, thus substituting for the excitement of battle, the nervous energy which directs the victories of modern progress. These elements of character show themselves not only in monumental works built under the conditions of concentrated capital, with which our elder brothers have to deal, but with that more widely distributed, ever-pressing demand for results accomplished quickly and economically, under which we, your younger brothers, are obliged to act and secure their own victories.

Our further thanks we can best express on our own soil, and we cordially invite you all to come and see us at such fitting and convenient time as may be arranged.

M. J. BECKER, *President.*
JOHN BOGART, *Secretary.*

(L. S.)

December, 1889.

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Sect. II.—OTHER SELECTED PAPERS.

(*Paper No. 2462.*)

"The Coasts and Rivers of Yesso."

By Charles Scott Meik, M. Inst. C.E.

During the years 1887, 1888, and 1889, the Author, acting under the instructions of the Japanese Government, made a complete inspection of the coasts, and a preliminary inspection of the chief rivers, of Yesso (or Hokkaido, as it is now called in Japan), with a view to reporting on the construction of harbours and the navigation of the main water-ways of the island.

Before referring to the coasts of Yesso in particular, however, it will be necessary to describe briefly the sea-currents which affect more or less the whole coast-line of the Japanese islands (Plate 3, Fig. 1), and especially the south and south-east coasts of the northernmost island, to which this Paper more particularly has reference.

The two principal ocean currents in the vicinity of the Japanese islands are the warm current, or the Japanese Gulf Stream, called the Kuroshiwo and a cold current called the Oyachiwo. The first of these is a continuation of the great equatorial current of the Pacific Ocean, which, after impinging upon the Philippines, is deflected to the north and north-east, south of Formosa, and flows on the east side of that island and along the south of the Loo-choo islands until it reaches the 26th parallel, where it splits into two currents, the chief current going in a north-easterly direction and reaching the south and south-east coasts of the Japan main islands, while the smaller current retains a northerly direction, and flowing to the westward of Kiushiu and the Goto islands, enters the Sea of Japan through the straits of Krusenstern. It then flows in a north-easterly direction through the Sea of Japan until it reaches the south-western extremity of Yesso, where it again forks, a portion of the current going through the straits of Tsugaru and entering the Pacific, while the main portion of this branch flows northward up the west coast of Yesso, and, passing through the straits of La Perouse, loses itself in the southern portion of the Sea of Okhotsk.

The main branch of the Kuroshiwo flows along the southern shores of Shikoku and Nippon, and strikes out into the Pacific in a north-easterly direction from Cape Inaboye, although it is sometimes met with as far north as the 40th parallel off the east coast of Nippon in summer. Before the first forking of the Kuroshiwo its temperature is 8° or 9° Fahrenheit higher than the neighbouring sea-water, and its current runs from 35 to 45 miles per twenty-four hours in settled weather, and sometimes as high as 77 miles with a south-west wind in winter. Between latitudes 34° and 35° North, this warm current is about 40 miles wide according to observations by the Challenger Expedition. The Kuroshiwo, or Japanese Gulf Stream, causes the southern and south-eastern coasts of the Japanese main islands to be much warmer in winter than the west coast of the main island (Nippon) and the coasts of Yesso, and it appears to have even a more marked effect in those regions than the Gulf Stream of the Atlantic has upon the climate of the west coast of Ireland. The Kuroshiwo rushes past the prominent capes on the south and south-east coasts of Shikoku and Nippon, such as Satanomisaki, Muroto Saki, Kii no Oshima, and Oshima, with considerable velocity, and causes the counter-currents in the bights between these promontories to be very distinct—a fact to be borne in mind by navigators, as ignorance of their existence has frequently been a source of disaster to vessels.

The Oyashiwo, or cold current, has its origin partly in the sea of Okhotsk and partly in Behring's Strait. It flows from Kamschatka past the Hurile islands, and strikes the east coast of Yesso as well as the south-east coast from Cape Noshapu to Cape Erimo, where it meets the easterly current setting through Tsugaru Straits. The two currents then combine, and, setting in a south-westerly direction, reach the coast of Nambu, or the main island of Nippon to the northward of the 40th parallel, and then run in a southerly direction along the east coast until the 38th parallel is reached, after which the combined current sets out into the Pacific ocean, mingling its waters with those of the main branch of the Kuroshiwo before referred to. The Oyashiwo, or cold current, on the south-east coast of Yesso, is not wide, probably not more than 20 miles at the most, and it seems to hug the coast very closely all the way to Cape Erimo. It has a very low temperature in winter, falling below 32° Fahrenheit, but in summer it reaches 60° Fahrenheit near Cape Erimo, while the warmer current through the straits of Tsugaru registers 42° Fahrenheit in winter and 70° Fahrenheit in summer, and this within a few miles to the west of Cape Erimo. On the east coast of Nippon the cold current flowing southward has a temperature of from 12° to 15° Fahrenheit lower than the main current of the Kuroshiwo south of Cape Inaboye in winter, and about 10° Fahrenheit lower in summer. In addition to these principal currents, there are others, shown in Plate 4, Fig. 1, the origin and features of which have not yet been clearly established.

It would seem that the western or Japan Sea branch of the Kuroshiwo is not felt in the straits of Tsugaru from February to May inclusive, when the temperature of the water in the straits is never higher, and sometimes 3° to 4° Fahrenheit lower, than the southerly current on the east coast of Nippon north of Kiukuasan point. During May and June the temperature of the water in Tsugaru Straits rises considerably, and in October, when highest, a difference of 10° is sometimes observed between the temperature of the water in the straits and that off the coast of Nippon. The influence of the Japan Sea branch of the Kuroshiwo is felt up the west coast of Yesso as far north as La Perouse Straits. The temperature of the sea near the Yesso coast is higher by 8° to 10° Fahrenheit than the sea on the Siberian coast near to Vladivostock; and it is chiefly due to this warm current that the west coast of Yesso is free from ice-drift during winter, while the east and north-east coasts are blocked by it. On rare occasions a westerly current is met with in Tsugaru Straits in summer and is always accompanied with foggy weather. The current in Tsugaru Straits is the main body of the current in the centre of the straits. Counter currents are met with close in to both shores, and these are much influenced by the tides; but the general set of the current on the north shore is in a westerly direction in the neighbourhood of Hakodate. As will be seen from the Appendix, the tides at either end of the straits vary considerably. The rise of a spring-tide at Hakodate averaging 3½ feet, while at the western entrance of the straits the same tide averages a little over 1 foot.

Owing to the low temperature of the Oyashiwo, or cold current, the east coast of Nippon and the southern coasts of Yesso are frequently visited by fogs of great density, which render navigation very difficult during the summer months. These fogs are entirely localized by this cold current, and are not met with as a rule more than 20 miles off shore, nor do they extend inland more than a mile or so, and sometimes only for a few hundred yards. The cold sea-water of this current causes the seaweed on these coasts to grow very luxuriantly, and a large trade is carried on by the inhabitants in collecting, drying, and shipping it to China, where it is extensively used as an article of food. The leaves of this weed are in some instances obtained as long as 90 feet.

From December to March drift-ice is met with along the north-east and east coasts from Cape Soya to Cape Noshapu. This ice has its origin in the northern portion of the sea of Okhotsk; it is packed along the shore for a width of from 10 to 20 miles, and completely stops all traffic by sea. Drift is not met with on the west coast of Yesso, and very rarely on the southern coasts, although in February 1889 it found its way along the south-east coast as far as Kuchiro, about 80 miles to the west of Cape Noshapu, and extended for several miles out from the shore. This ice-field is very destructive to timber erections in the sea and in river mouths, as the rising and falling of the ice under the action of the tide gradually lifts the piles out of the ground in the course of a severe winter.

The prevailing winds appear to coincide with the direction of the littoral currents along the different coast-lines, especially on the north-east, south-east and south coasts. Consequently the sand and shingle travel at a great rate in the direction of flow of the littoral currents; but this action would appear to be due chiefly to the winds, since the currents are sluggish as a rule. All the river mouths on these coasts have a direction away from the quarter from which the prevailing wind blows, and rivers frequently run parallel to, or within a few yards of, the coast-line for miles before entering the sea. As a consequence, a number of lagoons are formed on the coast, with a bank of sand and shingle a few yards wide separating them from the sea. The largest of these lagoons is on the north-east coast at Saruma. It covers an area of 80 square miles, and is separated from the sea by a sandbank varying in width from 300 to 1,000 yards, and having a maximum depth of 9 fathoms. Notwithstanding that it receives a fresh-water discharge of about 1,000 cubic feet per second from various small rivers and streams, and that the tidal flow is considerable, the entrance to this lagoon is frequently blocked with sand, causing the water to rise therein to 7 feet or more above the normal level, and it would doubtless continue rising to a still greater height if the inhabitants on its banks did not turn out in force and cut a passage through the sandbank to allow the water to escape, and so prevent their houses being flooded. So large is the quantity of sand that travels along these shores under the action of a strong wind, and so rapidly does the sand accumulate, that rivers having a fresh-water discharge of 2,000 cubic feet per second and more are blocked at their mouths in the course of a day or two.

The maximum tides on the coasts of Yesso are met with on the south-east and south coasts, and are said to rise as much as 8 feet, although the highest rise that the Author can vouch for is not more than 7 feet, while the rise of an ordinary spring-tide may be taken at 4½ feet. The rise of tide gradually decreases as the coast is followed north from Cape Noshapu towards Cape Soya, and thence southward down the west coast (Appendix).

A considerable diurnal inequality exists all round the island. On the south-east coast this inequality amounts to about 3 feet at a spring-tide. The lowest tide at new and at full moon occurs about 10 A.M., and the second daily tide reaches a minimum about three-and-a-half days before new and full moons, or at the change of the tides from springs to neaps. On the south-east coast this minimum second daily tide occurs about 6 P.M., and only registers a few inches rise on the gauge; while on the north-east coast at Abashiri there is practically only one tide in the twenty-four hours for four days before and one day after new and full moons, and during this period the tide takes sixteen hours to rise and eight hours to fall. The small rise of tide on the west coast is most likely due to the tidal wave generated in the Pacific Ocean not being able to find its way into the Sea of Japan through the Straits of La Perouse and Isugaru, owing to the counter-current of the Kuroshiwo.

The character of the coast-line of Yesso as a rule is plain and uninteresting. The western coast from the Bay of Ishikari southward, however, is bold and rocky in the extreme, with occasional stretches of sandy beach near the mouths of the small rivers there finding their way into the sea. The northern portion of the west coast, the north-east and east coasts have sandy foreshores backed by undulating country, with occasional abrupt headlands jutting into the sea; while the southern coasts are for the most part sandy beaches in front of flat table-land 80 to 100 feet above sea-level, the material forming the rocks of which the cliffs are composed being invariably of volcanic origin—andesite and traclyte predominating. The tableland of Cape Erimo, the southerly point of Yesso, is a promontory 200 to 300 feet above sea-level.

Of the rivers of Yesso the Ishikari (Plate 3, Fig. 3) is the most important and is the largest in Japan. Its length is 230 miles and its watershed may be taken at 5,500 square miles. The average annual rainfall at Sapporo, in the lower Ishikari valley, for the twelve years ending 1888 was 40·5 inches; but considerably more rain is known to fall in the upper Ishikari valley. The result of the Author's observations gave the average discharge of the Ishikari during the year 1888, at Barato, 11 miles from the sea, as being approximately 19,000 cubic feet per second.

On the 14th of October, 1888, the Author found the discharge of the river at Kabato, 61 miles from the sea, to be nearly 10,000 cubic feet per second with a maximum surface velocity of 6·5 feet, and a mean velocity of 4·5 feet, per second; and on the 18th of October with a rising river he ascertained that the discharge at Barato, 11 miles from the sea, was equal to 39,000 cubic feet per second, with a maximum surface velocity of 3·45 feet and a mean velocity of 2·80 feet per second. At Barato during these observations the river-gauge indicated 3·5 feet above the lowest summer-level of the river. The greatest difference in water levels in the lower Ishikari valley, since the establishment of river-gauges, occurred in the year 1879, when the difference between lowest summer-level and highest flood-level was 12·80 feet at Barato, while at Horomui (35 miles) it was 28·30 feet. Particulars relating to floods in the River Ishikari are shown in Fig. 3. During the flood of May, 1879, the total discharge of the Ishikari at Barato must have exceeded 70,000 cubic feet per second, and the mean velocity have been equal to 3·0 feet per second. Up to 1889 the highest up-river gauge was at Horomui; but in June of that year additional gauges were established at Kabato (61 miles), Sorachi landing (98 miles), Kamoikotan (139 miles), and Biyé river mouth (149 miles). Approximately the fall between Kamoikotan and Sorachi landing gauges is $3\frac{1}{3}$ feet per mile, and between Biyé mouth and Kamoikotan gauges 11 feet per mile.

From indications on the river banks at Kabato and Sorachi landing, it would appear that all floods tend to equalize the gradient from the mouth of the Sorachi down to the sea; and that the gradient of a high flood is rather more than 0·90 foot per mile between Kabato and the sea, and rather more than 1·00 foot per mile between Sorachi landing and Kabato.

The mean difference between high and low water-levels of all tides at the Ishikari gauge was found by the late Mr. Van Geudt, a Dutch engineer in the service of the Japanese Government, to be 0·88 foot, and at Barato gauge 0·77 foot. These figures were arrived at in the years 1879 and 1880.

Owing to the small rise and fall of tide in the Ishikari, that river loses its tidal character entirely at Barato during a flood, and at the Ishikari gauge the influence of the tides is much diminished during such occurrences. The maximum rise of tide at the mouth of the Ishikari is certainly not more than 3 feet, and it is to be regretted that it has not been found possible to erect a gauge outside the bar, where the influence of river-floods would not be felt. The difficulties of maintaining and recording a tide-gauge in such a position have, however, hitherto proved insurmountable. The current observations above referred to were all made with the double float, from three to six floats being used for each observation according to the width of the river.

The river next in size to the Ishikari is the Togachi (Plate 4, Fig. 2) which flows into the Pacific on the south-east coast of Yesso. It has a length of about 150 miles, with numerous branches, and has a watershed of about 3,268 square miles. It enters the sea through two mouths, the greater volume of water, five-sixths of the whole quantity, flowing out at one of them. The total discharge of this river, from the observations of a Japanese surveyor, was 5,660 cubic feet per second on the 23rd of July, 1888, the maximum velocity 7 feet and the mean velocity 3 feet per second. The rainfall on the Togachi watershed is considerably less than that on the watersheds of the rivers discharging into the sea on the west coast. In addition to Sapporo, rain gauges have been established at Hakodate, Cape Erimo, and Nemoro on the south and south-east coasts. The rainfall at Hakodate on an average of nine years is 42·15 inches at Nemoro, from eight years' observations 31·38 inches, while at Cape Erimo it amounted to 30·35 inches from one year's observations.

As an instance of the great volume of sand-drift on the south-east coast, it may be remarked that the west, or principal mouth of the River Togachi has been more than once completely blocked up by sand during the summer months.

The river third in size as regards the quantity of water discharged, but second as regards length, is the Teshiwo. This river discharges into the sea on the west coast to the northward of the Ishikari, and has a length of about 200 miles and a watershed of about 1,966 square miles. Owing to the heavier annual rainfall on the west coast, the Teshiwo has very nearly as great an average discharge as the Togachi, although the area of its watershed is considerably smaller. The fresh-water discharge of the Teshiwo on the 4th of October, 1888, amounted to 5,411 cubic feet per second, while the maximum velocity was 5 feet per second and the mean velocity 1·10 foot per second. The Teshiwo runs parallel to the coast-line in a southerly direction before entering the sea, differing in this respect from the other rivers on this coast. The mouth of this river is apparently again moving to the northward, and it is at the present time about 1 mile from the south end of the lagoon forming the old river-bed.

That the predominating drift is to the northward, on this coast, is instanced by the enormous quantity of timber, roots of trees, &c., found on the beach between the mouth of the Teshiwo and the north end of the island which must all have come down that river or some river further to the southward. Hardly any drift-wood, however, is met with south of the Teshiwo.

These three rivers are capable of great improvement; they can at present be navigated by small craft for a considerable distance up from the sea. The Ishikari could, once the difficulty of the bar at its mouth were surmounted, be navigated in its present condition for a distance of 35 miles from the sea by vessels of over 1,000 tons burden; while river steamers could ascend for 140 miles whenever some of the largest of the numerous snags were removed from the channel of the stream. A judicious expenditure of capital in the formation of a permanent deep-water mouth to the river, and for the removal of snags and other obstructions, would make this river the means of opening up a large tract of the best land in the island, besides providing an outlet for the large coal mines about to be sunk in the neighbourhood of the Sorachi valley, one of the tributaries of the Ishikari (Plate 4, Fig. 2). The Japanese Government is, however, devoting all its energies and capital to the construction of railways, neglecting the development of water communication, which has lately attracted so much attention in Europe as being the cheapest method of transporting heavy goods and minerals. Perhaps the fact that all works hitherto undertaken for the improvement of river mouths and the construction of harbours in the south of Japan have proved anything but a success has deterred the Japanese from attempting similar works in the northern island. No artificial harbours at present exist in Yesso, nor has any attempt been made to form one at any of the existing anchorages or river mouths around the coasts. Secure, natural anchorages exist at Hakodate in the Straits of Tsugaru, and at Mororan in Volcano Bay; while fairly good anchorages are found at Akkeshi, Hamanaka, Otaru, Hanasaki, Kushiro, Esashi, &c., and inferior anchorages exist at Abashiri, Soya, Mashike, Rumoi, Sutsu, Iwanai, and Nemoro (Plate 4, Fig. 2). Most of these places are capable of great improvement as harbours, and at a moderate expense; but in the Author's opinion the formation of a deep-water entrance to the Ishikari, and the improvement of that river, is of more importance than the construction of works at any of the anchorages mentioned; the formation of a first-class harbour at the mouth of that river would do more to develop the resources of the island of Yesso than any work carried out, or in contemplation, by the Japanese Government.

In conclusion the Author has to acknowledge his indebtedness to Mr. N. Fukusi of the Survey Department of Japanese Government, and to the direction of the "Nippon Yuseu Kaisha," for valuable information embodied in this Paper.

The Paper is accompanied by several tracings, from which Plate 4 has been engraved.

APPENDIX.

THE COASTS and RIVERS of YESSO.

Tidal Observations.

Name of Place.	Rise of a Spring Tide.		Maximum Rise observed.	Observations extend over—
	Mean.	Maximum.		
	Feet.	Feet.	Feet.	
Rumoi	1·15	2·20		1 month.
Mashike	1·17	2·35		1 month.
Esashi	1·40	3·40		1 year.
Ishikari	0·88	3·00	3·95 (N.W. gale and flood in the river.)	4 years.
Hakodate	3·50 (English Admiralty chart.)			
Mororan	4·90	6·20	7·00	8 months.
Kushiro	4·78	6·00	8·00 (Japanese observation doubtful.)	Over 1 year.
Akkeshi	3·75	4·40	5·00 (H.M.S. "Sylvia.")	1 month.
Hanasaki	4·16 3·75 (Japanese chart.)	5·20	5·20	1 month.
Nemoro	3·94	5·15	5·25 (Japanese chart.)	1 month.
Abashiri	2·90	3·50	5·00 (Japanese obser-) vation.	1 month.

Note.—The Ishikari mean rise is for all tides, both springs and neaps. The gauge at Ishikari is 1 mile inside the river bar, and the tides are much influenced by floods.

(*Paper No. 2340.*)

"The Design of Railway Stations and Yards."

By Richard Marion Parkinson, Assoc. M. Inst. C.E.

Few things have more influence on the punctual and economical working of a railway than the careful laying out of its station-yards.

When a line is first constructed the sidings should be planned in such a manner as to be capable of considerable extension, for in many cases it is impossible to estimate the amount of traffic, and it is better to provide too little accommodation, if it can be easily added to, than to spend money on works that are afterwards not required.

In many cases that have come under the Author's notice, where room for extension has not been provided, additions have been made from time to time, on no fixed plan, and thus the shunting operations are ultimately carried on with the greatest difficulty.

General Arrangements of Yards.

Some examples of railway station-yards are given in Plate 5, Figs. 1 to 4. In these London is supposed to be on the left, so that the upper main-lines are the down lines.

Fig. 1 represents a passing-place on a single line. The accommodation given would be sufficient for all ordinary requirements, but even this could be increased. To begin with, one main-line and platform (on the down side), a siding (No. 2), a goods shed, and temporary cattle-pens, might be provided; and the other main-line platform, and sidings added as required. It will be seen that the passenger-station is on one side of the line, and the goods yard on the other; and that there is a through siding behind the up-platform, by means of which the other sidings can be reached, without any fly or rope shunting, by both up-trains and down-trains.

All single-line stations are tied by the Board of Trade regulations that facing-points must be avoided as much as possible, and be within 180 yards of the signal-box; and by the necessity of providing only one signal-box for economical working.

Fig. 2 gives another example of a station on a single line. Here, both station and yard are on the same side of the line, and the arrangements are, in consequence, not so good for shunting. One special feature is that the goods shed is between a siding and the platform, and is therefore available both for trucks and "brake" goods, being approached from the end by the carts. Sufficient length is given in the siding beyond the shed for standing wagons that have been loaded. The same provision should be made at the cattle-pens, in order that the loaded cattle-wagons may be pushed on, and others brought up. The up-sidings here are only shown to prove that there is room for the two cross-over roads between the other junctions and the end of the platform.

Fig. 3 illustrates a passenger-station where a large traffic has to be dealt with. Far more can be done to relieve a line from over-pressure of traffic by providing well-arranged stations than by adopting relief-lines between stations. This, however, depends on the nature of the traffic. Here it will be seen that a down goods-train can at once be received in the siding A A, to wait till one or more up-trains have passed, before crossing to the goods-yard, instead of waiting on the main-line, and so checking everything behind it. A down passenger-train may come in and stop at B B, and another at C C, and either can be despatched without disturbing the other; or they can be joined, in order to proceed as one train, in a very short space of time.

In Fig. 3 only one-half the station is shown, as the other half is exactly similar, with the exception that a siding corresponding to A A is not required for up-trains.

The plan of putting the refuge-siding between the main-lines is convenient at wayside stations where there is some local traffic; for where the trains are frequent, it is often most difficult to block both the up-lines and the down-lines at the same time, to enable a train to shunt from one side to the other, whereas if there is a refuge-siding between them, one line can be blocked at a time. A great economy of time may be effected by having facing-points to refuge-sidings, as they save the delay and consequent risk caused by a heavy goods-train pulling up and then setting back into the siding.

In Fig. 4 is given an example of perhaps the most difficult case to deal with, namely, a passenger-terminus. An in-coming train may stop at A A, and when cleared set back into B B. While it is in either of these positions, another can stop at C C, and also set back into B B. Both trains can do this without affecting the down-traffic; for they can wait in B B, which should be long enough to take several trains, until the line is clear, when they can be sent forward to the carriage-sheds. A train of empty coaches can run into the platform-line E E, or into one of the refuge-sidings, from which it may be drawn forward, and set back into E E, or G G. From E E it can proceed through the main line H H without disturbing a train that may be loading in G G.

These examples are not intended to be complete, but are given to illustrate principles; and they will be again referred to in what follows.

Platforms.

In designing a passenger-station, one of the first considerations is the length and width of the platforms.

The length depends on the length of the trains that may be expected. On country lines, where the usual train consists of three or four coaches, provision must often be made for excursion-trains of fifteen or more. On single lines, the making a platform more than 350 feet long considerably cramps the goods sidings; one platform of this length will take a train of about twelve ordinary coaches. It is to some extent dangerous, and a cause of delay, for a train to have to pull up twice at a platform, but the Author thinks that, in general, a length of 350 feet should be sufficient for country lines; and this is what has been allowed for in Figs. 1 and 2. The cost of the platform itself is in general so small as to be of secondary consideration. For main and for suburban lines, 450 feet is a good length, as this will take an engine and train of fifteen 27-foot coaches.

The width should rarely be less than 12 feet. In Fig. 1 the up-platform is shown as 12 feet wide, but some of this width is taken off by the waiting-rooms and signal-box. This should be avoided if possible; for it is hardly too much to say that the width of a platform is the width of its narrowest part. The Board of Trade requires that no standing structure, such as a column, shall be within 6 feet of the front of a platform. The Author would go further than this and say that no columns or projections of any kind should be placed on it where it can be avoided; they cause an obstruction out of all proportion to their size, and generally happen to be at the very point where most room is required. For a suburban station, a width of 15 feet is common; and for a large junction or terminus, as in Figs. 3 and 4, 30 feet will generally be sufficient. The arrival-platform (Fig. 4) is 70 feet wide, divided into two 20-foot pavements for passengers, and a 30-foot roadway for cabs, which can stand one line at each pavement, while a double stream is going out. To get to this roadway, a way over or under the branch-lines must be provided; if the latter, a headway of only 9 feet is required; and a width of 8 feet, and a gradient of 1 in 10, is all that is necessary in either case.

The platform must end by ramps, not by steps; the best inclination for these is 1 in 6. For the height, the Board of Trade recommends at least 2 feet 6 inches; this is perhaps the best and most common height, though 2 feet 9 inches, 3 feet, and even more is often adopted. The platform should slope at about 1 in 50 to the wall, and the floor of the station be raised accordingly; but there should be no step from the waiting-rooms to the platform. A section of a brick platform wall is given in Fig. 7. If the wall is of concrete or of stone, it should be about one-third thicker. When a bank has been newly tipped, it is not always necessary to go down to a solid foundation, but a wide base, as in Fig. 7, should be given to the concrete, and the trench for it well punned and watered. It is shown to be coped with 14 inches by 6 inches bull-nosed Staffordshire blue bricks, chequered on the top; 18-inch bricks are hardly required, but economy can be derived from using the 9-inch by 4½-inch size. Staffordshire bricks perhaps make the best coping, but York stone and concrete are sometimes used. From the running face of the rail to the coping should be 2 feet 4¾ inches; and it is better, though not necessary, that the wall should be a little back, the coping being carried by two sailing-courses. As a space of 6 feet must be allowed between the main lines, the width between the copings of the two platforms in Figs. 1 and 2 should be 20 feet 7½ inches.[1]

Horse and carriage docks, coal-wharfs, cattle and goods platforms should be the same distance from the rails as passenger-platforms. The best height is 3 feet 9 inches, except for carriage docks, which should be 4 feet, or 4 feet 3 inches high. A good section of wall is shown by Fig. 8, where the coping is represented as being of 9 inches by 4½ inches Staffordshire bricks.

Two of the best kinds of fences are shown by Figs. 9 and 10. One of these is a pale-and-space fence on two rails, 5 feet high, with spaces of not more than 2½ inches, so as to make it unclimbable. The pales should be 3 inches wide by 1 inch thick; the rails out of 4 inches by 4 inches, cut diagonally, and the post 7 inches by 5 inches. The other is of iron, and is quite as cheap and costs less for maintenance.

[1] See Table of Standard Dimensions.

Cattle-Pens.

A convenient wooden cattle-pen is illustrated by Fig. 15, and an iron one by Fig. 16. The distance from centre to centre is 21 feet, to agree with the length of the longest ordinary cattle-wagons. All pens and lairs must be paved, and also the walks where these are shut off from the road by gates; hence it is not usual to hang a gate at the entrance of the walk, but to leave it open. A width of 9 feet is sufficient for the walk. Water must be laid on, and water-troughs provided.

Goods Sheds.

For wayside stations goods-sheds of two kinds are usually employed; one, in which the trucks are passed into the shed, a siding going through, as in Fig. 14; and the other kind in which they go under a shelter outside, as in Fig. 13. The advantage of the latter is that it may be shut up without any risk of trucks being sent through the doors, and is also better for storing in; but it is less convenient for loading from, more especially when a crane is used. The carts either back into a dock, or have a shelter outside. The dock is again more convenient where there is a crane; a height of 12 feet from the platform, or 15 feet 9 inches from the rails to the roof principals, is sufficient for this. The length and width to a great extent depend on the special requirements of the station, but the width should rarely be less than 20 feet, or even 25 feet. For country stations, 40 and 60 feet are common lengths, but the ends should be so arranged as to allow for extension. At these, however, a goods shelter on the passenger-platform, some 15 or 20 feet square and 8 or 10 feet high, is generally sufficient, and often more convenient, as one truck is frequently loaded for and from several small stations. Figs. 11 and 12 exemplify the more common types of a large shed. In the upper part of Fig. 11 the carts are unloaded on to a platform some 50 feet wide, at the end of the sidings, and the goods conveyed in barrows up the island platforms to the different trucks. These island platforms should be 12 feet 9 inches, 23 feet 10½ inches, or 35 feet wide, that the sidings which end at them, as shown in Fig. 11, and which can be taken up as more platform-length is required, may be laid the standard distance apart of 11 feet 1½ inch, from centre to centre. The best width is 23 feet 10½ inches, and the best length 600 or 300 feet, this being sufficient to hold a whole or a half train of thirty wagons, which can thus be loaded and sent off with little or no shunting, as an experienced foreman can generally judge how many trucks are wanted for each station. In London only one shed is required, for the loading is principally done between noon and midnight, and the unloading between midnight and noon; but at intermediate important stations two sheds —or rather two sets of platforms—must be provided, the one for inward, and the other for outward traffic. In the arrangement shown in the lower part of Fig. 11, the carts can back up to the platform opposite the trucks to which their contents are to be consigned; but it generally happens that a cart brings goods for different parts, which in consequence have to be conveyed in barrows down one platform and up another, causing more work; but there may be a special traffic for which such an arrangement is convenient, so that the combination in Fig. 11 is often adopted.

Fig. 12 illustrates a shed where the traffic is worked by hydraulic turn-tables and capstans, a length equal to six trucks being allowed for in each dock. Empty trucks are brought in from the siding No. 1, and the loaded ones turned out into No. 2, from which they are formed up into trains, or are removed and marshalled some way down the line where space is not so valuable. Capstans able to lift 1 ton should be provided, as these are capable of moving about nineteen 12-ton trucks, taking the resistance to traction at 10 lbs. per ton.

Upper floors for warehousing goods or grain should be placed above the platforms and sidings, and hoists to lift 2 tons provided. One or two floors 10 feet high are generally sufficient. The whole space where carts can be loaded should be commanded by 1½ or 2-ton cranes, but they are not so much required for loading trucks; they may, however, be wanted at any spot, so that it is perhaps better to provide enough to command every truck, although some form of travelling crane seems more suitable for the purpose. One such crane running on rails on the platform, about 6 feet from the edge, so as not to interfere with the stacking space, seems to be what is required. For heavy goods 5-ton, 20-ton, or even larger cranes should be provided, but these need not be under cover. Weigh-bridges of a capacity of 2 tons should be placed on the platforms some 50 feet apart, and larger ones in the roadway for carts and sometimes trucks, but these latter are not wanted at all stations. The smaller goods are generally weighed on movable scales. The roadway between two platforms should be 45 feet wide to allow carts to pass up and down while others are backed up to the platforms.

The best method of closing small sheds is by sliding doors, which should, where possible, slide outside the shed so as not to take up wall stacking space. In calculating the strength of the floors and roofs, provision must generally be made for about 3 cwt. per square foot for the floor, and in the case of the roof for any required lifting tackle over and above the 40 lbs. per square foot, usually allowed for wind pressure.[1]

SIDINGS.

It is best to lay out mileage and coal sidings in pairs with roadways between, as in Figs. 1 and 2. The width of these latter should be sufficient to enable carts to be loading on each side while others are going backwards and forwards. A width of at least 35 feet ought therefore to be given, and one of 45 is better, especially where there are coal-stacking grounds.

The length of lay-byes is influenced by the gradients as shown below, but the longest ever required is 1,000 feet. For marshalling sidings, a good length is about 400 feet. If they are made too long much time is spent in reaching the end trucks.

Buffer stops should be provided at the ends of all sidings; wheel stops are too injurious to the wagons, though perhaps more effectual in their object. Two good designs are given in Figs. 17 and 18.

GRADIENTS.

If resistance to traction on the level be taken at 8½ lbs. per ton, a carriage will just begin to move of itself on a gradient of 1 in 264, and for this reason the Board of Trade has fixed 1 in 260 as the steepest gradient on which a station may be constructed.

Where one line has to rise, and pass over another, and get down again in the shortest possible distance, the gradients should be regulated according to the following Table, which has been prepared on the assumption that the tractive power of an engine is one-sixth of the weight on the driving-wheels, and that the resistance on easy curves is 10 lbs. per ton and on sharp curves about 20 lbs. per ton.[2]

For gravitation sidings an inclination of 1 in 100 will overcome a resistance of 22·4 lbs. per ton, and this is sufficient to make all

[1] For passenger stations and buildings under the control of the Board of Trade 56 lbs. per square foot wind-pressure must be provided for.

[2] Minutes of Proceedings Inst. C.E., vol. xviii. p. 68; vol. xxiii. pp. 390 and 403; and vol. lxiii. p. 103.

but the very worst running trucks move.[1] On sharp curves an additional resistance of about 10 lbs. per ton has to be overcome, and this will be done by an inclination of 1 in 70.[2]

Curves and Angles of Crossings.

For facing-point junctions, which fast trains may run through, a radius of 15 or 20 chains should be given. For ordinary cross-over roads and junctions 9 chains, and for goods sidings not less than 5 chains. The Author has seen a six-wheeled coupled engine go round a curve of 2½ chains radius, a four-wheeled coupled round a curve of 1½ chain, and a truck round one of 1 chain (although three horses were in this case required to draw it); but he can hardly recommend anything less than 5 chains, and this only when absolutely necessary.

Through cross-over roads should, where possible, cross the other roads at an angle of 1 in 8; this gives a distance of 9 feet 4 inches from the centre of the crossing to the points of a compound (or slip), Fig. 5, and this should be the angle of the distributing road of the fan in Fig. 4, with the sidings K K. It is just possible to get in slips when the angle is 1 in 6, but that is all, Fig. 6; and, where the lines are curved, especially, the angle of a through cross-over should not on the other hand be easier than 1 in 8, or there will be no guard at the elbows, and trucks will constantly get off the road.

In a through 1 in 8 cross-over, the curve of a compound (or slip) begins at the first crossing and ends at the other, for 4 feet 8½ inches × 2 × 8 = 75 feet 4 inches; hence the points are at a distance of 9 feet 4 inches from the centre of the crossing, which can be easily managed. With a 1 in 6 the points would come at 4 feet, which is too near to be properly managed, though it can just be done. So also in the fan, Fig. 4, the best angle for the distributing siding to make with the others is 1 in 8, but 1 in 6 can just be managed.

In Figs. 5 and 6, details, showing the distances to which the rails of the crossings and elbows should be carried to avoid short

[1] This statement having been called in question, an experiment was made with some trucks taken at random from a station yard, and all started at once on the 1 in 100 gradient. There was a cross wind at the time, but the experiment was made in a cutting where the trucks were sheltered. It is perhaps better to make the gradients 0·75 per chain on easy curves, and 1·00 per chain on sharp curves.

[2] Minutes of Proceedings Inst. C.E., vol. xli. pp. 22 *et seq.*, and p. 39.

rails, are given. For new yards, fully dimensioned plans of all the distances between the crossings, &c., should be prepared, and where necessary the back rails lengthened as in Figs. 5 and 6, to avoid short lengths, as nothing looks worse than these, except indeed irregularity in the lines and curves.

The following Table gives the leading particulars of the curves most used.

Radius.	Angle of Crossing.	Distance from Heel of Switch to Centre of Crossing.	Purpose for which used.
Chains.		Feet. Ins.	
20½	1 in 12	81 0	Facing-point junctions.
14¼	1 in 10	67 6	Do. do.
9	1 in 8	54 0	In sidings where engines and six-wheeled coaches run.
7	1 in 7	47 3	
5	1 in 6	40 6	In sidings where the speed is not likely to be high. (For goods wagons and engines.)

Station Buildings.

Two examples of station offices are shown in Figs. 19 and 20. The former of these is for a small country town, and the latter for one of some fifty thousand inhabitants. The accommodation required varies according to local circumstances, but the sizes may be taken as a general basis for working from.

The general waiting-room or booking-hall, and also the parcels office and cloak-room, should have dado boarding all round as a protection from luggage, and the doors should be 4 feet 6 inches wide. The parcels office and cloak-room should both have shelves 3 feet wide all round placed 3 feet apart vertically, opening windows both to the platform and the roadway, each with a shelf 3 feet above the ground and 2 feet wide, and a desk with three or four drawers. Where the booking-office does duty also for the parcels and cloak-room, the door should be divided and a shelf fixed on the lower half.

The booking-office should have, for the smaller stations, one ticket-window, and for the larger three ticket-windows, and these sometimes in duplicate. They should be 12 inches wide and 18 inches high, on a shelf 3 feet 6 inches above the floor. This shelf should project about a foot from the face of the wall to receive anything a passenger may be carrying. In front a barrier, also 3 feet 6 inches high and about 4 feet long, should be placed, a space of two feet being allowed between it and the shelf. Inside the office, provision must be made for the ticket cases which usually require a width of 6 feet. It is often convenient for the station-master's office, cloak-room and parcels office to communicate direct with the booking-office.

The porters-room should have in it a small cooking stove, and a seat all round, with lockers under. At the larger stations, rooms should be provided for the guards, ticket-collectors, and inspectors.

The rooms for lamps, foot-warming apparatus and coals do not require plastering, but should simply be whitewashed. They should be situated away from the main building where possible, to avoid all risk of fire.

The ladies-room is really only a lobby to the water-closets, and need in no case be very large. For the first-class room the water-closet should be 6 feet long and 4 feet wide, and the pipes and cisterns should be covered with boxing, so fixed that the working parts can be easily got at. The gentlemen's water-closets should be 3 feet by 6 feet, but in case of need they may be reduced to 2 feet 9 inches by 5 feet 6 inches, or even 5 feet; but 3 feet by 6 feet is the proper size. It is better where possible to have the closets open at the top and to line them with white glazed bricks. The cisterns, &c., need not be boxed in. In all cases the seats should be 1 foot 10 inches wide by 1 foot 6 inches high. The divisions in the urinal should be not less than 2 feet apart, with a Yorkstone or concrete floor. For lavatories a single basin is generally sufficient for a ladies-room, and three basins for the gentlemen's.

The refreshment rooms should be provided with a counter 2 feet 6 inches wide and 3 feet 6 inches above the floor. Behind the counter there should be a width of 4 feet 6 inches, of which 1 foot is taken up by shelves placed in tiers one above the other, 18 inches apart at the bottom and 12 inches at the top. In front should be a space of from 5 to 8 feet, or more if provision is needed for tables. The kitchen should have a cooking range, and also a sink and supply of water. The cellar should be 6 or 9 feet wide to allow for one or two rows of barrels. An opening 3 feet by 3 feet should be made into it, and pipes laid to carry those from the machines, and a second opening with steps down should also be made.

WEIGHT OF ENGINES.

With regard to the weight of engines, none on the North Staffordshire, Eastern and Midlands, Maryport and Carlisle, Cambrian, Rhymney, Severn Bridge, Belfast and Northern Counties, Cork, Bandon and South Coast, Great Northern (Ireland), and Great Southern and Western Railways, weigh more than 45 tons in a length of 30 feet (buffer to buffer), or have a greater load on one axle than 16 tons. The London and South-Western, Mersey, and London, Tilbury and Southend Railways have engines with 18, 17, and 16 tons respectively on one axle.

The following are particulars of some of the heaviest engines in use:—

—	Length, Buffer to Buffer.	Weight.	Maximum Weight on one Axle.
	Feet.	Tons.	Tons.
Lancashire and Yorkshire . .	36·7	56·7	17·5
Metropolitan	31·8	46·6	18·6
South Eastern	32·7	46·3	15·8
Great North of Scotland . . .	29·7	35·7	13·5
Waterford and Limerick . . .	27·0	38·5	13·0

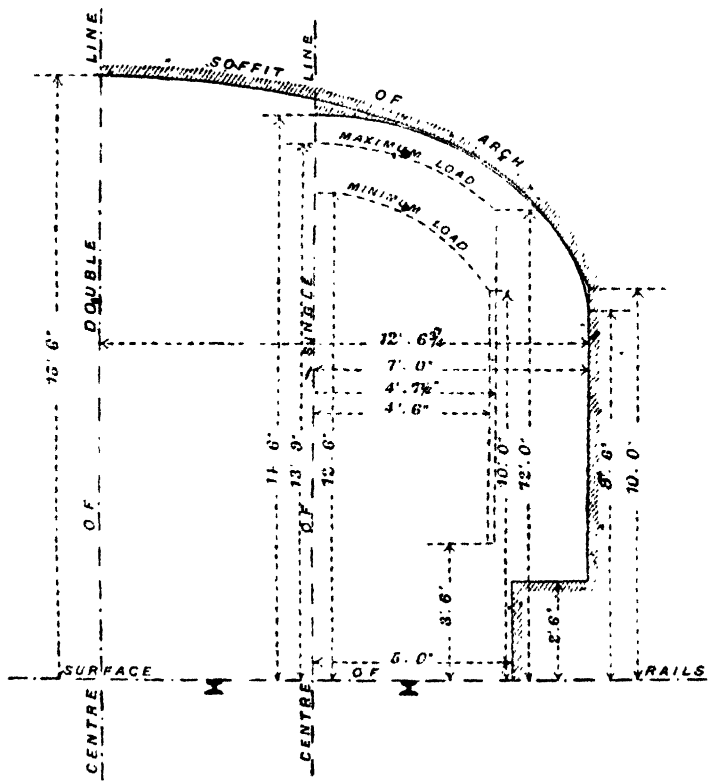
GENERAL DATA.

As to the height of platforms, General Hutchinson has informed the Author that the Board of Trade does not object to a greater height than 2 feet 6 inches. Messrs. Dawson, Landre, and Burke endorse the statements in the Paper relating to gravitation sidings and the tractive power of engines, and Mr. Keeling that as to gravitation sidings. Mr. Andrews states that the tractive power of the London and South-Western engines is, on an average, one-sixth the weight on the driving-wheels, and Mr. Tighe that on the Waterford and Limerick Railway it is more than this. Mr. Hunt uses 1 in 85 as the incline for gravitation sidings on the Lancashire and Yorkshire Railway. Mr. Stubbs, the late engineer of the Manchester, Sheffield, and Lincolnshire Railway, found 1 in 110, where the road was in good order, and 1 in 70 where it was not, as in the case of colliery sidings, to work well. He laid out three important gravitation sidings, in addition to many others for collieries. Mr. Johnson, the engineer of the Great Northern Railway, states that he has found 1 in 100 for easy curves, and 1 in 70 or 80 for sharp curves, to work well.

TABLE OF STANDARD DIMENSIONS.

This Table has been compiled from information supplied through the courtesy of the engineers of the different railway companies; it will be found valuable generally, especially to those who are designing works on lines that adjoin those given. It will be seen that there is a considerable variation in the standards of the different lines; but owing to the gradual way in which railways have been developed, this was only to be expected. To take one instance, the distance from the rail to the platform in the case

Fig. 1.



of two very important companies shows a difference of no less than 3 inches. What the Author himself considers either the best or the most common practice is given in the columns headed, "Suggested Standard," and he thinks that especially in some of the items the fixing of a common standard would be advantageous. *Fig. 1* shows the minimum structure which will allow for the passage of all the loads given in the

Table. The dotted lines marked Maximum Load and Minimum Load may, with a few exceptions, be taken:—the first as a guide for the minimum structure, and the second as the maximum gauge for the rolling-stock. In the minimum structure there is, of course, an exception in the case of the platforms as in Figs. 7 and 8.

The Paper is accompanied by the diagrams, from which Plate 5 and *Fig. 1* have been engraved.

APPENDIX I.—TABLE of STANDARD DIMENSIONS.—ENGLISH

—	Suggested Standard. Feet.	Ins.
Distance from centre to centre between main lines or sidings .	11	1½
„ „ centre of single line to coping of passenger platform[1]	4	9
„ „ „ „ goods „	4	9
„ „ „ „ cattle „	4	9
„ „ „ „ horse-box „	4	9
„ „ „ „ coal-wharf . .	4	9
„ between copings of platforms on double line . . .	20	7½
Height from surface of rails to surface of passenger platform .	2	6
„ „ „ goods „ .	3	9
„ „ „ cattle „ .	3	9
„ „ „ horse-box „ .	3	9
„ „ „ carriage-dock „ .	4	0
„ „ „ coal-stage for engines .	3	9
„ „ „ centre of buffers	3	5
Length of passenger platforms on main and suburban lines . .	450	0
„ „ „ branches	350	0
„ cattle pens between centres (*i.e.* length of cattle wagons, buffer to buffer)	21	0
Depth of engine-pit from surface of rails	2 9 down to 3 3	
Diameter of engine turntable	50	0
Distance from centre of single line to abutment from 2 feet 6 inches above the rails	7	0
Height from rail-level to soffit of arch at centre of single line .	14	6
„ „ „ 4 feet 6 inches from centre of single line	13	0
„ „ „ about 7 feet from centre of single line (*i.e.* at the abutment)	10	0
Width of passenger carriage with doors open	12	7
Width of load from 3 feet 6 inches above rail-level	9	0
Height „ rail-level in centre	12	6
„ „ „ at side	10	0

[1] With four exceptions the wall is set back 3 inches from the coping, which is carried by two sailing courses. The exceptions are on the London and South Western Railway, where it is set flush, and on the Maryport and Carlisle, the

AND SCOTCH LINES. Gauge, 4 feet 8½ inches.

Glasgow and South Western.		Great Eastern.		Great Northern.		Great Western.		Lancashire and Yorkshire.		Manchester, Sheffield and Lincoln.		Midland.		North British.		North Eastern.		London, Brighton and South Coast.	
Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.
11 1½ and 11 1¾		11 1¾ and 11 1½		11	3[2]	11	2½	11	1½	11	1½	..		11	1	11	1½	11	2
4	10¾	4	9	4	9	4	7¼	4	6¾[3]	4	9	4	10¼	4	9	4	9	4	8
4	9¾	4	9	4	9	4	7¼	4	6¾	4	9	..		4	9	4	9	4	8
4	9¾	4	9	4	9	4	10½	4	6¾	4	9	..		4	9	4	9	4	10
4	9¾	4	9	4	9	4	7¼	4	6¾	4	9	..		4	9	4	9	4	10
4	9¾	4	9	4	9	..		4	6¾	4	9	..		4	9	4	9	4	10
20	11	20	7½	20	9	20	5	20	3	20	7½	..		20	7	20	7½	20	6
2	6[4]	3	0	2	6[4]	2	9	2	6	2	9	2	6[4]	2	6	2	6[4]	2	6
3	6	3	3	3	6	3	3	3	9	3	9	..		3	6	3	6	3	6
3	6	3	6	3	3	3	3	3	9	3	6	..		3	6	3	6	3	3
3	[illegible]	3	6	4	3	3	3	3	9	3	6	..		3	6	3	6	3	3
3	10	3	9	4	0	4	0	3	9	4	1	..		3	9	3	6	4	3
3	6	3	9	4	0	10	6	7	0	8	0	..		10	0	8	0	3	6
3	5	3	6	3	6	3	5	3	5	3	5½	3	5	3	5½	3	5	3	6
400 0 to 700 0		450	0 (min.)	600	0	300 0 to 800 0		600	0	450	0	..		..		600	0	500	0
..		300	0	420	0	200 0 to 400 0		variable		300	0	..		..		330	0	400	0
20	0	variable		20	0	21	0	20	9	22	0	..		19	0	19	4	21	0
2 9 to 3 0		2	7	2	10	2	6	2 6 to 3 0		3	0	..		2 0 to 3 0		2	2	2	8
50	0	50	0	50	0	45	0	50	0	50	0	50	0	50	0	50	0	45	6
7	6	7	0	7	0	7	6	7	6¾	7	6	..		..		6	9	7	0
14	0	13	9	14	6	14	3	14	6	14	6	..		..		14	6	14	0
..		12	6	..		12	8	13	0	11	6	..		..		13	3	12	0
10	0	10	3	..		10	3½	10	0	10	0	..		..		11	1½	10	0
12	6½	13	3[5]	12	7	13	2	12	4¾	12	3½	..		12	5	12	6	12	5
9	0	9	0	9	3	9	0	9	0	9	3	9	0	9	0	9	0	9	0
12	9	13	0	13	9	13	2	12	6	13	5	13	9	12	11	13	6	13	6
11	0	11	0	10	3	11	0	10	0	10	5	10	9	10	6	11	0	12	0

[2] 11 feet for sidings.
[3] 4 feet 8¾ inches on curves.
[4] 2 feet 6 inches and 3 feet.
[5] Over handle, the carriage door itself is 13 feet 1 inch.

APPENDIX I.—TABLE OF STANDARD DIMENSIONS.—ENGLISH

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„ „ „ „ cattle „	4	9
„ „ „ „ horse-box „	4	9
„ „ „ „ coal-wharf „	4	9
„ between copings of platforms on double line . . .	20	7½
Height from surface of rails to surface of passenger platform . .	2	6
„ „ „ goods „ .	3	9
„ „ „ cattle „ .	3	9
„ „ „ horse-box „ .	3	9
„ „ „ carriage-dock „ .	4	0
„ „ „ coal-stage for engines .	3	9
„ „ „ centre of buffers	3	5
Length of passenger platforms on main and suburban lines . .	450	0
„ „ „ branches	350	0
„ cattle pens between centres (*i.e.* length of cattle wagons, buffer to buffer)	21	0
Depth of engine-pit from surface of rails	2 9 down to 3 3	
Diameter of engine turntable	50	0
Distance from centre of single line to abutment from 2 feet 6 inches above the rails.	7	0
Height from rail-level to soffit of arch at centre of single line .	14	6
„ „ „ 4 feet 6 inches from centre of single line	13	0
„ „ „ about 7 feet from centre of single line (*i.e.* at the abutment)	10	0
Width of passenger carriage with doors open	12	7
Width of load from 3 feet 6 inches above rail-level	9	0
Height „ rail-level in centre	12	6
„ „ „ at side	10	0

[1] With four exceptions the wall is set back 3 inches from the coping, which is carried by two sailing courses. The exceptions are on the London and South Western Railway, where it is set flush, and on the Maryport and Carlisle, the Brighton, and the Lancashire and Yorkshire Railways, where it is set back

AND SCOTCH LINES. Gauge, 4 feet 8½ inches.—*continued.*

London and South Western.		London, Chatham and Dover.		London and North Western.		London, Tilbury and Southend.		Cheshire Lines.		South Eastern.		North Staffordshire.		Highland.		Great North of Scotland.		Cleator and Workington.	
Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.
11	1½	11	1½	11	2	11	1½	11	1¾	11	1½	11	2	11	1½	11	1½	11	2
4	8	4	9¾	4	7	4	9¾	4	10¼	4	8½	4	8⅝	4	9½	4	8½	4	8
4	9¾	4	8¾	..		4	9¾	4	8½	4	8½	4	8⅝	4	9½	4	11½	4	8
4	10	4	8¾	..		4	9¾	4	8½	4	8½	4	8⅝	4	9½	4	11½	4	10
4	10	4	8¾	..		4	9¾	4	8½	4	8½	4	8⅝	4	9½	4	11½	4	10
4	10	4	8¾	..		5	3¾[2]	4	8½	4	8½	4	8⅝	3	3	4	11½	4	10
20	5½	20	9	20	4	20	9	20	10¼	20	6½	20	7¼	20	8½	20	6½	20	6
2	6	2	6	2	6[4]	2	6	3	0	2	9	2	6	1	6[3]	2	6	2	4
3	3	3	3	..		3	6	3	6	..		3	6	3	9	3	6	3	8
3	3	3	3	..		3	9	3	6	..		3	6	3	9	3	6	3	8
3	3	3	3	..		3	9	3	6	..		3	9	3	6	..		..	
3	9	4	2	..		3	9	4	0	..		4	3	4	0	4	1	..	
3	6	3	5	9	0	5	3	4	0	..		5	6	10	0	3	6	..	
3	5	3	5	3	5	3	5½	3	4½	3	5	3	5	3	5	3	4	..	
600	0	..		..		540	0	450	0	450	0	300	0	300 to 1200	0 to 0	400	0	200	0
300	0	..		..		540	0	350	0	350	0	300	0	300 to 400	0 to 0	300	0	200	0
21	0	21	6	21	0	19	6	20	0	..		19	0	19	0	20	0	18	0
3	0	2	9	2	9	3	0	2	9	..		2 to 3	9 to 1	3	0	3	0	3	3
50	0	50	0	50	0	42	0	50	0	45	0	42	0	50	0	50	0	42	0
7	0	7	0	6	7	7	0¾	7	6	7	0	7	0	7	6	7	6	7	0
13	9	14	6	14	3	13	9	14	6	14	0	14	0	13	6	14	0	14	6
12	0	..		12	2	12	6	11	3	..		12	0	..		..		13	0
10	6	..		10	3	10	3	10	0	..		10	0	11	3	11	3	10	6
12	6¼	12	6	12	9	12	2	12	3	..		12	2¾	12	7	12	7	12	0
9	3	9	0	9	0	9	0	9	3	9	0	8	6	9	0	9	0	9	6
13	4	13	6	13	6	13	0	13	8	13	6	13	5	13	0	12	9	13	0
10	10	10	11	11	0	11	0	10	4	10	11	11	6	11	0	11	3	11	0

[2] 8 feet 6¾ inches from main line; 5 feet 3 inches high on locomotive side; 4 feet on truck side.

[3] 1 foot 6 inches to 3 feet 6 inches.

[4] 3 feet at terminal stations.

APPENDIX I.—TABLE OF STANDARD DIMENSIONS.—ENGLISH

—	Suggested Standard.	
	Feet.	Ins.
Distance from centre to centre between main lines or sidings .	11	1½
,, ,, centre of single line to coping of passenger platform[1]	4	9
,, ,, ,, ,, goods ,,	4	9
,, ,, ,, ,, cattle ,,	4	9
,, ,, ,, ,, horse-box ,,	4	9
,, ,, ,, ,, coal-wharf ,,	4	9
,, between copings of platforms on double line . . .	20	7½
Height from surface of rails to surface of passenger platform . .	2	6
,, ,, ,, goods ,, .	3	9
,, ,, ,, cattle ,, .	3	9
,, ,, ,, horse-box ,, .	3	9
,, ,, ,, carriage-dock ,, .	4	0
,, ,, ,, coal-stage for engines .	3	9
,, ,, ,, centre of buffers	3	5
Length of passenger platforms on main and suburban lines . .	450	0
,, ,, ,, branches	350	0
,, cattle pens between centres (*i.e.* length of cattle wagons, buffer to buffer)	21	0
Depth of engine-pit from surface of rails	2 9 down to 3 3	
Diameter of engine turntable	50	0
Distance from centre of single line to abutment from 2 feet 6 inches above the rails.	7	0
Height from rail-level to soffit of arch at centre of single line .	14	6
,, ,, ,, 4 feet 6 inches from centre of single line	13	0
,, ,, ,, about 7 feet from centre of single line (*i.e.* at the abutment)	10	0
Width of passenger carriage with doors open	12	7
Width of load from 3 feet 6 inches above rail-level	9	0
Height ,, rail-level in centre	12	6
,, ,, ,, at side	10	0

[1] With four exceptions the wall is set back 3 inches from the coping, which is carried by two sailing courses. The exceptions are on the London and South Western Railway, where it is set flush, and on the Maryport and Carlisle, the Brighton, and the Lancashire and Yorkshire Railways, where it is set back

AND SCOTCH LINES. Gauge, 4 feet 8½ inches.—*continued.*

East and West Junction.		Eastern and Midlands.		Maryport and Carlisle.		Mersey.		Metropolitan.		Mid-Wales.[3]		Cambrian.		Rhymney.		Severn Bridge.	
Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.
11	2	11	1½	11	1¾[2]	11	1½	11	1½	11	1½	11	1½	11	1½	11	1
4	11	4	9	4	8⅜	4	11½	4	7¼	4	9	4	9	4	7½	4	9
4	11	4	9	4	8⅜	..		..		4	9	4	9	4	7½	4	9
4	11	4	9	4	8⅜	..		..		4	9	4	6½	4	7½	4	9
4	11	4	9	4	8⅜	..		..		4	9	4	7	4	7½	4	9
4	11	4	9	4	8⅜	5	1¼	..		4	9	4	7	4	7½	4	9
21	0	20	7½	20	6½	21	0½	20	4	20	7½	20	7½	20	4½	20	7
2	6	2	6	2	4	3	0	3	1½	2	0	2	6	2	9	2	6
3	9	3	9	3	9	..		..		4	0	3	9	3	9	3	9
3	9	3	9	3	9	..		..		4	0	3	9	3	9	3	9
3	9	3	9	3	6	..		..		4	0	3	9	3	9	3	9
3	9	4	0	3	6	..		..		4	0	3	9	3	9	3	9
3	9	3	9	..		4	8	3	10	4	0	3	9	3	9	3	9
3	5	3	5	3 5 to 3	6½	..		3	4	3	4	3	6	3	4½	3	5
500	0	350	0	600	0	400	0	300	0	variable		var.		300	0	310 0 to 210	0
350	0	350	0	300	0	400	0	400	0	..		..		..		..	
23	0	22	7½	19	0	..		..		20	0	19	0	21	0	..	
3	0	2 9 to 3	3	2	3	3	0	2	10½	3	0	2	8	3	0	3	0
42 0 and 46	0	47	0	45	0	50	0	..		40	0	40	2	45	0	50	0
6	9	7	0	6	7	..		6	10½	6	9	7	0	6	11½	7	0
14	0	14	0	14	0	..		13	0	14	0	14	0	14	0	14	0
12	6	12	3	12	0	..		11	5	12	0	12	6	..		12	0
10	7½	10	0	9	7	..		5	9	..		10	0	..		10	0
12	2	12	7	12	3	12	0	12	3¼	12	6	12	6	12	4½	..	
9	0	9	0	9	2[4]	..		9	0	9	0	9	0	9	0	9	0
13	6	13	6	13	4[4]	..		12	8	13	6	13	6	13	0	13	9
11	0	10	9	11	0[4]	..		10	6	10	6	11	0	12	0	10	9

[2] 12 feet 1¾ inch for sidings.

[3] As the Mid-Wales Railway is now part of the Cambrian system this column is cancelled.

[4] These differ from the Clearing House dimensions.

APPENDIX I.—TABLE of STANDARD DIMENSIONS.—IRISH

	Suggested Standard. Feet.	Ins.
Distance from centre to centre between main lines or sidings .	11	8
,, ,, centre of single line to coping of passenger platform[1]	5	2
,, ,, ,, ,, goods ,,	5	2
,, ,, ,, ,, cattle ,,	5	2
,, ,, ,, ,, horse-box ,,	5	2
,, ,, ,, ,, coal-wharf ,,		
,, between copings of platforms on double line . . .	22	0
Height from surface of rails to surface of passenger platform . .	3	0
,, ,, ,, goods ,, .	3	6
,, ,, ,, cattle ,, .	3	6
,, ,, ,, horse-box ,, .	3	6
,, ,, ,, carriage-dock ,, .	4	0
,, ,, ,, coal-stage for engines .	3	6
,, centre of buffers	3	5
Length of passenger platforms on main and suburban lines .	450	0
branches	350	0
,, cattle pens between centres (*i.e.* length of cattle wagons, buffer to buffer)	19	0
Depth of engine-pit from surface of rails	2 to 3	9 to 3
Diameter of engine turntable	45	0
Distance from centre of single line to abutment from 2 feet 6 inches above the rails.	7	8
Height from rail-level to soffit of arch at centre of single line .	14	0
,, ,, ,, 4 feet 6 inches from centre of single line	13	3
,, ,, ,, about 7 feet from centre of single line (*i.e.* at the abutment)	10	0
Width of passenger carriage with doors open . .	14	0
Width of load from 3 feet 6 inches above rail-level	9	0
Height ,, rail-level in centre	12	6
,, at side	9	6

[1] With one exception the wall is set back 3 inches from the coping. The exception is the Cork and Bandon, on which it is set flush.

LINES. Gauge 5 feet 3 inches.

Belfast and Northern Counties.		Cork, Bandon and South Coast.		Dublin, Wicklow, and Wexford.		Great Northern (Ireland).		Great Southern and Western.		Midland Great Western.		Waterford and Limerick.	
Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.	Feet.	Ins.
11	8	11	$7\frac{1}{2}$	11	8	11	8	11	$7\frac{3}{4}$	11	$8\frac{1}{4}$	11	8
5	0	5	$2\frac{3}{4}$	4	11	5	1	5	$1\frac{7}{8}$	5	$0\frac{13}{16}$	5	1
5	0	5	$2\frac{3}{4}$	4	11	5	1	5	$1\frac{7}{8}$	5	$0\frac{13}{16}$	5	1
5	0	5	$2\frac{3}{4}$	4	11	5	1	5	$1\frac{7}{8}$	5	$0\frac{13}{16}$	5	1
5	0	5	$2\frac{3}{4}$	4	11	5	1	5	$1\frac{7}{8}$	5	$0\frac{13}{16}$	5	1
..		5	$2\frac{3}{4}$	4	11	5	1	6	$3\frac{7}{8}$	5	$0\frac{13}{16}$	5	1
21	8	22	1	21	6	21	10	21	$11\frac{1}{2}$	21	$9\frac{7}{8}$	21	10
2	9	3	0	2	6	3	0	2	6	3	1	3	3
3	4	3	10	3	3	3	4	3	6	3	6	3	6
3	4	3	10	3	3	3	4	3	6	3	6	3	6
3	4	3	10	3	3	3	4	3	6	3	6	3	6
3	4	3	10	4	0	4	0	4	0	3	6	3	9
..		3	10	..		3	4	..		3	6	3	6
3	4	3	5	3	4	3	4	3	6	3	6	3	5
300	0	300	0	450	0	400 0 to 580	0	600	0	300 0 to 600	0	400	0
250	0	200	0	350	0	300 0 to 400	0	300	0	300	0	300	0
..		17	3	17	0	19	0	17	6 [2]	16	8	18	0
3	0	3	0	3.	0	2 6 to 3	3	2 0 to 2	3	3	0	3	0
40	0	22	0	45	0	42	0	45	0	42	0	44	0
7	6	7	0	7	0	7	0	7	4	7	8	7	0 [3]
14	0	13	6	13	6	14	0	14	0	13	9	14	0
..		..		..		13	3	12	0	12	5	12	6
..		..		..		9	6	10	0	10	4	6	6
13	0	13	6	13	6	13	3	13	$3\frac{1}{2}$	13	8	13	6
10	0	10	0	9	6	9	6	10	8	9	6	9	0
13	0	12	6	13	6	13	3	14	0	12	9	13	6
10	9	9	6	11	0	11	6	12	1	11	6	11	6

[2] No cattle pens, but open wharf with guides.
[3] 7 feet 6 inches for arches.

APPENDIX II.—TABLE GIVING THE TOTAL LOADS AND NUMBER OF 12-TON TRUCKS OR COACHES THAT DIFFERENT ENGINES WILL TAKE UP VARIOUS GRADIENTS.

Weight of Engine and Brake.	4-coupled with 8 Tons on each Axle. 36 tons.		6-coupled with 8 Tons on each Axle. 36 tons.		4-coupled with 12 Tons on each Axle. 48 tons.		6-coupled with 12 Tons on each Axle. 48 tons.		4-coupled with 16 Tons on each Axle. 60 tons.		6-coupled with 16 Tons on each Axle. 60 tons.	
Gradient.	Total Load.	No. of Vehicles.	Total Load.	No. of Vehicles.	Total Load.	No. of Vehicles.	Total Load.	No. of Vehicles.	Total Load.	No. of Vehicles.	Total Load.	No. of Vehicles.
Easy Curves.	Tons.		Tons.		Tons.		Tons.		Tons.		Tons.	
1 in 40	90	4	135	8	135	7	202	13	181	10	270	17
1 in 60	126	7	189	12	189	11	284	19	252	16	378	26
1 in 80	157	10	235	16	235	15	352	25	314	21	470	34
1 in 100	184	12	276	20	276	19	414	30	368	25	552	41
1 in 200	281	20	421	32	421	31	631	48	562	42	842	65
Sharp Curves.												
1 in 40	78	3	117	6	117	5	175	10	156	8	236	14
1 in 60	104	5	156	10	156	9	234	15	203	12	312	21
1 in 80	124	7	186	12	186	11	280	19	250	16	373	26
1 in 100	141	8	212	14	212	13	320	22	283	17	423	30
1 in 200	191	13	286	21	286	20	430	32	383	27	575	43

(*Paper No. 2465.*)

"The West Hallington Reservoir."

By Charles George Henzell, Assoc. M. Inst. C.E.

This reservoir, which was begun in April 1884, and finished in January 1890, is the completion of a system commenced in the year 1876. It has no separate drainage area, but is used in conjunction with the East Hallington, Little Swinburn, and the Colt Crag Reservoirs, which have a total drainage area of 9,915 acres, with an available rainfall of 12 inches. It is situated nearly 10 miles north of Corbridge-on-Tyne, and is 24 miles from the district of supply.

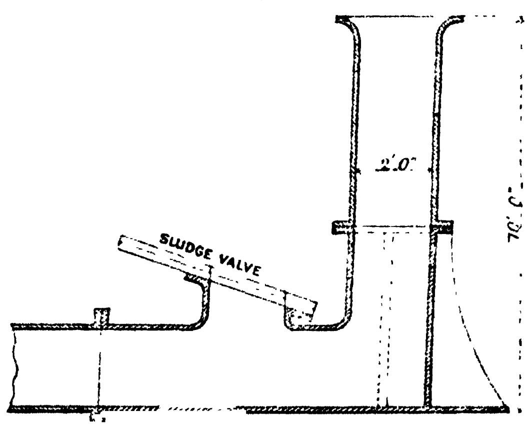
The reservoir is directly on the west side of the East Hallington, with which it is connected by a 42-inch cast-iron pipe. The height of the West Hallington reservoir is 504 feet above Ordnance datum, and 2 feet above the east reservoir; it has a water-area of 126 acres, and contains 743,417,097 gallons when full. The depth is 34 feet 6 inches to the lip of the sludge-valve. It is intended to use this as a reservoir for water from the River Rede.

The geological formation, which consists of the Bernician series and limestones, is very faulty, owing to the Great Whin Dyke, which runs between the Colt Crag and Hallington reservoirs. The outcrop of the limestone in the Colt Crag reservoir has caused a great deal of expense and trouble. All over the basin of the reservoir is a layer of hard boulder-clay at varying depths, and this is again overlaid by boulder-clay of a soapy nature, called the book-leaf marl, from its finely laminated structure.

The East Bank.—The first part of the work commenced was the East Bank and outlet-pipe. The main dimensions of the bank are:—height, 41 feet 3 inches at the old aqueduct; a slope of 3 to 1 inside, and of 2 to 1 outside; a puddle-wall 8 feet wide at the top, with a batter of 1 in 12 downwards. The bank is 14 feet wide at the top, and the inner face is protected by 2 feet of stone pitching.

The outlet-pipe was laid along the course of the old aqueduct, and the cutting carried into the boulder-clay, which was here reached at 45 feet below the top of the bank. At the centre of the trench a mass of concrete was laid, 24 feet long by 15 feet wide, and altogether 7 feet 6 inches high, in which the pipe was bedded, and on the centre pipe was cast a flange 2 inches thick, to which was bolted a wrought-iron plate ½ inch thick, extending 3 feet above and below the centre, and 5 feet on each side. The pipes themselves were 1½ inch thick, and, for three pipe-lengths, flanged and jointed with planed joints, with ¼-inch groove for lead-wire packing. After leaving the centre stop, the pipes were socket-jointed with ordinary lead and yarn packing. The pipes are surmounted by a layer of concrete, 1 foot thick below and 6 inches above, and a stop 1 foot wide and deep was made in concrete all the way round at every 10 feet. At the inside toe was placed the bell-mouth opening to the outlet-pipe; it stands

Fig. 1.



Scale ⅛ inch = 1 foot.

INLET PIPE.

10 feet high, and there is no method of closing it on the inside. The sludge-valve is 7 feet 6 inches below the bell-mouth, and is only used when the water is low (*Fig. 1*). The whole is set on concrete 2 feet thick, and is surrounded by a horse-shoe forebay of brick in cement. The wall is 10 feet high; 6 feet 6 inches at the bottom, and 2 feet at the top, coped with ashlar cope 8 inches thick; it was made strong on account of the book-leaf marl, which ran along the cutting. The sludge-valve rod is taken up the bank to above top water-level, and is there worked by a worm and screw-gearing. At the toe on the outside is placed the first valve-well, in which is a double-faced valve and a 4-inch air-pipe taken from the inside of the valve, and carried up the bank to the top, ending in a rose-head. After the outlet-pipe had been

laid, the puddle-trench was proceeded with. The hard boulder-clay was reached at an average depth of 8 feet throughout, and the book-leaf marl was only touched in the old cutting. It was very soft at this point at the south side, and the old aqueduct had been piled and piped through this portion. However, the lie of the clay and the solid brickwork placed at the toes stopped any movement that might have been caused by the weight of the bank. At a point between 8 and 10 chains some running sand was met with below the book-leaf marl, so that the gutter had to be carried down to 25 feet 6 inches below the surface of the old cutting. Going south from this place, an ancient British burial-place was cut into, and an urn with ashes found.

The east bank was well put up, and little settlement occurred until January 29th, 1885, when it went down 2 feet in the centre for about 2 chains' length between 8 and 10 chains, and just over the book-leaf marl. On the 30th it again went down 1 foot, but since then very little settlement has occurred.

The cost of the bank for labour and shore-work was £4,398, or 2*s.* 9*d.* per cubic yard, including cutting puddle.

The bank is protected on the water side by a wash-wall, 4 feet high, 2 feet 9 inches thick at the base, and 16 inches at the top. This wall is necessary, as the banks are only 4 feet higher than water-level, and with the strong north-westerly gales the spray washes over.

The outlet-works consist of a pipe-track 22 chains long; a brick and stone bridge, a valve-well, and a gauge-tank. After leaving the valve-well at the toe of the bank, the pipe is laid along the course of an old aqueduct for a distance of 21 chains; at 17·50 chains an 18-inch sludge-pipe is taken off, and discharges into the Erring Burn. At 18 chains a brick and stone bridge, 63 feet long, is built over the Erring Burn to carry the outlet-pipe over. It is 5 feet wide in the clear, and has a span of 10 feet. The spandril walls are 1 foot 6 inches thick, and have buttresses at each side 2 feet wide and thick. The parapet-walls are panelled out, and there is a short iron hand-rail fixed above the coping. The foundations were all put in with concrete, and the piers built up in stone to the springing courses. A little further on is the second valve-well. It is of brick and stone, 9 feet by 8 feet inside; the walls are 1 foot 9 inches thick, built in cement; it has also a brick and cement floor, laid in concrete 6 inches thick. It contains a double-faced valve, commanding the gauge-tank and outlet. It is covered with cast-iron plates, upheld by light T girders, 2½ inches deep. Immediately beyond the valve-well stands the gauge-tank. It is on made ground, and was difficult to get water-tight, owing to settlements in the soft ground. The foundation consists of concrete 12 inches thick, and above that a brick-on-end in cement. The walls are 2 feet 9 inches thick, and rendered on the inside with 1 inch of cement to make them water-tight. The water enters at the narrow end through a bell-mouth pipe, and is stilled by a series of bridges, three in number, 1 foot 6 inches thick, and 10 feet long, leaving 4 feet between the bridge and the side of the tank. Beyond the last bridge is placed the weir, 12 feet long, and the water in the tank must be 4 feet deep before it can flow over. The weir is of cast-iron, to which is bolted a wrought-iron plate with a knife-edge. The water is regulated by an ordinary ball-float, contained in a casing placed at the left of the weir. The tank is 14 feet wide, and 30 feet long. After leaving the gauge-tank, the water enters the open aqueduct, which conveys it to Whittle Dean.

The South Bank (Plate 6, Fig. 2) is 47·60 chains long. It has two bends, one at 22 chains called the Middle Bend, and the other at 39 chains called the West Bend. It was intended to build it on the same proportions as the East Bank, but it is now very much encumbered with offsets both on the inside and out. The depths at the east end are 45 feet at Burn, 16 feet 9 inches at Middle Bend, and 32 feet at West Bend. The slopes are 2 to 1 outside and 3 to 1 inside. It is covered on the inside by pitching 2 feet thick, and soiled on the outside. The puddle wall is 8 feet thick at top with a batter downwards 1 in 12.

There are two concrete walls, one at the east end 66 yards long, 8 feet deep and 4 feet thick, and one at the west end 99 yards long, 10 feet deep and 4 feet thick. There are also two sets of sheet piling, both at the east end; one at the toe outside 230 feet long, 20 feet deep and 6 inches thick between 6 and 9 chains, and the other on the toe inside directly opposite 254 feet long, 16 feet deep, and 6 inches thick. There is a wash wall 21 chains long, along the east end of the bank from the overflow to the Middle Bend.

As this bank for a part of its length is 10 feet below low-water level, it was necessary while sinking the trench and preparing the base to leave the old burn course open, until the bank had been tipped on either side above that height. In sinking the puddle trench many very serious difficulties had to be contended with, and as it was absolutely necessary to reach the boulder-drift, the trench had often to be sunk 30 feet or nearly so. Over the trench where the burn crossed, a trough was fixed 3 feet wide and 1 foot

6 inches deep, made of 3-inch planks, and the trench excavated below.

The foundation for the whole length was very bad, and the thin soapy book-leaf marl was frequently met with, especially between 5 and 13 chains (Plate 6, Fig. 3), where it was from 3 to 10 feet thick. It occurred also between 14 and 17 chains, and again between 38 and 43 chains (Plate 6, Fig. 4), with a thickness of from 2 to 7 feet. There was also a good deal of sand at the east end, where it extended from the surface down to the hard drift. At 13 chains there was a very thick bed, and the drift had to be gone through where it overlapped the sand. The trench here was 27 feet deep, and very close timbering was necessary. At 15½ chains a pot-hole had to be followed, in which a small feeder was met with coming from the inside; this was easily beaten back by the puddle. At this place no less than 20,000 lineal feet of 11-inch by 3-inch planks were in the trench at one time, and the trench had to be excavated in bays of 16 feet or 18 feet lengths, and timbered at the excavating end, the puddle cutters working the layers to within 5 feet of each other, until the surface level was nearly reached. After getting through the trouble at 15 chains a better foundation was met with, namely, a good standing marl which continued until 37 chains, the depths being from 12 to 18 feet. Beyond 37 chains the book-leaf marl was again met with near the surface, and below this a layer of wet sand 5 feet thick; there were two small pot-holes, which were soon bottomed. At 41 chains 7 feet of wet sand lay above the book-leaf marl, which was 2 feet thick; and below the marl was another layer of wet sand. When this had been gone through, a layer of soft boulder-clay was passed, into a white marl, very soft, and in August 1886, a black freestone was reached at 22 feet (Plate 6, Fig. 4). As there is no black freestone known within reasonable distance, it is supposed to be a huge boulder over 150 feet long and 70 or 80 feet wide. When the freestone was reached, a spring of 60,000 gallons in the 24 hours burst in and drowned everything out, so that two 6-inch pumps and one 4-inch hand-pump had to be kept going continually. The excavation was very costly, being 10*s.* per cubic yard. After getting the rock cleaned a total thickness of 8 feet of concrete was put in upon it, and the small quantity of water which still kept coming up between the concrete and the soft sides was soon completely stopped by the puddle. From this point, 42 chains, to the end there was nothing but layers of wet and dry sands. As the overflow had to be built between 0 and 1 chain, the puddle was stopped straight up at 2 chains, and cut up against the solid; this was afterwards removed and the puddle stepped back to enable a tight joint to be made with the by-wash tongues. In all the slips and settlements of the bank the puddle was never observed to go more than 6 inches out of the centre.

In the early part of 1886 the bank between 14 and 16 chains (Plate 6, Fig. 2) was observed to be cracked on the inside, and in April the ground at the toe bulged up. As it was not supposed to be serious, the cracked portions were taken out, the bank stepped up and the earth put back again in thin layers and well pounded. In May it was found necessary to put in a concrete wall. This wall was 4 feet wide, and was carried down through the soapy clay into the harder ground below, the timber used during the excavation being all left in. An offset was carried over it and across the burn to the other side, 3 feet deep over the concrete wall, and it may be noted that there was never any further trouble at this point. While the offset was being tipped over here, the bank, which was then 19 feet above the surface, was bulging out on the inside toe between 8 and 12 chains and on the outside between 7 and 9 chains. To prevent any further movement sheet piling was put in (Plate 6, Fig. 3). The piles on the toe outside were 20 feet long and 6 inches thick, and were driven through the marl and sand into the hard drift; there was 250 feet put in on the outside, and 248 feet, 16 feet long on the inside directly opposite. The piling was commenced on July 17th and finished September 7th, and within two days after, the clay had crept over the tops of the piles, which had been left 2 feet above the surface. On September 28th an offset was started on the inside, 26 feet from the top of the bank and 43 feet wide, and the outside was also weighted for a distance between 5 and 12 chains. This offset was finished in February 1887, but before it was quite completed the toe beyond the offset between 11 and 13 chains showed signs of bulging, and some extra weighting was put on which stopped it for a time. (This is No. 1 offset on the section, Fig. 3.) The bank had been slowly built up while the offsets were being put on. About May 1887, the toe on the outside between 5 and 7 chains showed signs of bulging, and an offset (No. 2) was commenced. This was 44 feet wide and 28 feet from the top of the bank. It was carried forward to 12 chains, but in June, as the outside toe between 12 and 14 chains showed bad signs it was continued further to 17 chains and finished there. The bank was then proceeded with, and in August when the top of the bank had almost been reached, the outside offset bulged up and overtopped the overflow by-wash wall, and the bank against the puddle settled down for 2 feet between 7 and 9 chains. No. 3 offset (Figs. 2 and 3) was at once proceeded with. It is 55 feet wide and 20 feet from the top of the bank, and has a slope of 1½ to 1 instead of 2 to 1 owing to the nearness of the by-wash wall During September the inside toe commenced to move from 7 to 11 chains, and a quantity of large stones and weighting was roughly put on, and an offset (No. 4) formed on the top of No. 1. The offset commenced at the edge of the beaching on No. 1, and sloped upwards at 4½ to 1, finishing in a flat 10 feet wide, at 8 feet from the top of the bank. Though this was commenced during October 1887 it was not finished until the middle of 1888, the whole length of the south bank being allowed to stand untouched until February 1888. The bank at the east end did not settle very much, and was easily dressed and finished. During the time the offsets were being put on at the east end, the book-leaf marl was again making the bank in a bad state at the west end. One offset and concrete wall had been put on during May 1887 (Fig. 4). The bank had gone down vertically about 6 feet during two days and bulged up 4 feet at the toe on the inside between 38 and 42 chains, the bank being then 7 feet from the top of the bank. Measures were at once taken to put in a concrete wall at the toe, 100 yards long and 8 feet wide. The ground was found to be in a very bad state and full of water, and one 6-inch pump had always to be kept going. There was a large amount of timber put in which was never removed but concreted up. A tolerably hard foundation was reached 10 feet below the surface. The wall was finished July 14th, and a heavy offset (No. 5) was commenced, 58 feet wide and 24 feet from the top of the bank, and after this was finished another offset was run along the top of the first, 48 feet wide [1] and 18 feet from the top of the bank; these were roughly beached over with 2 feet of Whin beaching, and finished during October 1887.

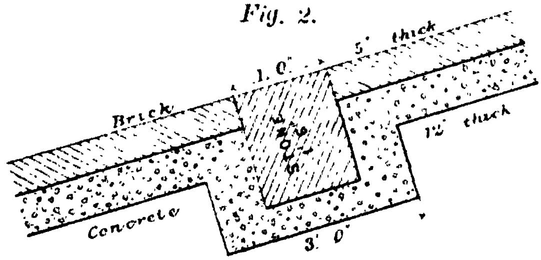
During September the toe outside had begun to move, and again in April, 1888. The slope of the bank from the West Bend to the end was, therefore, altered from 2 to 1 to 2½ to 1. In April, 1889, the outside again showed signs of giving, and a commencement was made to run an offset over it. A dry rubble retainment wall had to be built, as the toe was too near the boundary wall. It was made of large stones well bonded, and all placed by hand, and between this wall and the toe of the bank the offset

[1] This is wrongly given as 49 feet in Plate 6, Fig. 4.

was tipped (No. 7, Plate 6, Fig. 4). It is 20 feet from top bank, and 40 feet wide, and it was the last offset necessary on the bank, as since then there has been no sign of either settlement or movement. At the east end of the south bank, between 0 and 1 chain, is the overflow, which is 50 feet long, and narrows by curves into the by-wash.

The by-wash (Fig. 2) was built parallel, and is 10 feet wide and 10 chains long. For 130 feet it descends in steps, each step having a fall of 12 inches, and for the rest of the distance, it has an inclination of 6 inches to the chain, until it reaches the counterfall. This is a basin 6 feet deep, and below the floor of the by-wash: it has a slope from the by-wash of 1 in 4, and up into the tailbay of 1 to 2. The tailbay is at right angles to the by-wash, and is 12 feet wide, and 24 feet long, delivering into the burn below the south bank. The counterfall has always 5 feet of water in it, and is for the purpose of breaking the force of the current coming down the by-wash. The by-wash floor is laid in concrete varying in thickness from

Fig. 2.



1 foot to 4 feet, and owing to the nature of the strata, which consists of sand and the soapy clay, the concrete was stepped into the ground at every 10 feet, and an 18-inch sill let in; between the sills was laid the brick floor 5 inches thick (*Fig. 2*). The side walls are built of brick in cement, and are 2 feet 6 inches thick, backed with 1 foot of concrete up to 150 feet from the counterfall, and 6 inches thick beyond. The overflow sill is constructed of stones 3 feet deep and 18 inches wide, set on a foundation of concrete, which is carried into the boulder clay 6 feet below the bottom of the sill; the concrete is brought up on both sides of the sill, and in front is lipped over the puddle worked there, and is then beached with stone. Behind the sill the concrete is brought up to within 2 feet of the top, and stone slabs 3 feet wide and 12 inches thick set above. The side walls are carried to the top bank, 4 feet above the sill; they are built of brick 3 feet thick, and behind the walls is a thickness of 12 inches of concrete with two tongues 2 feet wide and 2 feet deep, into which the puddle is cut.

The West Bank, which is connected by the puddle wall to the south bank, is 19·50 chains long, 24 feet 3 inches deep at the burn, and 21 feet 6 inches on the flat. It contains 48,782 cubic yards of earthwork; 14,879 cubic yards of puddle, of which 6,138 cubic yards are extra; 994 cubic yards of concrete in the puddle trench at 9 and 12 chains. There is also a concrete wall at the toe inside between 11 and 14 chains, and 7,145 superficial yards of pitching. The cost of the bank for labour was £7,366, of which £3,761 is for extras.

The foundations on which the bank rest are very bad between 9 and 15 chains—in one place there is no less than 14 feet 9 inches of book-leaf marl; the remainder of the bank rests principally on hard marl and boulder-clay.

The puddle trench was begun in April 1887 at 10 chains, and the firm boulder-clay was reached at 12 feet, and the trench finished at 14 feet 6 inches, there being only a thin layer of book-leaf marl. After leaving 10 chains to work south, the boulder-clay turned very soft and sandy, and the book-leaf marl thickened to 14 feet 3 inches. At 9 chains it was also very wet, and the timbering could hardly be made to stand the working. The boulder-clay below the marl at 9 chains turned out very bad, and it was necessary to sink 12 feet lower before a firm foundation was reached. When 17 feet down, a small spring was touched in the drift, and followed down. From 10,000 gallons it increased to 60,000 gallons, and at 27 feet 6 inches it had risen to 244,000 gallons in the twenty-four hours; the bottom was then in firm hard clay, and a bore-hole was put down at 9·25 chains to test the strata. The result was 4 feet gravel, 4 feet boulder-clay, and 14 feet shale. At that depth (22 feet) another spring was touched, and an attempt was made to plug it up, but without success, so that it was found necessary to pipe the springs to surface. During this time two pulsometers (a No. 3 and No. 6) had been continually working. There were three springs, two nearly together at 9 chains, and one out of the bore-hole at 9·25. A wrought-iron tank, 5 feet by 3 feet of ¼-inch plate, was made with a flange-hole at the top for an 8-inch pipe. This was placed over two of the springs, and sunk into the ground 6 inches, on a frame of timber. An 8-inch pipe, with a 4-inch branch, was then fixed to the flange, the suction-pipe of the large pump put in, and the water pumped from the tank. The other pump was used to keep the third spring and surface-water down. The concrete was then carried up in layers to the socket in which the suction-pipe of the pump was placed; the suction-pipe was withdrawn, and a length of 8-inch pipe placed over it, the whole lowered into position in the fixed pipe, and the joint made. In this way every length was fixed until the surface was reached, when the pipes were carried through the outside part of the bank, enclosed in concrete resting on piles. The quantity of water diminished rapidly as the pipes were fixed, and when the surface was reached the flow was only 2,500 gallons during the twenty-four hours. There has been no trouble with the bank at this point since. The excavation for the trench was comparatively light towards the south. At 7 chains it was 13 feet deep through hard marl to the firm boulder-clay, and at 2 chains only 9 feet had to be excavated. In going north from 10 chains, there was not so much book-leaf marl, but the boulder clay at 11·50 chains was again soft, and in following the sandy part down the shale was reached. At 13 chains the soapy marl again became soft, and when the boulder-clay was reached at 14 feet a spring was met with, the trenchway concreted for 8 feet, and a length of 45 feet. The water was dammed back by the concrete, but there is no doubt it was partly the cause of the bank going at the inside toe afterwards. From about 17 chains to 19·50 the boulder-clay was overlaid by dry sand, and the puddle-trench was stepped well into it beyond the end of the bank. The bank was carried up in layers of nearly 3 feet, and no trouble was experienced until October, 1888. It settled altogether 4 feet 6 inches at 13 chains in a week, and bulged at the toe inside. On October 19th the excavation was commenced for a concrete wall 4 feet thick at the toe between 11 and 14 chains. After passing through wet marl and sand a harder bottom was reached at a depth of 10 feet: the wall was finished November 20th, and weighting put on the top about 3 feet high, and beached over. The bank was allowed to stand all the winter, and was dressed up and finished the next spring.

Old West Bank.—The only remaining bank is the old west bank (Plate 6, Fig. 1), *i.e.*, the old bank of the east reservoir, which it was necessary to raise 2 feet. This was done during the winter of 1888, the outside slope pitched with stone, and connection made between the two reservoirs by a 42-inch cast-iron pipe.

The Main Inlet to the reservoir is by an aqueduct at the north-east end (Fig. 1). It commences at the Nine Wells, where a number of springs come out of the limestone, about 26 chains above the reservoir. As a considerable quantity of water came from the springs and drainage-area in times of heavy rain, the aqueduct was made very large. The length is 20 chains above the sluice, and 6 chains below it into the reservoir, and the fall is

1 inch to the chain for the first part, and 3 inches to the chain after. It is 6 feet wide at the bottom, and has a slope of 6 inches to the foot on the sides, which are of brick in cement. The floor is laid in concrete 6 inches thick. It was widened without much trouble, and cost £453, or 16*s.* per lineal yard for labour. There is a small covered culvert 3 feet by 3 feet, at 4 chains from Nine Wells, to bring in the drainage-water.

The stone supplied was got from a quarry three miles north-west of the works. It is a fine and hard freestone, which both stands the weather and works well, though it hardens with exposure.

There were over 750,000 bricks made by the company on the ground from the book-leaf marl. They were well burnt, and have stood the wear and weather well, all the outworks connected with the reservoir having been built with them.

The reservoir was finished in January, 1890, when nearly 20 acres of land round the banks were planted with yews, larch, and other trees.

The total quantities for the banks were:—

Earthwork	347,443 cubic yards.
Puddle	57,738 „
Pitching	43,246 „
Cement	2,170 tons.

The cost of the reservoir for labour was as follows:—

—	Proper. £	s.	d.	Extras. £	s.	d.
Works	3,092	0	8	..		
Roads	498	15	11	..		
East Bank	4,268	2	8	130	0	0
South „	12,671	5	0	18,799	3	9
West „	3,605	8	7	3,761	11	2
Old West Bank	1,552	10	0	..		
Outlet works	288	8	0	404	7	0
Aqueduct	932	6	7	..		
Forty-two-inch culvert	64	16	7	..		
Overflow	1,013	13	5	341	1	5
Other works	87	1	1	121	6	6
	£28,074	8	6	£23,557	9	10

	£	s.	d.
The total for labour	28,074	8	6
	23,557	9	10
	£51,631	18	4

Or 2·55*s.* per cubic yard.

The Author acted as Resident Engineer under Mr. J. R. Forster, Engineer to the Newcastle and Gateshead Waterworks, and with permission presents this account to the Institution.

The communication is accompanied by ten tracings, from which a selection has been made for reproduction in Plate 6, and by the two *Figs.* in the text.

(*Paper No. 2448.*)

"Description of the Cleator Iron Ore Company's Barytes and Umber Mines and Refining Mills in the Caldbeck Fells."

By Percy Leonard Addison, Assoc. M. Inst. C.E.

In the following Paper, the most improved methods of grinding and "floating" umber, and of grinding, "floating," and bleaching sulphate of baryta, or "heavy spar," are described in detail.

About five years ago a mining Royalty, in the Caldbeck district in Mid-Cumberland, was brought before the notice of the Cleator Iron Ore Company, and the Author received instructions to inspect and report on certain mineral veins. The Royalty, which is the property of Sir Francis Denys, Bart., is known as the Caldbeck Fells, and has been worked for lead and copper for many centuries, often with considerable success. After a careful examination of the surface of the ground, and one or two levels which were still open, the Author was able to report:—

(1.) That one drift had followed a vein of brown umber for a distance of 25 fathoms, the mineral being left in the roof, sole and fore-breast of the working.

(2.) That there were strong indications over the whole Royalty that sulphate of baryta existed in large quantities.

After receiving this report, the Company decided to drive a trial-level 4 fathoms below the sole of a drift at the north end of the Royalty, in which barytes had been found in considerable quantities. When this level cut the vein, the barytes was found to be 4 feet in thickness, and of a fairly good colour.

The uses for umber are limited; and as each trade has its own particular shades of colour, it is not easy to adapt the mineral in one form to the use of all. The manufacturers of brown-paper, who are probably the largest users of umber for staining purposes, have each their own favourite tint of paper, and for this reason the mineral is seldom used in its pure state.

The umber now being worked by the Cleator Iron Ore Company is light in colour, but it has an exceptionally high staining power, and the process of levigation separates, as far as possible, the oxides of iron and manganese from the silica and alumina with which they are mixed. The vein is situated ½ mile to the west of High Pike, at a point called Hare Stones, and at a level of about 1,800 feet above the sea. The mineral has been formed in a vein in a rock of the granite or hypersthenite orders, the chief constituent of which was feldspar, now decomposed and forming a mass of impure china clay. As this clay contains crystals of quartz, distributed more or less evenly throughout the mass, it has never, in all probability, been true hypersthenite; but as the nearest granite outburst is that of the Skiddaw Forest—the "Skiddaw Forest granite" of Sedgwick—its identity is difficult to determine. The Author inclines to the idea, after examining the enclosed quartz, that this china clay is the relic of a granite mass similar to that which disturbed the Skiddaw series of the Lower Silurian slates a few miles to the south. The umber has now been proved to a depth of 8 fathoms, and is from 2 to 6 feet in width. An overhead tramway has been erected to convey the mineral to the levigating works at the head of Roughtongill.

Throughout the Caldbeck Fells there are indications of manganese; and, although several places have been tried, this mineral has not been found in workable quantities, nor of a quality sufficiently rich to be of any use to chemical manufacturers.

The Cleator Iron Ore Company now decided to erect machinery on the most improved principle for grinding and levigating the umber; first, because the mineral, when washed, was considered by experts to be superior in colour and staining-power to any umber found in England; and, secondly, because the vein was so filled with crystals of quartz that the most effective separating process was considered necessary in order to free the mineral from grit, and any substance which would detract from its staining qualities.

The order for the machinery was placed in the hands of Messrs. Rushton and Bradburn, of Liverpool, and while it was being made, the wooden buildings in which it was to be placed were erected. A light over-shot water-wheel, 30 feet in diameter and 2 feet breast, was removed from Redgill, where it had been used for crushing lead ore, and after being repaired it was re-erected at Roughtongill Head.

The nearest railway station from which a good road exists is Mealsgate, on the Bolton branch of the Maryport and Carlisle Railway, and this being about 12 miles from Roughtongill Head, the question of the carriage of the heavy grinding mills was a serious one. The level of the umber levigating works is 1,300 feet above the sea, and the appliances at hand for moving and erecting heavy machinery were few. Plate 7, Fig. 1, shows the way in which the machines are arranged, and the system employed in refining the mineral is as follows:—

The umber, having been brought down from the mine on the overhead tramway already referred to, is tipped into a hopper, from which it is passed into the washing-barrel, Fig. 2. This was constructed at the Company's workshops at Cleator, from the Author's design, and is used for washing the umber from stones and large crystals of quartz, which are intimately mixed with it. The shaft with which the barrel revolves is a hollow perforated tube, with a watertight gland at one end, and is driven by a belt from the end of the main shafting. The barrel, having been half-filled with crude umber, is caused to revolve, and water is forced into the middle through the perforations in the hollow shaft. The bars composing the outside of the barrel only being $\frac{1}{8}$ inch apart, all the larger stones are kept back, while the umber is washed through the spaces and falls into a trough below. The washing-barrel is placed about 8 feet above the main floor of the building. The umber and water are next carried into the bottom of the edge-runner mill, Fig. 3, which is a cylinder 5 feet in diameter and $4\frac{1}{2}$ feet in depth cast in one piece. The bottom, which is dish shaped, and has a central socket for the shaft, is also a single casting. The two cast-iron rollers, which are driven from a vertical shaft, and are 3 feet 6 inches in diameter, run on a cast-iron bed. When working, this mill is full of umber slurry, and the rollers are submerged. It will be understood that the rollers—which travel round the cylinder about fourteen times every minute—keep the slurry in a state of agitation, and cause the finest particles to "float," or rise to the surface, and to flow into a $2\frac{1}{2}$-inch pipe, by which they are conveyed to the bottom of No. 1 drag mill, Fig. 4. The internal bed of this mill is composed of a single block of granite, and to the four arms at the bottom of the vertical shaft buhrstone blocks are loosely attached, which, as the shaft revolves, are dragged over the granite bed, covering, during one revolution, its whole area. The outside cylindrical casing of this mill is similar to that of the edge-runner mill; it is also full of umber slurry, which is agitated by the movements of the buhrstone blocks and the arms to which they are attached, and as the finer particles rise to the surface, they are conveyed to the bottom of No. 2 drag-mill, which is of the same construction as No. 1. After being again ground, the umber rises to the surface of No. 2 drag-mill, and is passed through a fine brass-wire sieve of 60 meshes to the lineal inch, in order that small pieces of peat and heather, which have floated on the surface throughout the process, may be removed. Passing through the sieve, the umber is conveyed by covered boxes to the settling-tanks, which are composed of brickwork lined with cement, and are about 7 feet square and 5 feet deep. By means of little sluices, any one tank may be filled while the umber in those previously charged is settling. As the umber sinks, the clear water is drawn off the top by removing plugs, about 3 inches apart, from holes in the sides of the tanks. In four hours four-fifths of the water may thus be removed, leaving the umber lying in the bottom of the tanks of the consistency of gruel.

Pipes are conveyed to the bottom of each tank, and, by regulating three-way taps at the junctions, the contents of any one tank may be pumped out, and forced at a pressure of from 30 to 40 lbs. per square inch against the strong twilled calico coverings of the "plates" of the filter press. The water passing through the calico escapes from taps which are connected with the inside of each "plate," and the umber, now half-dry through pressure, remains on the outside of the calico. A bogie, or trolly on four wheels, is now run underneath the press, and the plates having been separated by loosening a powerful screw which has hitherto held them together, the cakes of umber, twenty-four in number, 2 feet square and from 1 inch to 2 inches in thickness, are loosened from the calico by means of wooden spatulas, and fall into the bogie beneath. When full, the bogie is run into the drying-stove, and the umber is placed on the shelves.

The finished mineral is of the following average composition:—

Analysis of Umber.

Peroxide of Iron	47·14
Peroxide of Manganese	11·17
Oxide of Copper	3·23
Alumina	7·66
Lime	trace
Magnesia	trace
Silica	24·70
Combined water	6·18

It is sent away in two forms—in lumps, or finely pulverized. In the former condition it is chiefly used for staining coarse brown paper; and in the latter it is sold to paint and oil-cloth manufacturers, and to the makers of the finer kinds of brown paper. In producing pulverized umber the cakes are, when thoroughly dry, pushed through a small door in the side of the stove into a room in which a conical buhrstone mill is placed. This mill is provided with a hopper, into which the lumps are thrown, and as they pass downwards they are broken up by the screw which feeds the mill. The grinding is effected by means of a conical buhrstone, revolving at from 800 to 1,000 revolutions per minute, within a hollow cone of the same stone. A sack is placed under the outlet from the mill, and into this the umber passes in the form of fine dust. The man attending to the mill has to wear a respirator over his mouth and nose, as the dust has proved irritating to the throat and lungs. When the hand is placed in a sack of umber prepared in this way it produces the same sensation as if it was plunged into a bag of silk; and when a handful of the powder is squeezed out between the fingers, leaving little in the palm, the moisture on the hand is at once absorbed, producing an unpleasant feeling of dryness, and it is difficult to remove the stain from the finger-nails.

Seeing how well the umber machinery performed its work, the Cleator Iron Ore Company decided to proceed with the erection of plant for producing barytes in its most refined form. This was an undertaking which necessarily involved the employment of considerably more power, and the Author deemed it advisable to place the machinery about a mile lower down the Roughtongill valley, where the water-supply of a much larger drainage area of the fells could be concentrated for the purpose of driving a powerful water-wheel. At this point stood a row of miners' cottages, long disused, the walls of which were, however, in a sound condition. The contract for the grinding machinery was again let to Messrs. Rushton and Bradburn; and while it was in course of construction the buildings were adapted for its reception, and a new one erected, extending from the north end of the cottages to the fell road above (Fig. 5). The floor of this building was stepped, and a secure foundation for the heavy machines obtained in the firm deposit of boulder-clay which forms the lower part of the hillside at this point (Fig. 6). A powerful water-wheel, 36 feet in diameter, 5 feet breast, and with buckets 2 feet deep in the direction of the radius, was constructed at the Company's workshops at Cleator, from the Author's design. The bosses of the wheel are 6 feet in diameter, and are of cast iron; the segments are also of cast iron, and the arms of pitch-pine; and the buckets, which can be removed for repairs, are made of yellow-pine boards, 1 inch in thickness.

The following are the processes through which the barytes passes, from the time it leaves the mine till it is packed in casks and carted to Mealsgate station. As already stated, the mine is entered by a level in the hillside. Unfortunately the colour of the mineral is injured by a layer of fine red clay, about $\frac{1}{4}$ inch in thickness, which lies between the barytes and the hanging cheek of the vein. The crystals are more or less broken, and the red clay washing into, and remaining between them, together with a small quantity of oxide of iron, gives a slightly pink colour to the mass, and to remove this involves considerable trouble. In certain parts of the vein the colour is also slightly impaired by the presence of oxide of manganese. On the barytes being brought from the mine, it is tipped on to an iron grating, and an adjacent stream pours a constant flow of water over it, washing out a part of the clay and other impurities above referred to. After having been picked, the barytes is carted over the fell to a depot by the roadside, shown in Fig. 6. A man is here employed in breaking the large lumps, and in washing the mineral a second time in a trough below the depot. When clean, the barytes is thrown into a wooden shoot, which conveys it to a crusher, the rollers of which break it up into pieces, none exceeding $\frac{1}{2}$ inch cube in size. At this point the mineral is again passed into a long shoot, which either conveys it to a second depot, or, as is more usual, direct to the flat-stone mill. The flat-stone mill is composed of two circular mill-stones, built of buhrstone blocks dove-tailed together in the usual way. The upper stone, which weighs 35 cwt., revolves on the lower one, which remains stationary. It was at first intended to drive the upper stone at 120 revolutions per minute, and to grind the barytes when dry. It was, however, found that the mineral contained so much moisture that it could not be dried without the employment of artificial means, and as this was impracticable, a jet of water was allowed to play between the stones, and the speed was reduced to 40 revolutions per minute. The partially-ground barytes flows from this mill in a semi-fluid condition, and is carried down a steeply-inclined trough to the bottom of No. 1 drag-mill (Figs. 4, 5, and 6). The drag-mills used in grinding the barytes are of precisely the same construction as those employed in grinding umber. An india-rubber hose-pipe, $\frac{3}{4}$ inch in diameter, conveys a constant supply of water into No. 1 drag-mill, in order that the contents may be kept in a liquid condition. The movement of the buhrstone blocks, which revolve at 18 revolutions per minute, and of the arms on the vertical shaft to which they are loosely attached, keeps the barytes and water in a constant state of agitation, and the smallest particles rise to the surface, or, as it is technically termed, "float," and are conveyed to the bottom of No. 2 drag-mill through a $2\frac{1}{2}$-inch pipe. On rising to the top of No. 2 drag-mill, the barytes and water has the appearance of milk, and the grinding process is ended. The overflow from No. 2 drag-mill is conveyed by a trough to a large receiving tank, where it is kept in constant motion by means of an agitator driven from one of the countershafts. The mineral is of such great weight (specific gravity 4·3 to 4·8), that, were any of the agitators employed in the following process allowed to stand for two hours, the barytes would settle into so solid a mass at the bottom of the vats that it would be difficult to mix it again with water.

When the receiving tank is about half filled the agitator is stopped; the barytes rapidly sinks, and, as it does so, plugs are removed from the side of the tank and the clear water is drawn off. When about half the total volume of water has been removed in this way, the agitator is again set in motion, and the contents of the tank are pumped into No. 1 bleacher (Figs. 5 and 7). The bleachers (Fig. 7), are stone tanks, 6 feet square inside, and 4 feet 6 inches deep. The sides are 5 inches thick, and the bottoms 8 inches, each side being a single slab of fine-grained red sandstone. They are provided with pitch-pine agitators, as this wood withstands the action of sulphuric acid and steam better than oak or any other common wood. When No. 1 bleacher has been filled, the agitator is stopped and the barytes is allowed to settle; and as it does so the water is siphoned off the top, the object being to remove as much water as possible prior to the addition of the sulphuric acid used in the bleaching process. When charged, the bleacher contains from 25 to 30 cwt. of barytes. By means of an india-rubber hose-pipe, steam is carried to the bottom of No. 1 bleacher, and when the contents boil, 70 lbs. to 80 lbs. of sulphuric acid is poured in and thoroughly mixed with the barytes, by means of the agitator which is kept in motion. The action of the acid is to dissolve and remove all trace of the oxides of iron and manganese, which, if allowed to remain, would give the barytes a yellow colour, and render it unsuitable for many kinds of work.

After the acid and barytes have been boiled for about one hour steam is shut off, and cold water is turned into the bleacher, in order that the contents may be cooled before being run into one of the washing-vats (Fig. 8). As the vat is filled the agitator is kept in motion, and two or three hose-pipes of cold-water are at the same time turned into it. When the bleacher is empty and the washing vat full, the agitator in the latter is stopped, and as the barytes rapidly sinks to the bottom, the acid water is run off the top by means of plug-holes in the side of the vat. The vat is again filled with water, and the process is continued until all the acid has been removed, and the liquid does not change the colour of litmus paper. The last water having been drawn off, and the agitator set in motion, which is done by means of a clutch on the horizontal countershaft attached to the bevil pinion, there is put into the vat which is now one-third full, and contains about 30 cwt. of barytes of the consistency of cream, from six to eight table-spoonfuls of ultramarine blue, which is allowed to become thoroughly mixed. The effect of the blue is to give clearness to the white, but it must be used very sparingly, or it produces a pearly tint, which is considered objectionable when the barytes has to be used in the manufacture of white paints. The barytes is now run into a small catch-tank, and is at once pumped through a press, in every respect similar to the one already described at the umber works. The cloths, owing to the weight of the mineral, have to be very strong, and the material is specially prepared for the Company by Messrs. Rylands, of Manchester.

When the filter-press is full, the safety-valve, which is loaded to 40 lbs. per square inch, rises. The pressure is then discontinued, and the cakes of barytes, now of the consistency of putty, are removed to one of the drying-stoves. Each of these rooms is heated by about 600 feet of 2½-inch steam-piping, and the normal temperature is 100° Fahrenheit. When the contents of one of the stoves are dry, the steam is shut off, and the doors at either end are thrown open; 40-gallon paraffin-casks, which have been thoroughly cleaned, are rolled in, and, having been lined with paper, are filled with barytes, which is well beaten down with wooden rammers. Each cask contains about 10 cwt.

The composition is as follows:—

Analysis of Barytes.

Sulphate of Baryta	96·29
Silica	2·60
Lime and Alumina	0·10
Oxide of Iron	0·01

It will have been noted, that large quantities of water are necessary at all parts of the grinding and bleaching processes. In the latter it will easily be understood that this water must be very pure; that is to say, as free from sand and vegetable matter possible. Clear as the mountain streams of the Caldbeck Fells first sight appear to be, they in reality carry with them large tities of fine sand, and during floods, which at these high are frequent, a considerable amount of peat-moss also, and if these were allowed to remain in the water, the barytes would, for the finest work, be rendered useless. The water-supply is obtained from the troughing, which conveys the water to the water-wheel; and the Author adopted the following plan for removing the impurities named:—The troughing is placed at a level of about 22 feet above the floor of the building. To the side of the troughing, about 3 inches from the bottom, is fixed a pipe, 2 inches in diameter. This pipe conveys the water to the bottom of a column of 9-inch cast-iron pipes 25 feet in height, the bottom-length of which is 12 inches, and the upper part 9 inches, in diameter. At the bottom of the column is fixed a sludge-cock, and at the top of the 12-inch piece the column is intercepted by a sheet of brass-wire gauze, of 1,600 meshes to the square inch. The supply of water is drawn from a few feet from the top of the column. It will be understood that all the water used in the washing process has to rise to a height of 20 feet in a 9-inch column of pipes, and that it is checked in its flow by having to pass upwards through fine wire-gauze; it is therefore quite free from sand and peat. By opening the sludge-cock the pressure of water above thoroughly cleans the meshes of the gauze. It may also be mentioned that a board, 4 inches deep, is placed across the bottom of the troughing immediately in front of the outlet-pipe, and that this catches a considerable quantity of sand, a portion of which would otherwise find its way down the pipe to the water column.

It would be difficult to say which part of the process demands the greatest care and attention. The speed of the machines, the quantity of vitriol, and the length of time the boiling is continued, are all of importance, and the art of obtaining invariably the same shade of white and the same degree of fineness is necessary to commercial success.

The Author is indebted to his pupil, Mr. J. J. G. Howes, for the preparation of the accompanying ten drawings, from which Plate 7 has been produced.

(*Paper No. 2466.*)

"Calorimeters for Testing Fuels on a Small Scale, with Notes on Fuel-Testing Stations."

By Bryan Donkin, Jun., M. Inst. C.E., and John Holliday, Assoc. M. Inst. C.E.

Heat in the abstract is not generally considered a marketable commodity. Nevertheless it is to obtain heat that coals are bought, and the coal which gives the most heat per ton is rightly regarded as the best. But if coal or any other fuel is bought only for the sake of the latent heat it contains, the test of its value should be its heat-producing power, and a buyer of coal ought therefore to require definite information of the amount of heat he obtains for his money, or in other words, to demand from the coal-merchant a guarantee of the calorific value of the coal purchased. This is actually done in some cases on the Continent, and a guarantee given that a ton of coal will evaporate a minimum of so many tons of water.

The calorific value of any fuel is the number of heat-units developed or given to water by the complete combustion of a given weight, say 1 lb. In this Paper the unit is taken as the amount of heat required to raise the temperature of 1 lb. of water, at 32° Fahrenheit, 1°.

The determination of the calorific value of fuel is an important subject which has not received the attention it deserves, especially in this country. One consequence of this neglect is that although there are many methods of determining this value, no one of them is recognized as the standard. The methods may be classified in three well-defined groups, namely:—

I. By calculation from the chemical analysis of the fuel.
II. By combustion on a small scale (a few grams) in some form of calorimeter.
III. By combustion on a large scale (a few tons) under a well-arranged steam-boiler, used as a test-boiler.

I. In order to calculate the heating value of a fuel, a reliable

Moreover, when the analysis is obtained, the leading authorities are not yet quite agreed upon the value to be assigned to the various combustible elements, nor upon the allowances to be made for possible changes of state during combustion, from solid to liquid, or from liquid to gaseous. Nor are they agreed concerning the chemical combinations which exist previous to combustion, and their effect on the results; whether, for instance, when hydrogen and oxygen are both present, they are necessarily already combined as water, or combine during combustion.

The following are the calorific values of the elements generally found in all fuels:—

Carbon	14,544	British thermal units.
Hydrogen	62,032	" " "
Sulphur	4,032	" " "

or, in other words, 1 lb. carbon by complete combustion can raise 14,544 lbs. water 1° Fahrenheit. Assuming that the behaviour of carbon, hydrogen, &c., in combination is the same as that of carbon alone, the calorific value of a sample of coal of the following chemical analysis can be calculated thus:—

From Analysis of Coal.	Parts by Weight.	Calorific Value of 1 lb. of Each Element.	Heat in 1 L. of Coal.
	Lbs.	Thermal Units.	Thermal Uni
Carbon	0·880	14,544	12,799
Hydrogen	0·045	62,032	2,791
Sulphur	0·008	4,032	32
Oxygen, nitrogen, and ash	0·067	0	0
Totals	1·000		15,622

Recently the calorific value of carbon in the conditions of amorphous carbon, graphite, and diamond, has been most carefully determined by Messrs. Berthelot and Petit. The results obtained by these experimenters were:—

	Thermal Units.
Amorphous carbon	= 14,647
Graphite	= 14,219
Cape diamond	= 14,146

The result obtained with amorphous carbon is practically the same as that of Favre and Silbermann above, namely, 14,544. Messrs. Berthelot and Petit's experiments were made with the bomb calorimeter.

In the example given the whole of the carbon in the coal was supposed to develop 14,544 thermal units, but Mr. Cornût assigns a higher value than this to the volatile portion, namely, 20,185 thermal units, and retains the value 14,544 for the fixed portion of the carbon. He thus values a coal rich in hydrocarbon much higher than an anthracite coal.

Another method of calculating the heating power of a coal from analysis is known as Dulong's. It is assumed that all the oxygen and hydrogen present in the coal are combined in the form of water, so that only a part of the hydrogen is available for combustion. Taking the analysis of coal above given, if the oxygen present be 0·032, the available hydrogen $= 0\cdot045 - \frac{0\cdot032}{8} = 0\cdot041$, and the thermal units derived from the hydrogen are accordingly reduced from 2,791 to 2,343.

Another formula by Mr. Ser gives the calorific value in thermal units of any coal as $= 5{,}184\left(\frac{\text{carbon}}{3} + 8 \text{ hydrogen}\right)$.

These various methods of calculation have been compared by Mr. Scheurer-Kestner in a recent article on "The Study of an English Coal."[1] The following are his figures:—

	French Calories.	British Thermal Units.
Calculation by the formula of Dulong . . .	8,452	15,214
" " Scheurer-Kestner and Meunier .	8,586	15,455
" " Cornût . . .	8,674	15,613
" " Ser	9,268	16,682
Experimental result by Mr. Scheurer-Kestner	8,864	15,955

In this particular instance Cornût's method gives the nearest approach to the result obtained by experiment; but this is not always the case. Sometimes one and sometimes another method approximates most closely.

It is the practice of Mr. Scheurer-Kestner and other authorities to give the calorific value as of pure coal; that is to say, the results obtained in any experiment are corrected for the quantity of incombustible matter present, and the figures given represent what

[1] Bulletin de la Société de Mulhouse (1888), vol. lviii. p. 324.

the result would be if the sample were all combustible. A reason for this practice will be found on referring to Mr. Scheurer-Kestner's Paper, where he frequently records large differences in the proportion of ash from the same coal.

Another important point to be considered is the necessity for correcting the calorimetric determinations of the value of a given coal for the latent heat of vaporization of the water produced by the combustion of the hydrogen. In the calorimeter the aqueous vapour is generally condensed when the latent heat of vaporization becomes sensible, and the coal is declared to possess a certain amount of heat which no possible arrangement could extract from it in boiler-practice. If this correction be applied to the example given above, it will be found that the hydrogen produces 0·4 lb. of water, and with 966 as the latent heat of vaporization, the difference 391·2 thermal units is the quantity by which the calculation should be reduced. The same result may be obtained directly by taking the calorific value of hydrogen at 52,357 instead of 62,032 thermal units.

II. The determination of the exact amount of heat developed in chemical operations (generally combinations of the substance with air or oxygen) is a subject which has received considerable attention from a number of skilful experimenters, including Lavoisier and Laplace, Rumford, Dulong, Despretz, Favre and Silbermann, Andrews, Berthelot, Thomson, and others. Most of these scientists devised special apparatus to test the substances they were studying, but none of them produced a simple instrument, by means of which the calorific value of a complex material like coal could be fairly and accurately determined, without the assistance of skilled experts. This was practically effected some years later by a calorimeter designed specially for burning coal.

Messrs. Favre and Silbermann, between 1845 and 1852, made various determinations, which have since become classic, of the calorific values of different substances. The apparatus they used is so well known, and has been so often described that it is sufficient to say that the substance was burned in a copper vessel, in a stream of oxygen gas, the products of combustion passing out through a coil round which water circulated. Elaborate precautions were taken to minimize losses by radiation, and the gases of combustion were sometimes analysed, to study the results. The correctness of the calorific value of amorphous carbon obtained by Favre and Silbermann has lately been verified by the experiments of Messrs. Berthelot and Petit.

The instrument, however, was found by Messrs. Scheurer-Kestner and Meunier not to be sufficiently well arranged in some of its parts for coal, and they made various modifications in it. Even with these improvements, Mr. Robert Galloway did not succeed in obtaining results agreeing with the calculated values.[1]

More exact results with combustibles may perhaps soon be expected, as Mr. Scheurer-Kestner is making a series of experiments with the modern form of the bomb-calorimeter of Mr. Berthelot. The fuel to be tested is placed inside a strong steel sphere filled with oxygen gas at a pressure of 360 lbs. to the square inch, and is ignited by an electric current passed through platinum wire. More recently Mr. Berthelot has used a calorimeter of very thin glass, to enable the operator to watch the progress of combustion, which is effected in somewhat the same way as in Professor Thomson's instrument, oxygen gas being introduced through one glass tube and the products of combustion allowed to escape by a second. The fuel is ignited by introducing a small piece of burning carbon, and combustion takes place in a small porcelain cup.

But the present Paper is concerned, not so much with these laboratory calorimeters as with instruments more quickly and easily worked, which may be relied on to give results sufficiently accurate for commercial purposes, the limit of error not exceeding, say, from 2 to 4 per cent. One of the earliest calorimeters was designed by Rumford, in 1814. It consisted of a vessel containing a known quantity of water placed above a small chamber, in which a sample of fuel was burned. The products of combustion were collected in a hood, and passed through a coiled pipe placed in the water. The rise in temperature of the water was measured by a thermometer.

Dr. Ure's calorimeter was an improvement on Rumford's design, and the quantities of fuel and water employed were very much greater than in most instruments. The apparatus consisted of a large copper vessel capable of holding 100 gallons of water. A flat copper pipe passed through the bottom of the vessel, and communicated with the top of a small furnace, in which the sample of coal was burned. Air was supplied from a bellows, and circulated twice round the furnace before reaching the fuel. Ignition was effected by the addition of ½ oz. of glowing charcoal, and the heat developed was said to be completely absorbed by the water. But in this instrument combustion could scarcely have been perfect, owing to the small size of the combustion chamber.

[1] A Treatise on Fuel, by Robert Galloway. Trübner, 1880.

An analysis would probably have disclosed the presence of carbonic oxide in the gases of combustion, and of unburned carbon in the ashes.

Two calorimeters have been designed by Professor Schwackhöfer, and Dr. Fischer, and are used chiefly in Austria and Germany. The first is somewhat complicated, and is intended rather for laboratory than commercial purposes; the second resembles the Lewis Thompson calorimeter.

Of late years the Lewis Thompson calorimeter has been perhaps the best known, and most generally used, but the Authors consider that it is only valuable as an approximate instrument, and cannot be relied on for accurate working, except in very careful hands. As a rule, it does not give results nearer than 5 to 10 per cent.

At the request of one of the Authors, who sent him a Lewis Thompson calorimeter, Mr. Scheurer-Kestner made a series of experiments with it.[1] Having already conducted many trials on the heating power of coal with his own calorimeter of the Favre and Silbermann type, he was able to compare exactly the two sets of results with similar coal, and arrived at the conclusion that the Lewis Thompson calorimeter, in good hands, would give an approximation within 4 per cent., but that an allowance must be made of 15 per cent. instead of 10 per cent., as Lewis Thompson advised.

The apparatus, which is on the principle of the diving-bell, consists of a cylindrical glass vessel, about 3¼ inches in diameter, and 18 inches high, gauged to show 2,148 cubic centimetres of water. The fuel is burned in a thin copper cylindrical tube, called the furnace, ¾ inch in diameter, about 4½ inches long, and open at the top, which is supported in the middle of a copper base-plate. This base-plate, by means of springs, can be quickly attached to the bottom of a copper vessel called the condenser, which is in effect a kind of diving-bell. The fuel is thus kept perfectly dry, and is burnt under water. The products of combustion escaping through holes made in the base-plate, and being forced to rise through the water, they give up all their heat before escaping into the air.

The oxygen necessary for combustion is supplied by an oxygen-mixture composed of 3 parts by weight of chlorate of potash ($KClO_3$) with 1 part of nitre (KNO_3) which is intimately mixed with the finely-powdered fuel to be experimented on, the salts being decomposed by the heat evolved. The proportion of this

[1] Bulletin de la Société de Mulhouse (1888), vol. lviii. p. 506.

oxygen mixture to that of the fuel should be varied according to the nature of the latter. Ignition is effected by means of a small fuse of cotton steeped in nitre, which is put into the mixture and fired before the diving-bell is placed in the water. The quantity of fuel used for each operation is generally 2 grams (30 grains), and the quantity of water 2,148 cubic centimetres, at the ordinary temperature of the laboratory, but these quantities may be slightly varied. The above proportions are used in order to obtain the results in the desired form without calculation. Thus, the heat required to convert 1 gram of water at 100° Centigrade, or 212° Fahrenheit, into steam at atmospheric pressure is 537 calories, or about the quantity stored up in $\frac{1}{12}$ gram of coal; 1 gram of coal would therefore raise 537 grams of water 12° Centigrade, and 1,074 (537 $\times$ 2) grams 6° Centigrade. This rise of temperature in the water is convenient for accurate observation. If the thermometer shows a rise of 6° Centigrade, it is evident that the value of coal expressed in lbs. of water evaporated at 212° Fahrenheit per lb. of coal is 6 $\times$ 2 = 12, or 12 $\times$ 966 = 11,582 thermal units. In this calculation nothing, however, is allowed for heating the various parts of the apparatus, or for loss by radiation, imperfect combustion, &c. The rule given by Thompson was to add 10 per cent. to the results of the experiment, and this was supposed to cover all errors, but this percentage is insufficient.

The general rule when making experiments is to use 20 grams of oxygen mixture to 2 grams of coal, but different classes of coal require different proportions. The Authors found that, with coal rich in hydro-carbons, higher results were obtained by increasing the proportion of oxygen mixture up to at least 26 grams for 2 grams of [illegible] The larger quantity of oxygen mixture steadied the combustion by separating the particles of coal, and the fuel was more completely burned. It had also the effect of lengthening appreciably the duration of the experiments, and although the loss by radiation was thus greater a higher result was generally obtained. Unfortunately the copper combustion chamber soon became very thin at the top, a copper cylinder being found, after twelve experiments, to have diminished 0·8 gram per experiment. This wasting was attributed to oxidation caused by the heat. Probably a platinum cylinder, although costly, might be more satisfactory.

With coals rich in hydro-carbons this instrument was found to be fairly certain in its working, but coke and anthracite burned with difficulty and seldom thoroughly. In order to test the value of this and of other forms of calorimeters, the following method was adopted by Mr. Scheurer-Kestner. A sample of pure charcoal was burnt, and the rise in temperature of the water, divided by 14,540 thermal units (the calorific value of pure carbon), gave the value of the apparatus per degree, allowance being made for the amount of ash in the sample of charcoal used. The employment of charcoal for this purpose cannot, however, be recommended, as the purest obtainable samples often contain large and varying amounts of hydrogen. This must either be removed (a difficult operation), or the quantity determined by analysis and allowed for in the results. It is preferable to use a sample of a coal of known heating power, ascertained with one of the best laboratory instruments. By making a few trials with various coals of this kind an average is obtained, which for commercial purposes is sufficient.

The ingenious principle introduced by Lewis Thompson has been employed by other experimentors. Dr. F. Stohmann at Leipzig and Mr. C. von Rechenberg have made several investigations with their instrument, which is of the Lewis Thompson type, but much improved and modified. For the combustion-tube they use a cylindrical vessel of platinum, with the diving-bell attached by a bayonet-joint to the base-plate supporting it. The oxygen mixture is composed of red oxide of manganese, Mn_3O_4 prepared from common black oxide of manganese, and potassium chlorate, in the proportion of 1·67 gram of the red oxide to 13·33 of the chlorate. For each experiment 15 grams of the mixture are used, and Dr. Stohmann varies the weight of the different substances tested, in accordance with the special requirements of each, the amount of alteration being determined by making a few experiments in the platinum cylinder outside the calorimeter. The glass vessel containing the combustion-tube and diving-bell with a known weight of water is enclosed in a double air-jacket; outside this there is a water-jacket, and the whole is surrounded by infusorial earth. The top is covered, and the gases of combustion are collected and analysed. A simple test easily shows whether the whole of the potassium chlorate has been decomposed, and thus two means are provided to determine the completeness of combustion. Cane sugar is sometimes employed to assist ignition, if the substances are not readily kindled, and candle stearine, distributed through the mixture by means of ether, is used for regulating the temperature, and maintaining the combustion. The mixture is conveniently fired by an electric spark, and the duration of the action is from thirty to forty seconds. These rather complicated and expensive arrangements cause this excellent calorimeter to be classed as a laboratory-, and not as a commercial instrument; but the apparatus itself seems to be scarcely more difficult to manipulate than the Lewis-Thompson instrument, although far more accurate.

Dr. Stohmann has made few, if any, experiments with coals and fuel.

After considering carefully the different calorimeters in use, the Authors came to the conclusion that the best instrument for commercial and ordinary scientific purposes is that designed by Professor William Thomson, and described by him in a Paper read before the Society of Chemical Industry.[1]

In this instrument Lewis Thompson's diving-bell arrangement is retained, but instead of the oxygen for combustion being supplied by the decomposition of solid potassium chlorate, it is forced into the diving-bell in a gaseous state, and made to impinge as required upon the glowing fuel, perfect combustion being thus secured. In the first place 1 gram of fuel is placed in a small platinum crucible (*Fig. 1*), which stands on a clay support B, attached to the base-plate H. The glass diving-bell T is secured to the base-plate H when required by springs; a copper tube E fits loosely, and is made tight by india-rubber tubing. Flexible tubing connects the copper tube by a tap with the holder containing the oxygen gas. The bubbles of gas are broken up by screens as they rise, and the heat they contain is thus thoroughly imparted to the water. The charge is ignited by a very small fuse, and to minimize radiation the calorimeter is protected by a tin casing. One great advantage in this instrument, and an important improvement on others, is that the thermometer for taking the temperature of the water can be read through an opening in front, and combustion seen and watched the whole time.

Professor Thomson uses 1 gram of dried fuel to experiment with. The total heat capacity of his apparatus is equal to 72·8 grams of water, and the quantity of water used is 2,000 grams. Thus a rise of 1° Centigrade in the temperature of the water is equivalent to 2,072·8 calories, or 3·858 lbs. of water evaporated at 212° Fahrenheit per lb. of fuel. A small allowance is made, which should be determined experimentally, for loss by radiation, &c.

In making experiments with this instrument, the 2,000 grams of water are either weighed or measured into the glass vessel. With the exception of the platinum crucible, the whole apparatus stands in the water for a few minutes before starting a test, to bring it to the same temperature as the water. The different

[1] The Journal of the Society of Chemical Industry (1886), vol. v. p. 581.

parts of the instrument are then adjusted, the crucible is placed in position, the fuse lighted, and the diving-bell filled with oxygen. The requisite pressure in the gasholder is obtained by connecting it with any water main, and the oxygen is thus made to flow steadily into the bell. During combustion the products escape downwards through the perforated base-plate, and then ascend

Fig. 1.

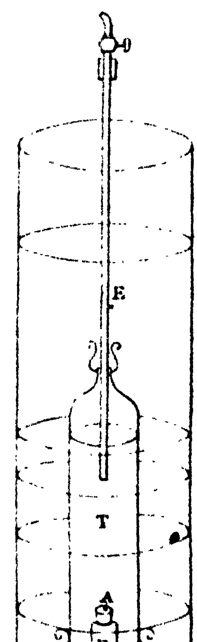
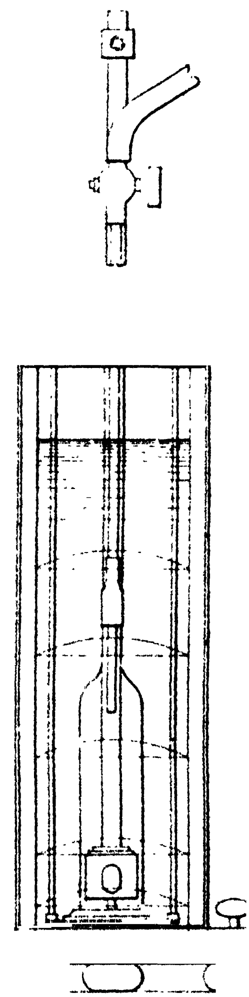


Fig. 2.



Calorimeters for testing Fuels.

through the water. At the beginning of combustion, especially with smoky coal, the end of the tube E is kept in the upper parts of the bell, but is gradually lowered into the crucible as the volatile portions of fuel are burnt. Towards the end it is moved, so as to direct the stream of oxygen on to the unburnt portions, and ensure complete combustion. All the coal having been consumed at the end of an experiment, the water is admitted into the diving-bell, its temperature is again taken, the rise in degrees multiplied by the value per degree of the instrument, and thus the required heat-value of the coal is obtained.

Any coal containing less than 25 per cent. of incombustible matter, such as anthracite, coke, and breeze, may be burned in this calorimeter. Coals that burn with a flame sometimes smoke, and are difficult to deal with satisfactorily; when this occurs the results should be rejected. The difficulty may be met: (1) by breaking the coal into pieces about the size of a pin's head, instead of into powder; (2) by keeping the end of the oxygen tube in the upper part of the diving-bell, till all the gas is given off and burnt. Combustion generally occupies from four to five minutes, and the ash is often found in the form of small shot melted like clinker in a boiler-furnace. Analysis of the escaping gases always shows a large excess of oxygen, and small quantities of carbonic oxide are sometimes found when smoky coals are burned, but not otherwise.

This apparatus has been slightly modified by one of the Authors (*Fig.* 2). The metal outer vessel is replaced by glass, through which the progress of combustion can be more clearly seen, and 2 grams of coal are used for each experiment instead of 1 gram. The calorimeter is mounted on a stand, with a rod supporting two thermometers, one for giving the temperature of the surrounding air, and the other that of the water of the calorimeter. The second thermometer is so fixed that when the bulb is half way down the glass vessel, the lowest reading is level with the top. The thermometer is graduated to mark from 7° to 30° Centigrade. Each degree is $\frac{3}{8}$ inch long, and is divided into twenty parts, it being essential to read the temperatures with the greatest accuracy. With 2 grams of coal combustion lasts from ten to twelve minutes. Experiments were made to determine the loss by radiation, which on an average was found to be 0·02° Centigrade per minute.

To test the value of the instrument, a sample of Welsh coal, the heating power of which had been already determined by many careful laboratory trials, was repeatedly experimented upon. After allowing, (1) for the heat absorbed by the apparatus; (2) for the heat carried away by the gases; and (3) for loss by radiation, the result was found to be between 2 and 3 per cent. below the previously ascertained value of the coal.

In certain cases where large interests are involved, it may be advisable to supplement the calorimetric results by investigations carried out on the scale of actual practice. In studying any coal it is of interest to know not only the results from the calorimeter, taking say a mean of three or four good experiments, but also to compare this combustion on a small scale with the more important results obtained by burning several tons of the same coal under a boiler. To find out the relation between these two methods of testing fuels is of importance. Much, of course, depends upon the boiler, although combustion under it can seldom be so perfect as in a calorimeter, and much also upon the rate of combustion and other conditions. With coals and gas coke the Authors obtained, as a general rule from various experiments made on the same kind of fuel, a difference of from 35 to 40 per cent. between the results given by a Lancashire boiler and by a calorimeter. In other words, if a coal gave 10 lbs. of water per lb. of coal in the calorimeter, it gave 6·5 lbs. of water per lb. of coal in the boiler, or 65 per cent. efficiency. In other cases higher results have been obtained, up to 80 per cent. about. This approximate relation having been ascertained for given conditions, and the calorific value of a coal given, it is easy to calculate what may be expected in practice.

A large consumer would find it of great advantage to get samples of the various coals offered him accurately tested in this way. But even if so disposed, it is not in his power to do this, as no public station exists in England for the practical testing of fuel by the ton. A station for this purpose might be established, and would probably be found useful in supplying a want that certainly exists, if not generally recognized.

In Germany a few testing stations have been working for some years. One of these is at Munich under the superintendence of Dr. Bünte. Here, in addition to calorimeters, and apparatus for gas and coal analysis, there is a tubular test-boiler. Fuel submitted for trial by the public is tested by burning samples in this boiler and also in a calorimeter, as well as by analysis. A complete report of all the results is forwarded to the client, accompanied by practical recommendations. This is one of the best heat-testing stations that exist on a large scale.[1]

Besides Dr. Bünte's there are several other stations on the Continent. The Imperial Naval Coal-testing Station at Wilhelmshaven was established in 1887. Samples of coal for the Belgian Government Railways are tested for a given specified evaporation, and also for a given amount of incombustible matter. If not up to the terms of contract, the deliveries are not accepted. The tests are made daily under a large locomotive boiler. There is

[1] Minutes of Proceedings Inst. C.E., vol. lxxiii. p. 328.

also a government station for testing fuels near Brussels; but the results are considered the property of the State, and are not published. The Imperial Marine Station at Dantzig, and the Boiler Insurance Company's Station at Magdeburg are also working.

Unfortunately no similar permanent coal-testing station exists in England at present. In 1867 a small marine boiler was erected at Wigan for the purpose of testing different kinds of coal, especially from Lancashire and Cheshire; but the gases of combustion were not analysed, nor were the distribution of heat, the losses, and the efficiency of the boiler shown.

The establishment and maintenance of a fuel-testing station is an undertaking that may yet receive the attention of engineers. Any ordinary building would serve as a testing-house, and it should contain the boiler, laboratory, and coal store, and should be furnished with the necessary measuring instruments. The staff might consist of a superintendent, who ought to be an engineer and chemist, and possess a practical knowledge of fuel, furnaces, and boilers, with one or two assistants. Such establishments may be called fuel calorimeters on a large scale. Possibly before long they may be erected in some of the chief commercial centres. Were their advantages understood, there would soon be a demand for them, and the valuable services stations of this description are capable of rendering to science and industry would be fully appreciated.

The Paper is accompanied by several tracings from which the *Figs.* in the text have been engraved.

(*Paper No. 2430.*)

"Ocean Jetties in New South Wales."

By William Andrew Harper, Assoc. M. Inst. C.E.

The southern coal-field of New South Wales has been gradually opened up from the Illawarra District northward towards Sydney. The seam at Kembla reaches a height of 500 feet above sea-level, and can be traced along the slopes of a range of mountains parallel with the coast-line northwards as far as Coalcliff, where it is nearly at sea-level, the dip of the field being N.W. on an angle of 1 in 100. The demand for the Kembla coal is very extensive for steaming purposes. Its constituents vary; but on the average it contains 70 per cent. of fixed carbon, 20 per cent. of hydrocarbons, and 10 per cent. of ash, and it is considered preferable to Newcastle (N.S.W.) coal for maintaining a steady heat. There is, however, no harbour south of Sydney, and the railway charges are, on account of the steep gradients and sharp curves, so heavy that no large quantities can be profitably carried for distances over 30 miles south of Sydney. Several of the collieries are distant about 6 and 8 miles from the sea-coast, and inclines are used for lowering the coal-wagons to the railway level. From the foot of the inclines the railways run to the coast-lines to the nearest point where some shelter from the southerly storms can be found for shipment from sea jetties, and as the shelter afforded by the longest of the points running easterly and north-easterly is very slight, it is necessary that these jetties should be built as strongly as possible. Two of these jetties have been recently designed by the Author—one at Bellambi and another at Port Kembla. The method of setting the piles hitherto employed has been to dowel them to the rock-bottom, a dowel of 3-inch iron being fixed in the rock, and the pile, in the bottom of which a hole had been bored, being fitted on to it. This mode of fastening was found to be useless, the constant vibration causing the dowel to become loose, so that the bottoms of the piles could get adrift. It was therefore decided to blast out holes large enough to hold the entire butt of the pile and, after fixing in position, to grout the interstices with concrete. The blasting was effected by successive charges of dynamite in a central bore 1½ inch in diameter, and 3 feet 6 inches deep. Divers were employed to carry out the boring-operations, the size of the holes being about 30 inches square. The butt end of the piles was fixed in the holes, and the grouting material (1 part of cement, 1 of sand, and 3 of pebbly grit), after careful mixture on top, lowered in covered boxes with movable bottoms, poured and carefully rammed into the holes.

The Kembla jetty is about 1000 feet in length, in spans of 25 feet each, the main body being 3-pile- and the end 4-pile-work. The depth of water at the outer end is 26 feet, and the elevation of the floor 30 feet above ordinary high-water mark. The piles are braced with transverse and diagonal braces, the lower walings being 10 feet above high-water mark, and the piers are secured by diagonal tension-rods of 1½-inch iron secured to the piles with iron collars. Only two rods are employed between each bay, the collars being fixed round the piles, one immediately under the corbel, and the opposite one under the lower walings. The rods are so placed that in each bay the one fastened to the top of the left pile of No. 2 pier runs down to the collar near high-water mark of the right-hand pile of the landward pier No. 1, and the other is secured to the top of the right-hand pile of No. 2 pier, and runs diagonally to its collar on the left-hand pile on No. 1 pier. The direction of the rods is so chosen that any bending thrust of the waves on the pier is converted into a direct thrust on the horizontal member of the system (the girders), which is firmly secured on the shore end, and the tie-rods also secure a perfect diagonal bracing of the system against side forces of any kind. All the rods are secured by union screws capable of adjustment whenever necessary from the effects of shrinkage or vibrations. For this structure it is considered by the Author that a great amount of strength is secured by a small number of tie-rods which do not offer any appreciable resistance to the waves. Vessels are held while loading by mooring cables secured to buoys, so that they cannot approach within a few feet of the jetty, and fender piles have been provided in addition, but instead of being secured to the main structures, they are independently fixed in the same manner as the main piles. Behind each fender-pile a strut-pile is fixed, and the head-stocks are secured by iron rods attached to lewis-bolts firmly fixed in the rock-bottom to prevent the displacement of the piles by an upward thrust.

(*Students' Paper No. 270.*)

"Some Applications of Electricity in Engineering Workshops."[1]

By Charles Frewen Jenkin, B.A., Stud. Inst. C.E.

During the last year and a half the Author has had the opportunity of making experiments on electric motors, in the Crewe Works of the London and North-Western Railway. Some of the results of these experiments are given in the following Paper. It must be understood, however, that none of the experiments were made with a view to their publication, and they consequently lack, to a certain extent, the accuracy and completeness desirable for this purpose.

It is necessary, for the successful introduction of electrical transmission of power into workshops, that the motors used should be as cheap as possible, and also, in many instances, as light as possible. This double requisite of cheapness and lightness leads to the consideration of what material is the best for the construction of the magnets and framework, since these form the heaviest part of the motor, and also allow of more variation in design than the armature and commutator.

It is generally found not to be desirable to magnetize cast-iron more than half as highly as wrought-iron; consequently the relative weights of cast-iron and wrought-iron must be as 2 to 1. On the other hand, cast-iron may be very cheaply obtained in any complex shape desired in order to simplify the framework of the motor. From these considerations it will be evident that any material capable of being cast, and yet having a higher magnetic permeability than cast-iron, would be of great use in the construction of motors. The use of steel castings for this purpose was suggested to the Author last year by Mr. F. W. Webb, M. Inst. C.E., and, in order to find out the suitability of this material, the

[1] This communication was read and discussed at a meeting of the Students on the 25th of April, 1890, and has been awarded the Miller Scholarship, session 1889–90.

Author made a magnetic test of two different qualities of steel castings, which appears to show that cast-steel lies in an intermediate position between cast-iron and wrought-iron in its suitability for magnets.

The Author *believes that* tests of the magnetic qualities of steel castings have not hitherto been published, so an account of them will be given here.

The method of testing used was a combination of Dr. Hopkinson's and Professor Ewing's.[1] The samples to be tested are arranged to form part of a closed magnetic circuit, the rest of which, called "the yoke," is of very low "magnetic resistance," compared with the test piece. The samples are then magnetized by means of a current in a solenoid wound round them, and the total induction measured by means of a small induction coil round the sample, connected with a ballistic galvanometer, the throw of which is observed when the magnetism is suddenly reversed in the sample.

The magnetic force $\mathfrak{H}$ is calculated from the equation—

$$\int \mathfrak{H}\, dl = 4\,\pi\, n\, c$$

where $\mathfrak{H}$ = magnetic force;
$d\,l$ = increment of length of magnetic circuit;
n = number of times the magnetizing current c passes through the magnetic circuit.

The force is assumed to be uniform along the sample; thus we get—

$$\mathfrak{H} = \frac{4\,\pi\, n\, c}{L},$$

where L is the length of the sample, neglecting the small quantity

$$\int \mathfrak{H}\, d\,l \text{ for the yoke-piece.}$$

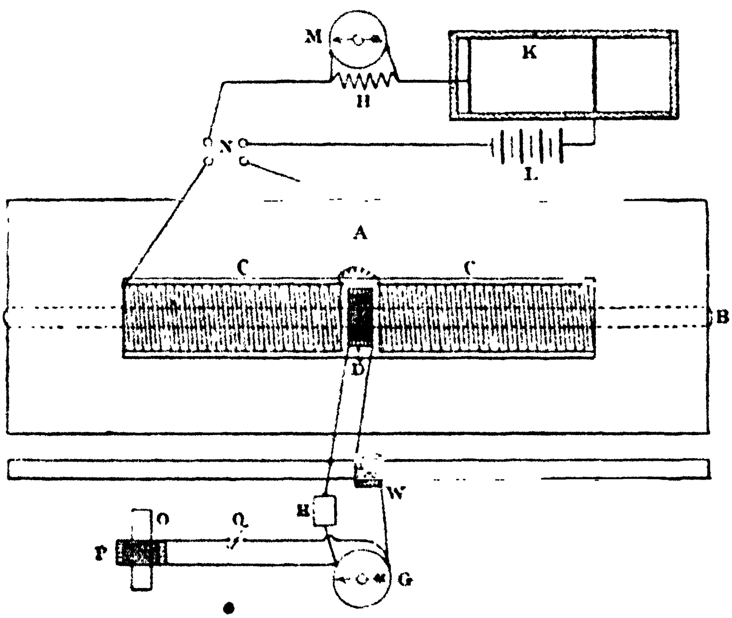
The general arrangement of the apparatus used is shown in *Fig. 1.* A is a massive soft-iron yoke-piece, 18 inches × 6 inches × 2 inches, having a rectangular piece cut out of the centre, 12 inches × 2 inches, and also having a ½-inch hole drilled through the two ends. These holes receive the sample to be tested, B, which is turned true to fit them, and is a straight rod, 18 inches long, ½ inch in diameter. C C are two magnetizing coils on brass bobbins, each coil being wound with 522 turns of No. 16 double

[1] Phil. Trans., 1885; pp. 455 and 523.

cotton-covered wire. They are connected through a reversing key N, a standard resistance H, and a variable resistance K, with the battery of accumulators L. M is a graded voltmeter for measuring the fall of potential across the resistance H, from which the magnetizing current is calculated. D is the induction-coil, consisting of 100 turns of small wire, wound on a wooden bobbin; it is connected to the ballistic mirror galvanometer G, through a variable resistance K.

In order to calibrate the ballistic galvanometer, Sir William Thomson's method was used.[1] A long solenoid was wound on a wooden core, and an induction-coil, W, wound over it in the

Fig. 1.



CONNECTIONS FOR TESTING CAST-STEEL.

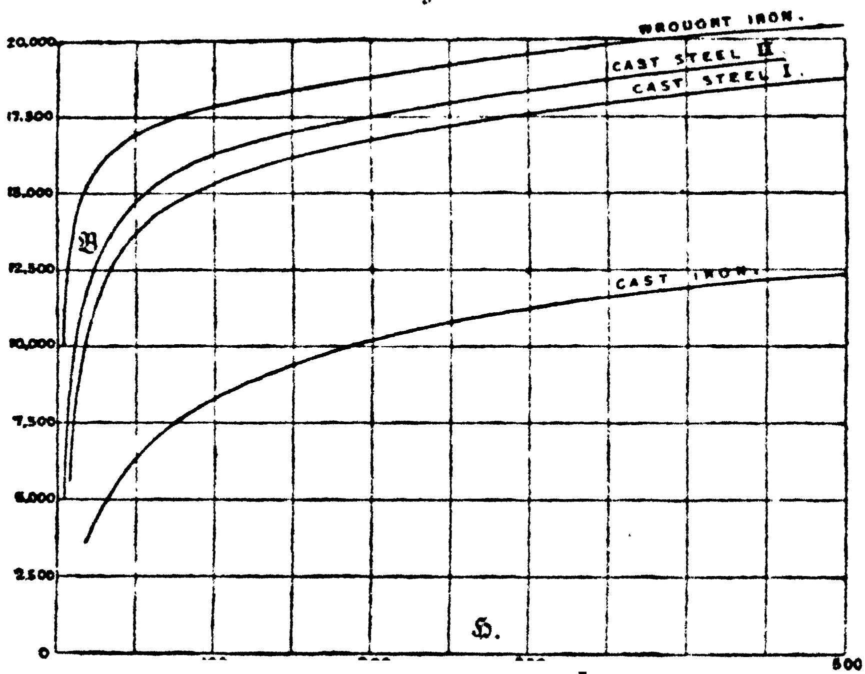
middle, and connected to the galvanometer. A current measured by a graded ammeter was then passed through the solenoid, and, after bringing the needle of the galvanometer to rest, the direction of the current was suddenly reversed, the deflection of the spot being observed, from which deflection the constant for the instrument can be obtained at once. Since this method of calibration allows for the damping of the needle, the damping may be made as great as is desired, without the introduction of troublesome corrections.

[1] Absolute Measurements in Electricity and Magnetism," by Andrew Gray, p. 320.

In order to stop the oscillation of the needle, and bring the spot to zero when required, a very simple and effective device was used, which Professor Ewing had suggested to the Author. A small permanent magnet, O, was fixed near the galvanometer, over which could be slipped a loose coil P, which was connected with the galvanometer. By slipping this coil on or off the magnet, the spot could be very quickly brought to rest.

The graded galvanometers were calibrated immediately before the experiment by means of a Clark's standard cell. The method

Fig. 2.



PERMEABILITY CURVES.

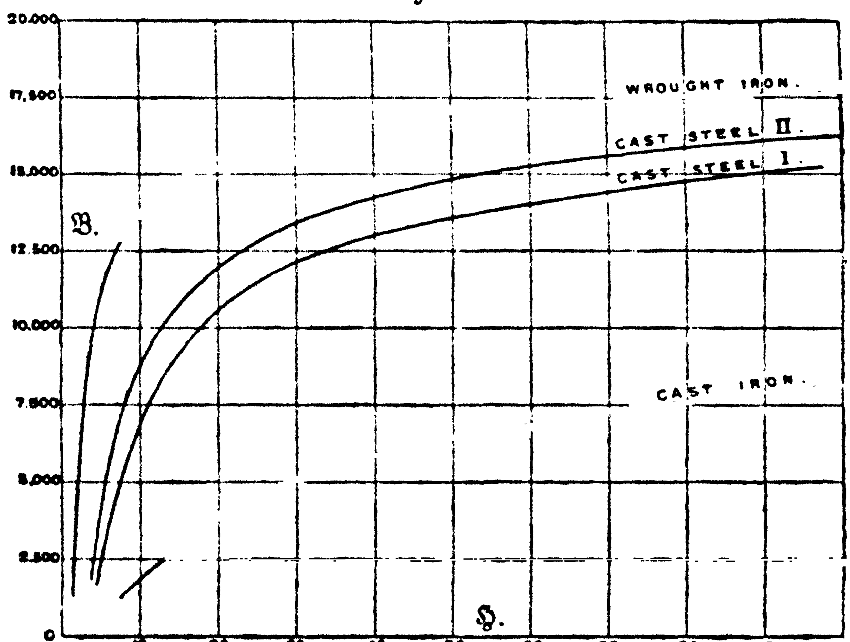
of making a test was as follows. A current from the accumulators was sent through the magnetizing coils, the strength of the current being regulated by the variable resistance, and measured by the voltmeter. The ballistic galvanometer-needle having been brought to rest, the current was suddenly reversed by means of the reversing switch, the throw of the mirror being noted. This throw gives the total change in the number of lines of induction passing through the induction-coil at the instant of reversal, and corresponds to double the induction due to the magnetizing current.

From the cross-section of the sample, the value of 𝔅 is obtained at once; and from the length of the sample, and total number of ampere turns in the magnetising coils, the value of ℌ.[1]

The results obtained are shown graphically in *Fig.* 2, where the abscissæ represent the magnetizing forces, and the ordinates the corresponding values of the induction. The corresponding curves for wrought- and cast-iron samples, tested at the same time, are given for comparison. In *Fig. 3* the horizontal scale is enlarged five times, in order to show the shape of the curves near the origin.

A chemical analysis of the samples tested was made at the

Fig. 3.



PERMEABILITY CURVES.

laboratory of the Works, to determine the quantity of carbon in the steel. The amounts were found to be as follows:—

Sample I. Combined carbon, 0·6 per cent.
" II. " " 0·28 "

By comparing the curves of the cast-steel with those of the wrought-iron and cast-iron, the relative advantages and disadvantages possessed by cast-steel may be readily seen.

The first motor constructed with cast-steel magnets was designed

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[1] *loc. cit.*

by the Author for driving a portable drill. Before describing this motor and drill, it may, perhaps, not be out of place to consider a few of the factors which determine the design of small motors.

The electromotive force of the leads off which it is to run is a very important factor. For instance, a small armature can be easily wound with 480 turns of No. 18 to run with 50 volts, but it becomes troublesome to wind it with 1,440 turns of No. 24 to run with 150 volts. Thus the size of the armature must be kept sufficiently large to make the winding fairly easy.

Again, the speed is very important. Of course, the faster the motor runs, the smaller it may be, and the fewer the turns required on the armature; but then the difficulty of gearing increases, and the mechanical construction must be very good for high speeds.

Also whether the motor is to be shunt or series-wound is a very important factor in determining the shape of the magnets. In a series-wound motor, the magnets may be of any form desired, since the winding, consisting of comparatively few turns of thick wire, can be put on by hand. But in a shunt-wound motor it is almost essential, especially in high-voltage machines, to make the magnet cores straight, so that the winding can be put on in a lathe. This difference in the shape of the magnets causes small shunt-wound motors to be heavier than series ones, since it is impossible to arrange them so compactly. The difficulty of winding shunt-magnets becomes considerable when high voltages are used, as the wire has to be very small.

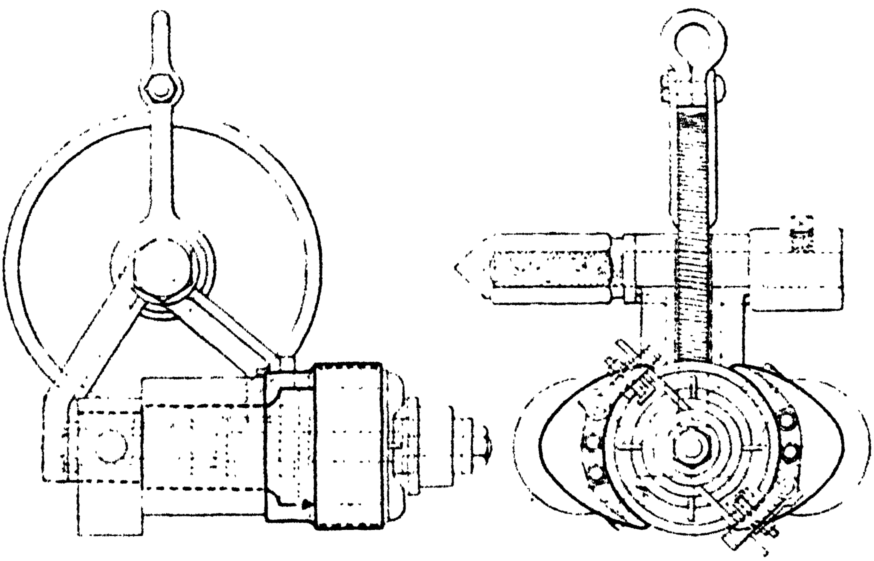
This points to the advisability of using series-winding, where possible, and for steady work there is no reason against it; but, where the load varies much, the difficulty of governing becomes very serious. This difficulty does not arise with shunt- or compound-wound motors.

The motor in question was required to drill holes up to ¾ inch diameter in wrought-iron or Bessemer steel, and there was considerable difficulty in estimating the power necessary for this purpose, as neither the power, nor the proper speed of running, nor the rate of feed for drilling holes in metal could be found in any of the reference books available.

The Author, therefore, made a few rough experiments on a common drilling-machine, to find out the power and rate of feed required. The drilling-machine was driven by a belt from a countershaft overhead, the belt being brought down on each weighted sufficiently to give the belt the necessary grip. The difference between the weights on the two sides of the belt was adjusted so that both jockeys could be kept floating when the drill was working at the desired rate. The speed and rate of feed experimented on were the greatest generally used in the shop, and the experiments showed that about $\frac{1}{3}$ HP. was the maximum power required to drive a $\frac{3}{4}$-inch drill when it was fairly sharp, cutting in Bessemer steel at the rate of about $\frac{1}{4}$ inch a minute.

The speed chosen for the electric drill was 60 revolutions per minute running light, or about 45 loaded. The motor was designed to run at 3,000 revolutions, and a steel worm on the shaft was arranged to gear into a brass wheel on the drilling spindle, thus reducing the speed in the ratio 50 to 1.

Fig. 4.



Drill.

The general design of the drill is shown in *Fig. 4*. It will be seen that the armature is overhung, the spindle running in two bearings, one on each side of the worm. The end thrust is taken on the end of the spindle. The brushes are carried on two small studs fixed on the poles of the magnets.

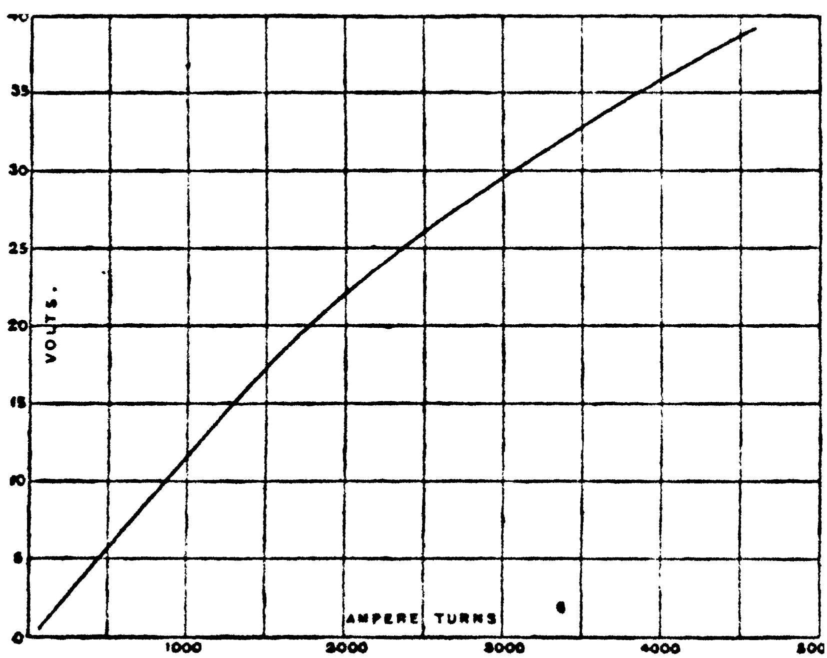
The armature is a Gramme ring, 4 inches in diameter, with a 3-inch hole $1\frac{3}{4}$ inch long. Two different windings have been tried, one consisting of 480 turns of No. 18, the other 1,600 turns of No. 24, for running with 50 and 150 volts respectively.

There are 40 sections on the commutator.

The magnets are wound with 9,800 turns, of No. 27, the resistance being 332 ohms, for working at 150 volts. Before this winding was put on, a temporary winding was put on for separately exciting them for testing.

In order to test the performance of the motor, a brake-test was made on full load. The load was increased slowly until the maximum safe temperature of the armature was reached. The motor being run for over two hours to make sure that the heating of the armature would not be too great. The brake used consisted of a leather strap hung over a wooden pulley on the motor-

Fig. 5.



Armature 1, at 3,000 revolutions per minute.

CHARACTERISTIC CURVE OF DRILL-MOTOR.

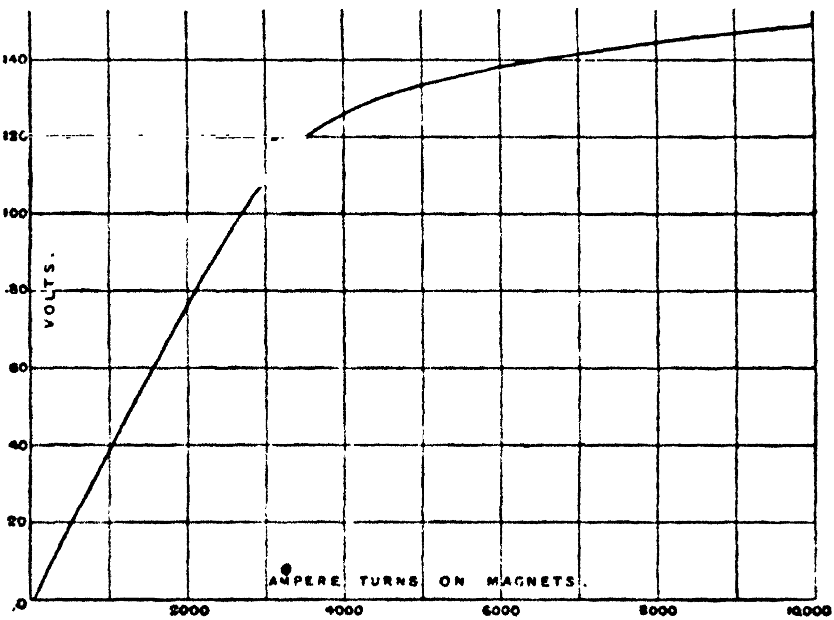
spindle, which was lubricated by a continuous stream of water. Both ends of the belt had weights attached to them; and the light end was partially supported when the motor was running on a Salter's balance. This arrangement worked very much more steadily than when the balance was put on the heavy side of the belt. The weight on the strap increased the friction in the bearings of the motor to a small extent; but no allowance was made for this in working out the results.

The brake-test gave the following result with the 50-volt armature:—

2,950 revolutions.
26·6 amperes.
47·7 volts.
B. HP. 1·05.
Efficiency 59·2 per cent.

The characteristic curve with this armature is given in *Fig. 5.* It was impossible to test the 150-volt armature on full load, as there was not a sufficient electromotive force available; but it was run to determine the maximum current which it would carry,

Fig. 6.



Armature 2, at 3,000 revolutions per minute.

CHARACTERISTIC CURVE OF DRILL-MOTOR.

which was found to be 5·6 amperes. If the efficiency of this armature is the same as that of the other, the maximum power will be 0·67 B. HP. The characteristic curve of the motor with this armature is given in *Fig. 6.*

The efficiency is not very high, but it must be remembered that, in designing the motor, lightness was considered of greater importance than very high efficiency. The weight of the motor alone, without the drilling-spindle, cannot be given quite fairly, since the magnets have been used to form part of the framing for carrying the drilling-tackle. The weights of the different parts, so far as they could be taken to pieces, are as follows :—

	Lbs.	ozs.
Magnets, bearings, and brushes	32	12
Armature	8	8
Boring tackle	15	4
Total	56	8

These figures bear out the claim made by the Author for the advantages of cast-steel over cast-iron, and the general design of the drill will show how much more cheaply the parts can be cast than forged. In comparing the weight of this motor with others, it must be remembered that it is a shunt-wound machine.

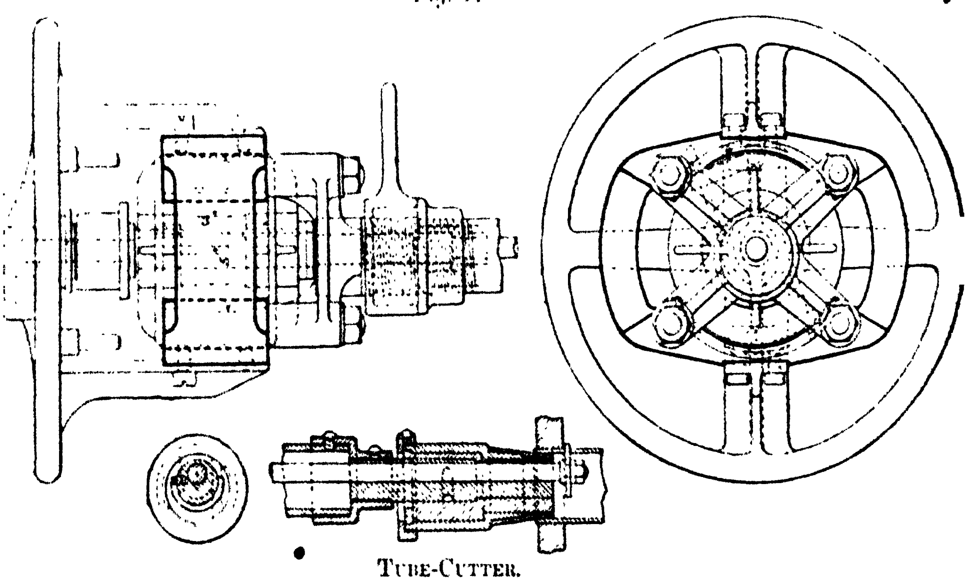
After the brake-tests had been made on the motor, the drilling-spindle was fitted on, and experiments made on the power required for actual drilling. These experiments showed that the motor was amply powerful enough for its work.

A $\frac{3}{4}$-inch hole could be drilled through a $\frac{3}{4}$-inch iron plate in 45 seconds, the electric power required being 0·732 HP. To test the efficiency of the machine in actual use, a spring-balance was attached to the arm used for preventing the machine from turning round, and the pull on it observed whilst the drill was at work. This gave the useful power. The electric power supplied to the motor was measured at the same time. The gross efficiency obtained in this way was found to be 34 per cent.

There are now in course of construction, at Crewe, two dynamos and two motors, varying from 100 HP. to 10 HP., with steel magnets; but they are not sufficiently far advanced to be tested, so the Author is unable, at present, to give any further tests of actual machines made with steel magnets. But there seems to be no doubt as to their success, since it is easy, from the tests already given, to calculate their characteristic curves within one or two per cent.

The next motor that the Author designed was for driving a small saw for cutting tubes out of boilers. The copper tubes in locomotive boilers have to be renewed from time to time, and the machine about to be described was designed to facilitate the removal of the tubes by sawing them off just inside the tube-plate. Mr. Webb suggested to the Author the use of a double eccentric motion similar to that used on an inside grinding-machine made by Messrs. Beyer, Peacock and Co. This double eccentric motion is fitted inside a plug which fits into the ends of the tubes. The saw spindle runs in a bearing in the innermost eccentric, and is either central or eccentric in the plug according to the relative position of the two eccentrics. Thus the saw is brought into its central position while the plug is introduced into a tube-end, and is then thrown out of centre so that it cuts into one side of the tube. By turning both eccentrics together the saw is made to cut all round the tube, after which the saw is again turned into its central position, and the plug withdrawn. The plug is attached to the motor-frame by a long pipe inside which the saw-spindle runs, which is coupled direct on to the motor-spindle. Handles are attached to the motor-frame for manipulating the apparatus with. Stops are arranged on the

Fig. 7.



TUBE-CUTTER.

eccentrics in the plug, so that, by simply turning the motor-frame through one-and-a-half turn in one direction, the saw is first thrown out of centre, and then caused to cut all round the tube. Half a turn in the reverse direction throws the saw back again into a central position, and allows the plug to be withdrawn.

A totally different design of motor from that used for the drill was adopted for the tube-cutter. It was thought advisable to use a series-wound motor, so it was no longer necessary to have straight magnets. In order to reduce the magnet winding as far as possible, a Pacinotti Gramme armature was used, and only $\frac{1}{32}$ inch air-space allowed on each side. The general design of the motor is shown in *Fig. 7.* The armature is 5 inches diameter outside, 3 inches long with a 3-inch hole through it. It has forty slots ½ inch deep round its circumference, and is wound with 840 turns of No. 19 double cotton-covered wire. The resistance, from brush to brush, is 0·96 ohm, cold.

The magnets are made out of a single wrought-iron forging, on to which are bolted the two phosphor-bronze brackets forming the bearings. The tube which carries the plug is screwed on to a boss on one of these brackets. Each magnet is wound with 190 turns of No. 14 double cotton-covered wire. The resistance of both in series is 0·44 ohm.

The motor was designed to run at 3,000 revolutions with 150 volts. This motor has not been tested on full load; but its efficiency has been tested by Swinburne's method.[1] The maximum safe load was calculated by comparison with the drill-motor. The result of these tests is as follows:—

Maximum load.	Watts absorbed .	2,600
	Efficiency . .	71·7 per cent.
	B. HP. . . .	2·5 HP.

The weight of the motor alone is 60 lbs. There are three times the number of turns on the magnets which are required for running at full load, sixty-three turns being then sufficient. The extra turns were put on to keep the speed moderate on light loads.

As the motor has to be stopped after each tube is cut to avoid the danger of the saws catching in the side of the tube as it is withdrawn, it is of great importance to be able to stop and start the motor rapidly. It is also necessary to prevent the motor's running away when there is no load on it. For this last purpose a resistance is put in shunt across the brushes of the motor, which allows sufficient current to flow to maintain the strength of the magnets. For starting, it is found that if the current is switched straight on to the brushes without extra resistance, the magnets give a very violent kick in the opposite direction to that in which the armature rotates. This is so unpleasant to the man holding the machine, that it has been found advisable to have a double contact switch, by which the current is first switched on through a resistance, and then direct. For quick stopping, short circuiting the brushes was tried; but this brought up the armature too suddenly, and caused excessive sparking at the brushes. But this difficulty was overcome by inserting a small

[1] "Practical Electrical Measurement," by James Swinburne, p. 111.

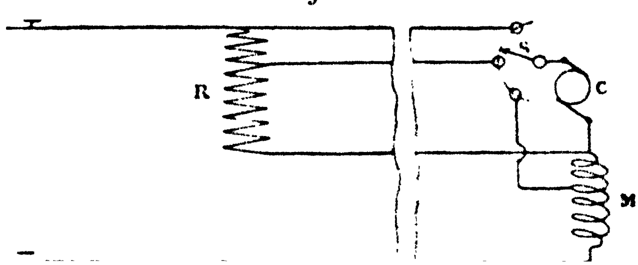
resistance. It was found possible to stop very quickly by this means without much sparking.

A number of different methods of connecting up the motor with resistances were tried with varying success, until a method was devised whereby both the extra resistances required for stopping and starting were done away with, and only one in shunt to the armature retained.

The way this was done is shown in *Fig. 8*, where C is the commutator and brushes, M is the magnet coils, S is the three-way switch on the motor, and R is the single resistance-box which stands near the machine when at work. There are four wires connecting this box, which acts as the terminal for the main leads, to the machine itself. They are all flexible wires and made up into a single cable.

For starting, the switch S is put on to the middle contact for a few seconds, then on to the top contact. For stopping, it is pulled

Fig. 8.



CONNECTIONS FOR TUBE CUTTER.

over on to the bottom contact, where it remains. The bottom contact is connected to the middle of the magnet-winding, thus the magnet-winding acts as the resistance through which the brushes are short circuited. In actual work it was found that the time taken to cut off one tube was 20 seconds, including starting, stopping, and putting into a fresh tube; that is to say, the machine will cut off three tubes in a minute.

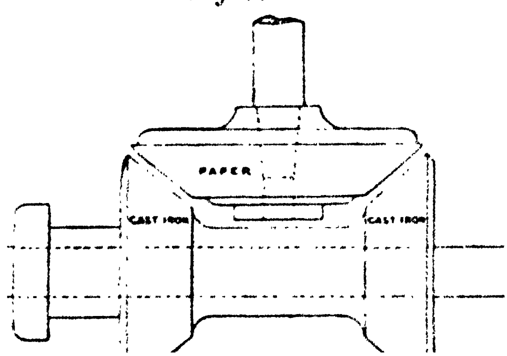
One of the first purposes for which motors were used was for driving travelling-cranes.[1] Nevertheless, the Author believes that they are not yet common enough to make the description of one which has been in daily use for the last six months, uninteresting.

A travelling-crane affords one of the most suitable opportunities

[1] Paper by W. Anderson, M. Inst. C.E., read before the B.A. 1888. *Electrician*, September 28, 1888; also *Electrical Review*, p. 599, November, 1888.

for the application of electrical power, and the practical difficulties met with in the mechanical construction and gearing are very few. The most important point to bear in mind in designing the gearing is, that the motor should run continuously while the crane is being used, and not require to be stopped or reversed for any of the motions of the crane. This necessity introduces the only really important problem, namely, the design of a clutch, or some form of gearing which can be connected at will with the motor shaft. The difficulty of this would not be so great, but for the fact that all three motions of the crane, viz., lifting, travelling, and cross travelling have to be performed in both directions. The commonest form of gearing suitable for this purpose is, perhaps, the double conical friction-gear, shown in *Fig. 9*; or a modification of it, *Fig. 10*, where the friction-wheels are replaced

Fig. 9.



FRICTION GEARING.

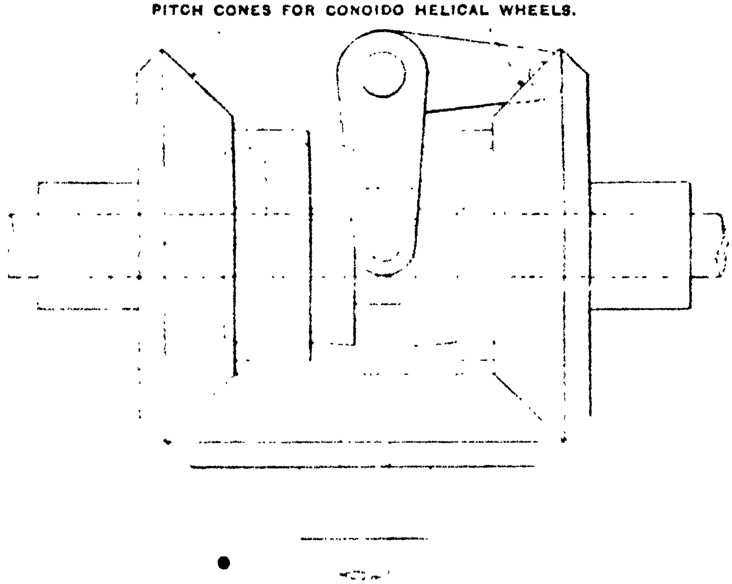
by mitre-wheels which are driven by a double friction-clutch. The first of these methods is suitable for transmitting small powers, and can be used therefore for the travelling motions of the crane; but it is not suitable where more power has to be transmitted. The second method with mitre-wheels is suitable for moderate speeds, but does not work well running as fast as it is desirable to run the motor. There is, however, a point which must not be overlooked in the case of the hoisting- and lowering-motions, namely, that much power is required for only one of these, the hoisting, while a very little power indeed is sufficient for lowering. This makes the difficulty much less, for it is only necessary to arrange a single-action clutch to transmit the power required for hoisting, while a subsidiary arrangement may be made for the reverse motion. The only other point of importance is connected with the construction of the motor itself.

The load on the motor, when used for working a crane, varies enormously and very rapidly. It varies in fact from zero to the maximum, which may be considerably above the full working load, since it has only to be borne for a short time. And these extreme variations are continually occurring. This makes it of great importance to design the motor so that there shall be very little or no sparking at the commutator under extreme variations of load. Mechanical devices for shifting the brushes are not suitable owing to the rapidity with which the variations occur.

The crane, however, which is about to be described was not originally designed to be driven electrically but by means of a fly-rope. The crane spans 38 feet, and travels 100 yards,

Fig. 10.

PITCH CONES FOR CONOIDO HELICAL WHEELS.



MITRE-WHEELS AND FRICTION-CLUTCH.

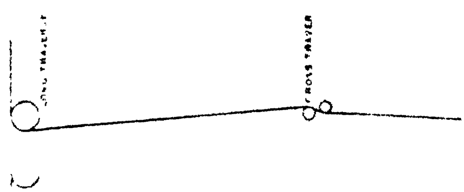
and is constructed to lift 10 tons. It used to be driven a ⅝-inch cotton rope running at a speed of 5,000 feet a minute. The rope was driven at one end of the shop by a 4-foot V-whee and was supported along one side wall on cast-iron slipper-block spaced 14 feet apart. At the further end of the shop it passe round a 4-foot straining-wheel, which was supported in a carria which could slip on two iron rails. The carriage was drawn bac so as to keep the rope tight by means of a chain and weight about 200 lbs.

The one side of the rope was made to run in a U-shaped pat across the crane and back, being guided by three 18-inch V-wheels on vertical spindles (*Fig. 11*). One of these spindles drove the travelling-gear by means of two belts. On the crab, the rope passed between two guide-wheels, on a loose bar, which could be moved by the crane-driver, so as to bring the rope into the groove on either side of a horizontal V-wheel, which drove the hoisting-gear by means of a worm and wheel. The rope also passed between two fixed guide-wheels on the crab, one of which drove the cross-travelling gear by open and crossed belts. Thus each motion was derived independently from the rope.

The speed of the wheels was very high, the hoisting-wheel running at 3,800 revolutions, the cross-travelling wheel at 2,400, and the long-travelling wheel at 1,060 revolutions per minute.

In applying electrical power to this crane, it was thought advisable to arrange it so that it could be replaced by the rope driving, with as little delay as possible in case of any failure. This was done in a very simple manner. The long fly-rope was

Fig. 11.



PLAN OF FLY ROPE ON CRANE.

replaced by a short piece on the crane itself. The path of this piece was the same as that of the old one, only that, instead of passing round the two 4-foot wheels at the end of the shop, it passed round two 18-inch wheels on the crane, one being on the motor-spindle, the other on a straining-carriage. Thus, the gearing was all left unaltered, and, by merely substituting the long the short one, the crane could be driven as before, in case of breakdown. The crane has, however, now been in daily use for six months, and this has never had to be done since the first day the short rope was put on.

Great diversity of opinion was expressed as to the power quired to drive the crane, and no very reliable information could obtained. Before making the motor, the Author attempted to asure the power transmitted by the rope, by measuring the ain on the tight side of it. This experiment, however, had to abandoned, as it was found that the irregularities in the speed of the steam-engine which drove the rope made any reading of the spring-balance employed impossible.

An attempt was also made to determine the power by indicating the engine; but the same difficulty arose, and no reliable results were obtained. The advice of the foreman of the millwrights was therefore taken, and a 10-HP. motor, of the Manchester type, was constructed and fixed on the crane.

In order to avoid sparking, a pair of small series-wound magnets were placed on opposite sides of the armature, so that their poles were on a horizontal diameter, and were over the section being short-circuited by the brushes. This method is described in Swinburne's patent, No. 6,754, 1887.[1] It was found to answer admirably, and entirely prevented sparking, no matter how quickly the load was applied.

It was determined to work with 150 volts, this being thought the maximum which could be used without danger to the men in charge. The current is conveyed to the crane through two steel angle-bars $1\frac{3}{4}$ inch by $\frac{3}{16}$ inch, which run all down the shop, and are supported, two feet apart, under two wooden planks. The details are shown in *Fig. 12.* The lengths of angle-bar are connected by ∧ shaped copper strips, fixed on to them by means of two $\frac{1}{4}$-inch set screws. This allows for the expansion and contraction of the iron.

The resistance of the double length (200 yards) is 0·033 ohm. The insulation is practically perfect. No leakage could be detected with the instrument available (a low-resistance mirror galvanometer).

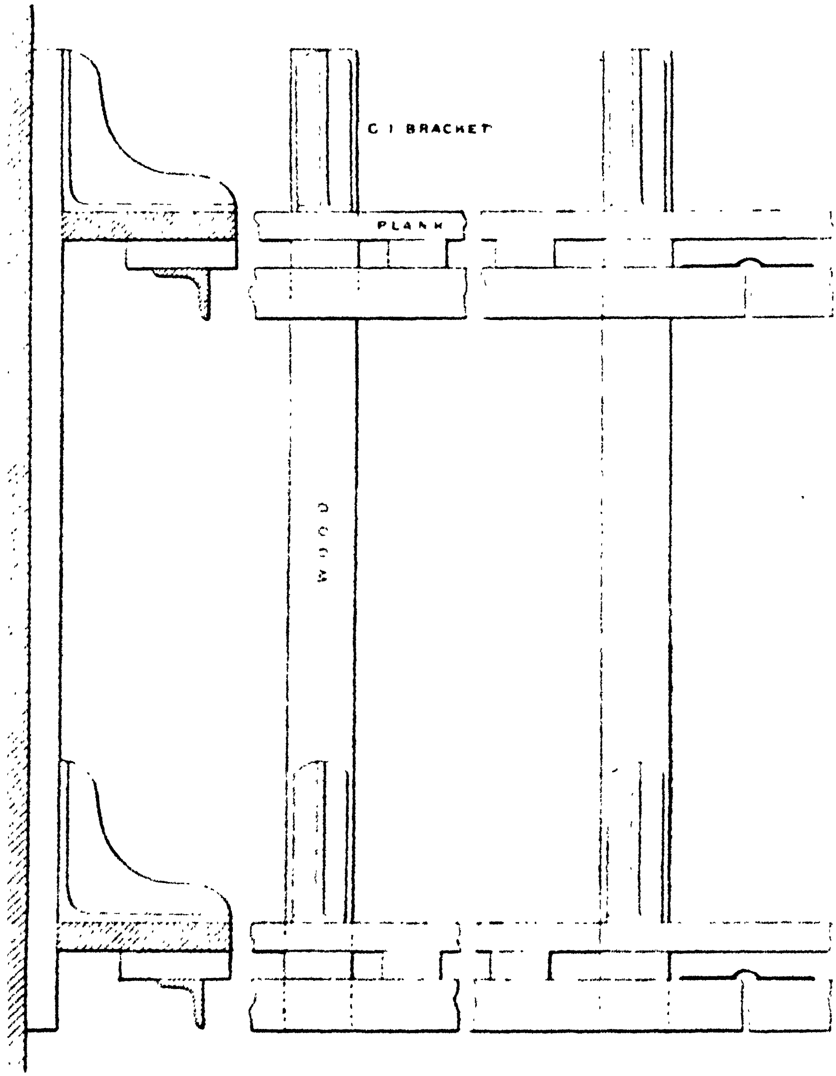
This method of support was adopted in order to avoid as far as possible, accidental short-circuiting by tools or other objects laid between the conductors, and also to make it very unlikely for any one, working on or about the crane, to receive shocks through touching both conductors at once. The wooden plank also keeps the dust off the rubbing-surface.

The outer face of the angle-bar was ground to remove the scale, and given a coat of vaseline to prevent rust. The connection to the motor is made through two sliding contacts. Each contact consists of three brass slippers on a spindle, which works in a short slot, each pressed forward by a small flat spring. This allows each slipper to bed itself flatly on the angle-bar instead of touching along one edge. The spindles are fixed on to two

[1] Also Proceedings Institution Electrical Engineers, Paper by J. Swinburne, Feb. 13, 1890.

wooden arms, hinged on the crane, the hinge allowing of both vertical and horizontal motion. Under each slipper a short steel guide projects, which slips along the under edge of the angle-bar. The arm is pressed forward and upwards by means of

Fig. 12.



Details of Angle-bars used as Conductors.

springs, and so follows the irregularities in the angle-bar. strength of the spring on the arm is adjusted to keep the ngs in the slippers about half compressed. (If it were much strong or too weak, the small springs would not act properly.) These contacts do not spark, and have given no trouble whatever. The brass pieces can be replaced, at a very trifling cost, when they wear out, but what their life will be is not yet known.

A double interlocking switch is arranged for starting the motor. The two contacts are so connected that the one must be made before the other, and broken after it. This is in order to insure that the magnet-circuit shall be made before the armature-circuit, and broken after it.

As an additional safeguard, the connections were made in a way suggested to the Author by Mr. R. H. Housman, which makes it impossible to complete the armature-circuit without the magnet-circuit. This device consists in sending both circuits through the first switch, and the armature-circuit alone through the second switch. In order to start gradually, a variable water-resistance was inserted in the armature circuit, which is cut out when the motor attains its full speed, and to avoid sparking on breaking the magnet-circuit, a second small water-resistance was arranged as a shunt to the switch. Both switches were arranged so that one movement of a lever first made contact through the water, then reduced the water resistance, and finally cut it out by a metal contact.

As soon as the new method of driving was fitted up, experiments were made to find the power required for the different motions. The power was obtained at once from the observed electric-power supplied to the motor, and its known efficiency. The power required to drive the short length of rope, and the four belts on the crane was 2·85 HP.

To lift 8 tons at about 4 feet per minute, 6·5 HP. additional.

To lift 4 tons at about 9 feet per minute, 7·0 HP. additional.

The cross-traversing at 27 feet per minute, about 0·6 HP.

The long-traversing at 47 feet per minute, less than 1 HP.

The motor was also arranged to drive the old fly-rope, the power required being 13 HP.

The total power absorbed by the motor, when lifting 8 tons, is thus shown to be 11·1 HP.

The total power required by the fly-rope on the same load is 19·5 HP.

Thus there is a saving of 8·4 HP., or 43 per cent.

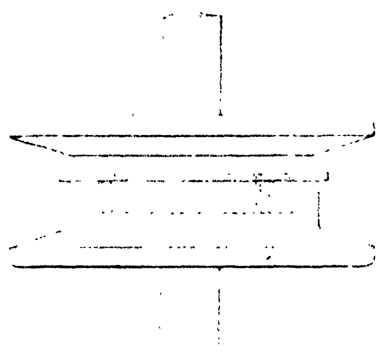
Since it is desirable to remove the rope altogether, experiments were made on various forms of gearing. The conical friction-gearing, already described, was tried, but it proved unfit to transmit sufficient power.

The mitre-wheels were also tried, running at 1,100 revolutions, but they made such a deafening noise that they were abandoned.

Another form of friction-gear was tried, but it failed also.

After the failure of these experiments, Mr. Webb suggested to the Author the use of a magnetic clutch. In order to test its suitability, one was made in the form shown in *Fig. 13*. The two taper flanges are for use with a third small wheel, for lowering; the diameter of the cylindrical portion is 6½ inches. The Author regrets that owing to some slip in the drawing, the proportions were not quite what he had intended. A coil of 240 turns of No. 19 wire was put into the recess shown in the figure, and connection made to it by means of two brass rings on the back, against which two small brushes pressed. This clutch was

Fig. 13.



MAGNETIC CLUTCH.

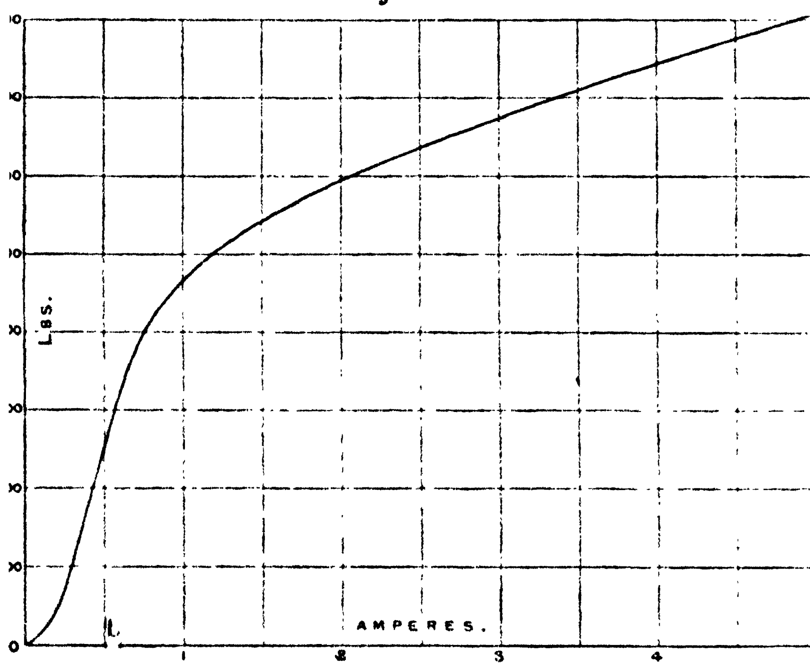
tried, running at about 1,000 revolutions, and transmitted 8 HP. satisfactorily, stopping and starting perfectly.

In order to test what couple it could transmit with varying magnetizing currents, two levers were fixed on to the two parts; and while one was held, weights were hung on the other. But this test did not give any results, for it was found impossible to keep the coefficient of friction between the surfaces sufficiently constant.

Another method of test was therefore tried. The spindles were hung up vertically, and the dead weight, which the magnet would support, was found by simply hanging on weights till the armature fell off.

The result of the test is shown in *Fig. 14*, where the abscissas represent the magnetizing current, and the ordinates the dead weight supported. From these weights it is possible to calculate, approximately, what couple it will transmit, by assuming a coefficient of friction. Assuming that the coefficient of friction is $\frac{1}{10}$, and that the pressure is equally distributed over the whole area of contact, then the power transmitted at 2,000 revolutions per minute will be 12 HP. Arrangements are now being made for fitting this clutch on the crane.

Fig. 14.



MAGNETIC CLUTCH.

In conclusion, the Author wishes to express his thanks to Mr. Webb for his kindness in affording him every facility for carrying out experiments, a few of which have been described in this Paper.

The Paper is accompanied by diagrams, from which the *Figs.* in the text have been engraved.

[APPENDIX.

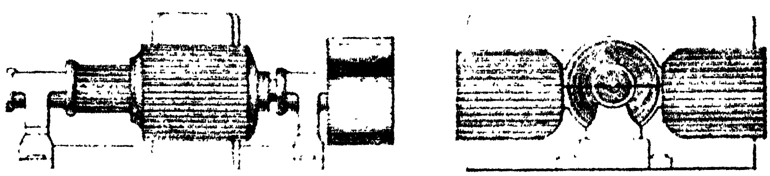
APPENDIX.

Definition.—The strength of field at a point, or the magnetic force at a point, is the force with which a unit magnetic pole would be urged if placed at that point.

In the interior of a magnet, the magnetic force is defined as the magnetic force at the middle point of a small cylindrical cavity, having its axis in the direction of magnetization, and whose length is infinite compared with its diameter.

When magnetic bodies, such as iron or steel, are placed in a field of force they become magnetized, and their magnetism is said to be induced.

Fig. 15.



The intensity of induced magnetization is measured by a quantity called the induction, which is defined as the force with which a unit pole would be urged, if placed in a very narrow crevice cut in the metal, at right angles to the direction of magnetization.

The ratio of the induction to the magnetic force is called the permeability.[1]

The Manchester dynamo, the construction of which is shown in *Fig. 15*, is a well-known type, introduced by Messrs. Mather and Platt.

[1] Clerk Maxwell, "Electricity and Magnetism," vol. ii. §§ 398, 428; Cumming, §§ 208, 214.

OBITUARY.

SAMUEL ABBOTT was born at Calverton, Notts, on the 28th of March, 1842, and was educated at Lincoln Grammar School. He was articled to Mr. George Smith, surveyor, &c., of Northampton and Peterborough. Mr. Abbott joined the engineering staff of the Great Northern Railway under Mr. Richard Johnson in 1864, and was engaged on surveys for new lines and stations until June, 1867, when he received an appointment from Mr. Prichard Baly to superintend the erection of several large bridges on the Transcaucasian Railway from Poti to Tiflis, and after that railway was handed over to an English Company he was employed to select a route and prepare plans and estimates for the projected line from Tiflis to Baku. Mr. Abbott returned to England in 1870, and rejoined Mr. Johnson's staff on the Great Northern Railway, and in 1871 he laid out the line and prepared the parliamentary plans, sections and notices for 45 miles of the Derbyshire and North Staffordshire Extension Railway. After the passing of the Act in 1872 he was appointed Resident Engineer on 20 miles of the line, and prepared the working drawings and carried out the whole of the works from Awsworth Junction in the Erewash Valley through the town of Derby to the Egginton Junction with the North Staffordshire Railway. After the completion of the Derbyshire Extensions and the maintenance thereof for twelve months, Mr. Abbott was transferred to Lincoln as Resident Engineer on the northern section of the Joint Great Northern and Great Eastern Railway (Spalding to Lincoln), and he designed and superintended the construction of the works on 20 miles of that railway. These works were completed in August 1882, and in November 1883 Mr. Abbott resigned his appointment and commenced practice on his own account; but wishing for a more active life, he applied for and obtained the post of Chief Resident Engineer of the Buenos Ayres Great Southern Railway Company. He left England to enter upon that important work in May 1885, and on the 17th of January, 1886, became Acting General Manager to that company, his appointment as General Manager being confirmed on the 1st of July of the same year.

By his strict integrity and devotion to duty, and by his kind and courteous demeanour, Mr. Abbott earned the respect and esteem of all who knew him, and his loss is felt, not only by those connected with the company, but by the community at large. He died suddenly of typhoid fever, on the 17th of May, 1890, at Buenos Ayres, in his 49th year. Mr. Abbott was elected an Associate Member of the Institution on the 3rd of December, 1872, and was transferred to the class of Member on the 28th of May, 1878.

CHARLES PRIME, born on the 9th of April, 1834. He served a pupilage of five years under Mr. Nash, of Norfolk, and was employed for two years longer by him, in charge of works and buildings. Subsequently he was engaged for ten years under Mr. Ennor, of London, as foreman and clerk of the works on important building and engineering works in England and on the Continent.

In March 1866 he was appointed draughtsman and framer of estimates and Superintending Officer in the Public Works Department of the Government of Ceylon, and at first had charge of the Galle district, under the provincial officer of public works for the Southern Province of Ceylon. He became Acting Provincial Assistant of the North-West Province on the 1st of September, 1874; Provincial Assistant of the Northern Province in 1876; Provincial Assistant, Uva, in 1878, and Provincial Engineer in 1886. Mr. Prime, during the course of his service, carried out a great many important and large public works—public buildings, roads, irrigation works and bridges—among the greatest of which was the large bridge across the wide channel at Elephant Pass, in the Northern Province of Ceylon.

Mr. Prime was one of those energetic and reliable men whose appointment to a responsible position was a guarantee that the work would be substantially and successfully carried out, under the greatest difficulties—even in the wilds of the jungle, and the most unhealthy climates.

Mr. Prime frequently had serious attacks of malarial fever, contracted in the discharge of his duties, and came on leave to England three times in the course of his twenty-four years' service, to recruit his health. Personally, he was a genial kind-hearted man, ever ready to help others, and zealous in the execution of his duties. He was a Captain in the Ceylon Light Infantry Volunteers, and was considered to be a most able officer. As an illustration of his love for work, and his facility of mastering practical details for which he had not been regularly trained, it may be mentioned that, while engaged in London as clerk of the works under Mr. Ennor, he joined the Tower Hamlets Engineer Volunteer Corps, and devoted his spare time so successfully to the duties of Military Engineering, that, when he was commanding a working party at one of the inspections of the Corps, the inspecting officer commended his work as being equal to that of the Royal Engineers, and expressed surprise at hearing that he had never been in that service.

Mr. Prime was elected an Associate of the Institution on the 7th of December, 1869, and was transferred to the class of Members on the 9th of December, 1879. He died from chronic diarrhœa, on the 28th of July, 1890, two days after his arrival in England.

WILLIAM HENRY STUBBS, the eldest son of Mr. William Stubbs, was born at Spalding, Lincolnshire, in October, 1847. He was educated at a private school conducted by the Rev. J. C. Jones, M.A. In 1862, he was articled to his uncle, Mr. Richard Johnson, engineer to the Great Northern Railway Company. During the years 1869 and 1870, he was engaged as assistant engineer on the Wood Green and Enfield Railway, and in the year 1870 was appointed resident engineer on the Bourne and Sleaford Railway. In 1871-2, Mr. Stubbs was engaged on the preliminary surveys for the Derbyshire and Staffordshire extensions of the Great Northern Railway, and was appointed resident engineer on the first section of 20 miles, the works of which he designed and carried out, including tunnels, viaducts, and other works of a very heavy description.

In July, 1877, Mr. Stubbs was appointed engineer to the North Staffordshire Railway Company, and continued in that position until May, 1886, when he was appointed engineer to the Manchester, Sheffield and Lincolnshire Railway Company on the retirement of the late Mr. Charles Sacré, M. Inst. C.E. Mr. Stubbs suffered in 1889, from aneurism of the arteries, and never afterwards entirely recovered his accustomed health; he died suddenly on the 21st of June, 1890, in the forty-third year of his age, whilst on a visit to Blackpool, where he was engaged in setting out a new line of railway. He was elected Member of the Institution on the 3rd of December, 1878.

GEORGE HUSTWAIT WRIGHT, second son of George Wright, of Girtford Bridge, Bedfordshire, was born at that place on the 13th of February, 1834. He was educated at a school at Biggleswade, and was articled to a Mr. John Bull. After three years' study of surveying and engineering, he was engaged for two years on surveys of railways in England and Portugal. He then proceeded to India to join his brother William, who was at that time employed on the construction of the Bhor Ghát Works, and entered the service of the Great Indian Peninsula Railway. After some time he was transferred from the construction to the permanent maintenance staff, and in the course of the twenty-five years that he served the company, he was Resident Engineer at Poona, Egatpura, and Nasik, and district engineer at Jabalpur. It was in a great measure owing to his exertions that the portion of the Great Indian Peninsula Railway adjoining the East Indian Railway at Jabalpur, was completed in time to be opened in 1866 by H.R.H. the Duke of Edinburgh. After the opening of the line to Jabalpur, the district of which Mr. Wright had charge was extended to Bhassawul Junction, the total length of lines included in it being upwards of 300 miles. He also for sixteen months officiated as chief engineer of the Great Indian Peninsula Railway. Mr. Wright's qualifications as a railway engineer were well known to his professional brethren, and he several times received the thanks of the directors, and was commended by the officers who came to inspect the line. That he was kind and just in his treatment of his subordinates is evidenced by the fact, that on three several occasions they presented to him testimonials of silver plate.

When the Volunteer movement was set on foot in 1872, Mr. Wright was unanimously offered the chief command of the G. I. P. Railway Volunteers, and held the office for five or six years. The camps of exercise at Egatpura, during the time he was Colonel-Commandant, were most successful, and he was highly complimented on the efficiency of his corps by Sir Richard Temple, Governor of Bombay.

In March, 1881, Mr. Wright resigned his appointment, and returned to England. Within a few weeks of his arrival he was offered the appointment of Engineer-in-chief to the Egyptian Government Railways, in succession to Mr. Lee-Smith, and in October he proceeded to Egypt. In 1882 the Arabi rebellion broke out, and for three months the railways were almost entirely in the hands of the rebels, and were much damaged by them.

Mr. Wright gave the British military authorities great assistance at Alexandria during the campaign, and was frequently under the enemy's fire while on the armour-clad train, which he invariably accompanied. For his distinguished services he received the British war medal and the Egyptian bronze star. In June, 1883, the cholera broke out at Damietta, and in a month's time more than four hundred deaths daily were officially registered in Cairo, the disease being most active among the native and European employés at Boulac. With the concurrence of the railway board, Mr. Wright promptly erected mat huts in the desert, ten miles from Cairo, and about two hundred families were transported there, the workmen being brought to and from the Cairo workshops by train. Mr. Wright visited this camp daily, and had the satisfaction of feeling that in this way a great number of people were enabled to escape infection. Mr. Wright had to bring into order a railway system 1,200 miles in length, which had been starved of money, materials, and intelligent supervision. His first step was to introduce lorries for the permanent way department, for up to that time the line had to be inspected on foot or on donkey-back. Considering the insufficiency of the staff he had Mr. Wright did wonders. The Railway Board of Administrators consisted of three irresponsible members, of three different nationalities, who could never agree on anything except masterly inactivity, and insisted that each matter, however trivial, should receive their solemn triple consideration and long-deferred sanction before any action could be taken. Mr. Wright did his best to alter this, and to carry on his reforms in spite of it. He gained the complete confidence of every administrator, and the respect and hearty goodwill of all his subordinates. His efforts to maintain the rights and redress the grievances of those under him, irrespective of their nationality, creed, or class, were universally acknowledged and admired. Under a regenerated board and improved regime many of the improvements and reforms which he had advocated have lately been carried out.

In July, 1887, the Railway Board appointed Mr. Wright their inspecting engineer in England, and on his leaving Egypt, H.H. the Khedive made him a Commander of the Imperial Order of the Osmanlieh, he having been made some years before a Commander of the order of the Medjidieh.

Mr. Wright died at his country residence, Whitchurch, Oxon, on the 11th of December, 1889, of typhoid fever, supposed to have been contracted by him in Scotland, during an official journey in his capacity of inspecting engineer to the Egyptian Railway

Administration. His kind-heartedness and geniality as a host, made him generally beloved by all who came in contact with him, whether in official or in private life. He was a keen sportsman, a good rider, and a great lover of flowers, and it may be mentioned that he did all he could to encourage gardening at railway stations. Mr. Wright was elected a Member of the Institution on the 3rd of December, 1867.

WILLIAM JEREMIAH HALL, B.E., was born on the 17th of July, 1851. He was articled in 1867 to Mr. John Long, and was with him as assistant engineer in 1868 and parts of 1870–71 during the construction of the Limerick Graving Dock. He studied at Queen's University, Ireland, from 1870 to 1873, and obtained the diploma of Civil Engineer in June, 1873, and the degree of B.E. in October of the same year, together with the triple first prize in Engineering. In December 1873 he became Assistant to Mr. W. Barrington, M. Inst. C.E., and remained with him for three years, having the superintendence of the Mulkear Drainage Works, which cost nearly £50,000, and the making of contract-surveys and plans for the Limerick and Kerry Railway. During the same period Mr. Hall was also engaged in work on his own account, and after leaving Mr. Barrington was appointed, in January, 1877, Harbour Engineer at Limerick. Under his superintendence many important works were carried out, including extensive subaqueous rock excavating, the deepening of the channel and erection of lighthouses, and other heavy operations for improving the navigation of the River Shannon.

The steel cellular gates of the Limerick Floating Dock, designed in 1852 by Mr. Robert Mallet, having become damaged to such an extent as to necessitate their removal, Mr. Hall decided upon constructing a new pair of gates on a somewhat modified plan, a description of which was communicated by him to the Institution.[1] He acted as Consulting Engineeer to the Limerick Waterworks from October 1880 to April 1883, when the works were sold to the Limerick Corporation, and placed under the care of the City Surveyor.

Mr. Hall was elected an Associate Member of the Institution on the 2nd of February, 1886. He died on the 21st of May, 1890, of typhoid fever, contracted while engaged in superintending the

[1] Minutes of Proceedings Inst. C.E., vol. xcvii. p. 335.

rebuilding of the wall of the Floating Dock at Limerick. He was deservedly popular with all with whom he came in contact, and made himself prominent in social and charitable entertainments, his good-humoured wit, combined with good taste, rendering his services always acceptable. The esteem in which he was held was evinced by the many wreaths which were sent to his funeral and the large crowds of all classes who followed him to the grave.

JOHN MITCHELL SALMOND was born on the 27th of May, 1842. He was educated for the Army, and went through the usual course at the Royal Military Academy, Woolwich, and served for a short time in India as Lieutenant in the Royal Artillery; but in 1873, in consequence of a misfortune that brought no dishonour on him, he sent in his papers. In 1874 he entered the Public Works Department of India, as a civilian, and was appointed, on the 10th of March of that year, temporary Assistant Engineer to the Madhubáni division of the Tirhút Relief Works, Bengal. In July 1875 he was transferred to the Rangoon and Irawaddy State Railway, and was appointed Assistant Engineer of the second grade. In April 1879 he was made Executive Engineer, with charge of the construction of the suburban line of the same railway. His next work was superintending the surveys for the re-alignment of the Sittang Valley State Railway, after which he had charge of the head-quarters division of the Rangoon and Sittang Valley State Railway, and subsequently of the first division of the same; and in July 1884 he was made responsible for the second division also. During 1886 he was engaged upon the railway from Toung-ngu to Mandalay; and in 1887 his promotion to third grade Executive Engineer was made permanent. Up to the time of his death Mr. Salmond was employed as an Executive Engineer upon the surveys and construction of the extension of the Rangoon and Sittang Valley State Railway to Mandalay. Mr. Salmond was elected an Associate Member of the Institution on the 2nd of December, 1884.

JAMES CONSTANTIEN MARILLIER was born at Harrow-on-the-Hill, Middlesex, on the 21st of June, 1827. He was articled to Mr. Thomas Wicksteed, Engineer to the East London, and several other London Water-works Companies, and remained with him for about six years. He then, after some temporary engagements, went to Messrs. Hawks Crawshay and Sons, at Gateshead-on-Tyne, in whose employ he gained considerable experience in the construction of iron girder-bridges, which subsequently proved of great advantage to him. He was afterwards for some time engaged in superintending the construction of the Turin and Novara Railway in Italy.

Mr. Marillier then went to India, and was engaged for several years by Messrs. Brassey, Wythes and Henfrey, in superintending the construction of the numerous iron bridges on the Delhi and Lahore, and the Eastern Bengal Railways, for the construction of which they had the contracts. All the works under his charge were carried out very satisfactorily. Whilst in India he established works in Calcutta, in conjunction with Mr. W. H. Edwards, since deceased, as partner, at which numerous iron bridges, jetties, wharves, and other important work were constructed.

Mr. Marillier retired from business some years ago, and since then resided principally at Paris and Nice, at which latter city he died, from inflammation of the lungs, on the 20th of June, 1890.

He was elected an Associate of the Institution on the 5th of April, 1859.

*** The following deaths, in addition to some of those included in the foregoing notices, have been made known since the 14th of July, 1890:—

Members.

GEORGE, ROBERT JOHN; *born* 10 May, 1841; *died* August, 1890. (*Bursting of a blood-vessel.*)

HODSON, RICHARD; *died* 22 July, 1890; *aged* 57. (*Cancer on the liver.*)

HURST, THOMAS GRAINGE; *died* 21 July, 1890; *aged* 66.

OGILVIE, CHARLES EDWARD WALKER; *born* October, 1823; *died* 30 August, 1890. (*Disease of the bladder.*)

WATSON, JOHN; *died* 8 August, 1890; *aged* 75.

Associate Members.

BIGG-WITHER, THOMAS PLANTAGENET; *died* 19 July, 1890; *aged* 44.

FLOYER, GEORGE WADHAM; *born* 19 November, 1863; *died* 29 August, 1890. (*Breaking of a blood-vessel.*)

, CONRAD HENRY WALTER; *died* 23 July, 1890; *aged* 29.

PADDON, WILLIAM VYE; *born* 10 July, 1859; *died* 9 July, 1890.

SINGLETON, ALFRED; *died* 1 June, 1890; *aged* 48. (*Gastritis.*)

Information respecting the life and works of any of the above is solicited in aid of the preparation of future Obituary Notices.—SEC. INST. C.E., *September*, 1890.

Sect. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

Continuous Utilization of Tidal Power. By Paul Decœur.

(Le Génie Civil, vol. xvii., 1890, p. 130.)

In connection with the training-walls to be constructed in the estuary of the Seine, it is proposed, in place of reclaiming the space behind the walls, to construct large basins, by means of which the power available from the rise and fall of the tide could be utilized. No excavation would be necessary. The method proposed is to have two basins separated by a bank rising above high water, within which turbines would be placed. The upper basin would be in communication with the sea during the higher one-third of the tidal range (rising), and the lower basin during the lower one-third of the tidal range (falling). If H be the range in feet the level in the upper basin would never fall below $\frac{2}{3}$ H measured from low water, and the level in the lower basin would never rise above $\frac{1}{3}$ H. The available head at all stages of the tide is shown by a diagram. It varies between 0·53 H and 0·80 H, the mean value being $\frac{2}{3}$ H. If S square feet be the area of the lower basin, and the above conditions are fulfilled, a quantity $\frac{SH}{3}$ cubic feet of water is delivered through the turbines in the space of nine and a quarter hours. The mean flow is therefore $\frac{SH}{99,900}$ cubic feet per second, and the mean fall being $\frac{2}{3}$H, the available gross HP. is about $\frac{S^1 H^2}{30}$, where S^1 is measured in acres. This might be increased by about one-third if a variation of level in the basins amounting to $\frac{1}{2}$ H were permitted. But to reach this end the number of turbines would have to be doubled, the mean head being reduced to $\frac{1}{2}$ H, and it would be more difficult to transmit a constant power from the turbines. The turbine proposed is of an improved model designed to utilize a large flow with a moderate diameter. Illustrations are given of one designed to produce 300 HP. with a minimum head of 5 feet 3 inches at a speed of 15 revolutions per minute, the vanes having 13 feet internal diameter. The speed would be maintained constant by regulating sluices.

It is proposed to establish power-stations of this kind on both banks of the Seine near Honfleur and Havre respectively. On the left bank the surface available would be nearly 2,500 acres, and the tidal range varying between 10 feet and 26 feet; 3,000 HP. could be realized at neap tides and 9,000 HP. at springs. The line of the training-walls on the right bank is not sufficiently known to enable the scheme to be worked out for that side. The cost of the special works necessary on the left bank (not including training-walls) is estimated at £72,000, or £12 per mean HP. developed on the turbine-shafts. It is estimated that the Government would be well repaid if it charged consumers £1 12*s.* per HP. (on turbine-shaft) per annum. Steam power costs at Havre on the average for small factories about £24 per HP. per annum.

C. F. F.

Notes on Tacheometry. By W. Jordan.

(Zeitschrift für Vermessungswesen, vol. xix., 1890, p. 401.)

Of recent years numerous contradictory, and possibly misleading, statements have been published as to the number of points it is possible to determine per day with the tacheometer. Ulrich, for example, has given the maximum number of points as seven hundred per day. The Author is of opinion that it would be more useful to ascertain the average number of points required under ordinary conditions per square kilometre. With this view, he has carefully collated the field-books of his surveys for the last seven years. The instrument employed in these surveys was a tacheometer-theodolite (described in detail in the Author's "Handbuch der Vermessungskunde," 1888, vol. ii., p. 592), and the staff was an ordinary metrically divided levelling-staff, the painting of which was slightly modified to enable it to be seen at long distances. It was held vertically, so that when the line of sight was inclined at an angle of α, the horizontal distance a, and the difference in level h could be calculated from the formulas:—

$$a = k\,l \cos^2 \alpha$$
$$h = \tfrac{1}{2}\,k\,l \sin 2\,\alpha.$$

The constant k was taken as 100. The following table shows the method adopted in surveying and calculating nine points from the station, No. 71, 90·30 metres above the datum:—

Survey in the Field.					Calculation in the Office.		
Point No.	Distance l.	Azimuth.	Zenith Angle.	Vertical angle a.	$a = l \cos^2 a$.	$h = \frac{1}{2} k l \sin 2a$.	Height above datum.
	Decimetres	°	° ′	° ′	Metres.	Metres.	Metres.
72	9·5	281·0	96 35	− 6 35	94·0	− 10·85	79·45
73	8·6	305·0	98 57	− 8 57	83·9	− 13·22	77·08
74	10·2	357·3	91 39	− 1 39	101·9	− 2·94	87·36
75	13·1	280·2	90 29	− 0 29	131·0	− 1·10	89·20
76	6·1	116·4	90 44	− 0 44	61·0	− 0·80	89·50
77	11·4	115·9	84 30	+ 5 30	113·0	+ 10·88	101·18
78	19·2	116·3	80 18	+ 9 42	186·6	+ 31·89	122·19
79	17·5	211·0	81 13	+ 8 47	171·0	+ 26·40	116·70
80	23·1	210·8	83 45	+ 6 15	228·2	+ 25·00	114·30

In the field the distances read, the azimuths and zenith angles were entered in the field-book, together with the vertical angles ($a = 90° - z$). The office work consisted merely in seeking the horizontal distance, $a = l \cos^2 a$, and the height $h = \frac{1}{2} l \sin 2a$, in the tables calculated by the Author,[1] and in adding the value of h thus found to the height of the station above the datum-line. In the example given it is assumed that the telescope is anallatic; or in other words, that in the formula for determining distances ($E = c + k l$), $c = 0$, and $k = 100$.

The results of surveys made by the Author and his pupils during the last seven years may be tabulated as follows:

Year.	Area in square kilometres.	No. of points.	Points per sq. kilometre.
1883	0·99	416	420
1884	1·26	700	556
1885	1·07	1,134	1,060
1886	0·70	656	937
1887	1·09	775	711
1888	1·20	791	659
1889	1·16	828	714
1889	3·30	1,861	564
1890	1·00	650	650
Totals and average	11·77	7,811	664

[1] "Hulfstafeln für Tachymetrie," Stuttgart, 1880.

These surveys were made at different localities in the neighbourhood of Deister and Hanover. With the exception of the second survey made in 1889, which was plotted to the scale of 1 to 2,500, they were all plotted to the scale of 1 to 2000. The results of these surveys show that, in round numbers, the average number of points required per square kilometre is 700, or 1,813 points per square mile. Assuming that these points are uniformly distributed, the distance between two adjacent points would be 38 metres (124·6 feet). Ulrich's results differ considerably from those obtained by the Author, who was never able to complete the survey of 1 square kilometre (700 points) in one day. Indeed, the results of a tacheometric survey he gives in detail show that even with considerable practice it is impossible to exceed 400 points per day.

B. H. B.

Anthracite-mine Surveying. By R. van A. Norris.

(The School of Mines Quarterly, New York, 1890, p. 328.)

As the mining-laws of Pennsylvania require accurate mine-plans to be filed with the inspector of mines in each district, very extensive surveys are continually being made. The methods of surveying employed are very varied, but the method described by the Author is believed to be one of the best. The surveying party consists of a theodolite man, station-man, backsight, foresight, and chain-man, with a fireman to attend to the safety of the party. Three tripods are used, but the wicks of the tripod lamps, which were found too large for accurate sighting, are replaced by steel wires $\frac{1}{16}$ inch in diameter, and $\frac{3}{8}$ inch high. The sights are taken to the bottom of this wire, and measurements are taken on the line of sight with a 300-foot steel tape, marked at every 5 feet; the station-man keeps ahead of the party, and fixes the stations by drilling a small conical hole in the roof, and suspending a plumb-line from an iron rod with a notched end fitting the hole. The point is then transferred to the floor. A better method is to put a horse-shoe nail with a hole punched in the end into a plug of wood driven into a hole in the roof, and then to suspend the plumb-line from the ring, and set up the theodolite underneath. A still better method is to put a shoe-peg holding a small loop of fine copper wire in the hole. Continuous azimuth angles are run, and the entries in the note-book consist of the vernier reading on a continuous graduation from 0° to 360°, and the quadrant reading or course. A needle reading is taken roughly with a view to detect serious errors. At the commencement of the survey, the vernier is set to the course of the starting stations taken from the note-book; the error in a closed survey of fifteen or more lines is rarely found to exceed three minutes. For levelling purposes, the vertical angles are read very carefully, the sight-wire being so arranged that it is just 0·5 foot below the centre of the instrument. The method of booking adopted is as follows :—

May 1, 1889. Continuation of Survey of No. 3 Plane.

Stations.	Courses.			Distances.			Elevations.			Remarks.
	Needle.	Angle.	Course.	Vertical angle.	Hor. dist.	Tape.	Ht. inst.	Staff.	Elevation.	Vertical distance.
1–2	..	..	N. 85° 24′ E.	..	..	..	− 1·54	..	+ 233·89	..
2–3	S. 4° E.	173·46	S. 6° 14′ E.	− 6° 00′	57·60	57·28	..	+ 1·90	+ 228·32	− 6·02
3–x	N. 82° W.	..	N. 83° 50′ W.	..	68·00	..	..	..	..	Face.
3–4	N. 85½° E.	84·21	N. 84° 21′ E.	− 2° 56′	22·76	22·73	..	+ 2·25	+ 228·01	− 1·16
4–5	S. 8° E.	170·45	S. 9° 15′ E.	− 5° 46′	52·10	51·83	..	+ 2·05	+ 223·08	− 5·23
5–6	S. 88° E.	91·24	S. 88° 36′ E.	− 3° 07′	27·64	27·60	..	+ 1·85	+ 221·88	− 1·50
6–x	N. 87° E.	..	N. 85° 30′ E.	− 2° 15′	106·0	105·92	..	..	..	..
6–7	S. 4½° E.	174·20	S. 5° 40′ E.	− 5° 56′	52·58	52·30	..	+ 1·85	+ 216·95	− 5·43
7–x	N. 85° W.	..	N. 86° 50′ W.	+ 1° 30′	86·00	..	..	..	..	Face.
7–8	N. 86° E.	84·59	N. 84° 59′ E.	− 3° 42′	25·19	25·13	..	+ 2·10	+ 216·08	− 1·62
8–9	S. 1° E.	177·33	S. 2° 27′ E.	− 4° 00′	34·37	34·28	..	+ 0·90	+ 212·99	− 2·39
9–10	S. 73° E.	107·50	S. 72° 10′ E.	− 5° 29′	99·96	99·50	..	+ 1·90	+ 204·94	− 9·55
10–8	N. 81° E.	80·12	N. 80° 12′ E.	− 4° 01′	50·00	49·87	..	+ 1·10	+ 201·14	− 3·50
8–7	..	..	N. 78° 55′ E.	..	..	..	..	..	..	..

The error on closing in this survey is one minute; the horizontal distances, elevations, and vertical distances, are calculated in the office; the column headed "staff" gives the distance from the centre of the instrument to the station in the roof; this method of levelling gives surprisingly accurate results, the error rarely exceeding 0·1 foot in a survey of fifty or more lines. Surveying in this way it is possible to attain great speed, from forty to fifty stations being considered a fair night's work. All main stations are plotted from calculated latitudes and departures, and the stations in the workings are filled in with the aid of the protractor.

B. H. B.

Apparatus for Measuring Strains within the Elastic Limit.

By L. LE CHATELIER.

(Annales des Ponts et Chaussées, June, 1890, p. 855, 1 plate.)

This is a description of an apparatus intended for measuring the strains in the members of iron bridges during the tests. The Author had the assistance of Mr. Digeon, and after many trials the present type was arrived at, and five are being made for use on the Arcole bridge. It was desired to construct an instrument which, while being perfectly exact, could be used by persons who were not testing-experts.

The direct measurement of strain at one particular section has not been attempted; the only feature which appears capable of measurement is the change of length of the specimen between two points, and the method consists in comparing the distance between these two points at any moment with the original distance, by means of a bar adjusted to the distance between the points before the test is made. It is necessary to fix test-points, as constructions in metal are not so fitted, and as the distance between the test-points is usually about a yard, it becomes a matter of the first importance to fix them rigidly; the ordinary method in which screw-clamps are used increases the liability to error in measurement. The Author has adopted the method of fixing each test-point to the part to be measured by two metal screws, well tightened up into tapped holes. The extra labour is not worth speaking of, and no injury is done to the structure, for screws of $\frac{3}{16}$ inch diameter are quite sufficient.

The principle upon which the apparatus acts, is the change of the variation in length into the movement of a diaphragm of large area acting on a vessel full of water, with which is connected a tube of small section open to the air; ordinary mechanical methods are therefore excluded, and the variations can be magnified as much as is desired.

One of the fixed points consists of an L plate, carrying a lathe-centre; the other fixed point is a casting which carries a bracket, in which slides a short steel rod, pointed at both ends like a lathe-centre; this casting also supports the water-chamber, which is like a saucer placed vertically, the mouth being closed by a corrugated diaphragm of German silver, similar to those employed in aneroid barometers, and into the water-chamber is fixed a metal tube, which is connected to the vertical glass tube; one end of the double-ended centre presses against the diaphragm, and the bar previously mentioned lies between its other end and the second fixed centre. If, therefore, the fixed points recede from each other, owing to elongation of the member of the bridge to which they are fixed, the pressure of the column of water in the tube forces out the diaphragm, and the height of the water in the glass falls; while, if the member contracts, the diaphragm is pressed in by the bar, and causes the water to rise in the tube, the whole instrument acting like a thermometer. It will be seen then that the variations of height of the water in the tube depend upon the laws of movement of a diaphragm with pressure all over one surface, and counter-acting pressure concentrated at the centre of the other surface; these laws are not known, but as the bore of the glass tubes is not absolutely regular, calibration is always necessary; and it is found that, with the diaphragm, the variations in height of the water are about two-thirds of what would occur if a piston were used in place of a diaphragm. In preliminary trials it was found that a variation in the distance between the fixed points could be magnified ten thousand times; but with a proportion of 1000 : 1, and taking the modulus of elasticity of wrought iron as 28,450,000 lbs. per square inch, a displacement of 3·15 inches is obtained per ton pressure per square inch, with a distance of 39·37 inches between the fixed points, and with a tube of about $\frac{1}{10}$ inch internal diameter. It is unnecessary to attempt to measure forces of less than $\frac{1}{20}$ ton; but it is very important to reduce the distance between the test-points as much as possible. In working on a length of 8 inches, a reading within about $\frac{1}{25}$ inch would give an approximation within 112 lbs. per square inch of the force applied. It is necessary that the points where the lathe-centres touch the bar should be invariable, but still open to side play, so as to allow for slight error in the fixing of the holding screws; this is attained by drilling a conical hole in the bar at a more obtuse angle than that of the point of the lathe-centre, so that the centre point touches the bottom of the hole. Both points and holes are of hard steel; the short double-ended centre must be a good fit in its slide.

The length of the bar must be tested at each experiment when in position.

The bar consists of a hard thin copper tube, into each end of which is fixed a gun-metal bush, and these are tapped for steel plugs which are drilled for the lathe-centres. These plugs allow of adjusting the length of the bar.

The water-chamber is filled by aspiration through the tube, while the chamber is in a vessel of water; the height of the water is then adjusted to about half the height of the tube by a small cock below.

The tube itself is in connection with the water-chamber by a spiral of soft copper tube, with a union joint at each end, so that the three pieces can be separated for transport. The readings on the tube can then be made upon a scale fixed at the side. The calibration of the instrument is effected by placing it on a small iron bed, and in place of the other L plate, a loose head provided with a micrometer wheel is used; the bar is then as usual placed between the centres, and pressure put on the diaphragm by turning the micrometer screw, corresponding readings being taken in the tube. It is found best to calibrate before each test, and for specially accurate work both before and after, so as to avoid any chance of error through injury to the diaphragm. The whole apparatus of course acts also as a water-thermometer, and a temperature error must be allowed for. Cloudy weather is best for experimenting; the time between the different tests should be as short as possible, and the instrument should be covered. The size of the water-chamber should be as small as possible; the one used, which magnified eight hundred times, gives a rise of about $\frac{3}{16}$ inch for each rise of 1 degree Centigrade in temperature. Such instruments have been used upon a railway bridge at Nogent sur Marne in November 1889, and also upon various other bridges, and details are given of the results obtained.

E. R. D.

On the Permanent Effect of Strain in Metals.

By R. H. Thurston.

(Advance-Proof Transactions of the American Society of Civil Engineers, 1890.)

"If a metal be subjected to a stress of any given kind, or in any stated 'sense,' sufficient to produce permanent strain and set, then its ultimate resistance to that, or to any other kind of stress, will be sensibly increased, and in all directions, whatever the line of section of the deforming stress." This is Mr. Thurston's enunciation of the principle deduced by him, as the result of much previous experimental investigation reaching back to 1876.

He gives the results of illustrative experiments conducted by Mr. G. W. Bissell, in Sibley College laboratory. Four series of experiments were planned, in each of which the material employed,—machinery steel (0·5 C.),—was subjected to strain in either tension, compression, or torsion, or by transverse loading. By the application of another straining force, the permanent effect of the first, with the altered elastic-limit and ultimate resistance were revealed.

For series A, four test-pieces, $\frac{3}{4}$ inch in diameter, 14 inches long, were turned down for a length of 2 inches at the middle to a diameter of ½ inch. One piece was set by tensile force; another was bent in the neck and straightened, in two directions at right angles; a third was twisted forward and back; the fourth was compressed. The four specimens were turned down to a uniform diameter for a length of 10 inches, then pulled in the testing-machine till a decided local reduction of diameter was effected. The necks were formed nearer one end than the other, leaving the central portions, which had been previously set, unaltered; and it was found that each of these portions was of visibly larger diameter than any other part of the specimen. The respective diameters are tabulated thus:—

SERIES A.

No. of Test-piece.	Diameter at 1¼ inch left of Middle.	Diameter at Middle of Previously Strained Section.	Diameter at 1¼ inch right of Middle.
	inch.	inch.	inch.
1	0·479	0·526	0·475
2	0·452	0·477	0·449
3	0·474	0·486	0·465
4	0·500	0·524	0·495

For series B, five torsion test-pieces were used; one was tested to rupture, the four others were strained by tension, compression, torsional, and transverse stresses, with permanent set. These four specimens were reduced to form as torsion test-pieces, and tested to rupture, showing augmented resistance and decreased ductility.

For series C, four pieces, 4 inches long, ⅝ inch in diameter, were turned near the middle to $\frac{7}{16}$ inch in diameter, for a length of $\frac{3}{16}$ inch. They were severely strained by tensile, compressive, torsional, and transverse stresses respectively; and from each was cut a test-piece for compression, ⅜ inch in diameter, ¾ inch long, comprising the previously strained portion at the middle of its length. Subjected to high compressive stress, all the specimens exhibited much larger diameters at the ends than at the middle, suggestive of the form of an hour-glass, instead of the familiar barrel form. These results indicated augmented strength and decreased ductility in the parts previously strained.

For series D, four ⅝ inch bars, 8 inches long, were turned down about the middle to $\frac{7}{16}$ inch in diameter, for a length of 1 inch; the neck was located to one side of the mid-length, 4 inches from one end, 3 inches from the other end. The several bars were subjected to the four kinds of stress, giving permanent set, and were turned down over the whole length, to a diameter of $\frac{5}{16}$ inch, and tested transversely on bearings 6 inches apart, by loads applied at the mid-lengths of the bars. The bars were bent almost entirely in that half of each bar which had not been previously strained. In two instances the treated half-lengths were perfectly straight.

D. K. C.

On the Strength of Parabolic Arches. By E. COLLIGNON.

(Annales des Ponts et Chaussées, April 1890, p. 385.)

This Paper explains a method of determining approximately the stresses in a parabolic elastic arch when the rise is small compared to the span—say less than one-fourth. The results obtained may for flat arches be applied to the circle, which differs but little from a parabola. The thrust of the arch is determined from the equation $\int M\,y\,ds = 0$, the integration extending from one abutment to the other, an equation which expresses the invariability of the span. dx is substituted for ds as an approximation (a proceeding justified in an appendix to the Paper), and y, being known as a simple function of x by the equation to the parabola, the equation is immediately integrable. If l is the span, and f the rise, the equation to the parabola referred to one abutment as origin is $y = \frac{4f}{l^2}\,x\,(l - x)$, and for a number of loads P at points x, y, the horizontal thrust Q is given by

$$Q = \frac{5\,l}{32 f^2} \Sigma\, P\, y + \frac{5\,l}{128 f^3} \Sigma\, P\, y^2.$$

If the curve be described whose ordinate $y' = \frac{y^2}{4f}$, *i.e.* $\frac{4f}{l^4}\,x^2\,(l - x)^2$, on the lower side of the axis of x (the parabola being on the upper side), this curve is called by the Author the auxiliary curve. If g be the centre of gravity of the weights P supposed applied at points on the parabola, and g^1 the centre of gravity of the same weights supposed applied at points on the auxiliary curve with the same abscissas, $g\,g^1$ is a vertical line and

$$Q = \frac{5\,P}{32}\;\frac{l \times g\,g^1}{f^2}.$$

To assist in tracing the curves, a table of the values of $\frac{y}{f}$ and $\frac{y'}{f}$ for nine values of $\frac{x}{l}$ between 0 and 1 is given.

It is then proved that the maximum horizontal thrust from a series of loads whose mutual horizontal distances are constant, is produced in such a position of the loads as brings their centre of gravity in the middle of the span.

For a uniformly distributed load *pa* covering a horizontal length, *d*, of the span from one abutment, the horizontal thrust

$$Q = Q_o t^2 \{\tfrac{5}{2}(1 - t^2) + t^3\} \text{ or } Q_o \phi(t),$$

where Q_o is the horizontal reaction for a load *pl* covering the span, and $t = \frac{a}{l}$. A table of the values of $\phi(t)$ for nine values of t is given.

The bending moments throughout the span for the same loading are represented by two parabolas having a common point and tangent at $x = a$ (where the load ends). It is shown how these parabolas can be drawn for any value of a. The envelope of these parabolas for various values of a is a curve whose ordinates represent the maximum bending moments at various points of the span as the load progresses. The points at which the maximum bending moment reaches its greatest value are at one quarter and three quarters of the span, and its value is about $\frac{1}{60} p l^2$.

The shearing force is next discussed. Its value is $\frac{d\,M}{d\,s}$, for which $\frac{d\,M}{d\,x}$ is used as an approximation. The maximum shearing forces are at the abutments and at the springing,—at the abutments when the load covers about three-tenths of the span, and at the springing when the load covers half the span.

The effect of an isolated load is then dealt with in great detail as regards bending moments, shearing forces, and compression in the arch. The uniformly-distributed load is calculated which would give the same maximum compression as a single isolated load, and it is shown that, the single load being P, the distributed load $p\,l$ can be approximately expressed by $p\,l\left(1 \cdot 1 + 0 \cdot 007 \frac{l}{f}\right)$.

Two further chapters are devoted, one to the determination of the weight necessary for an arched rib of a given span and rise to carry a given load when designed on the above principles, and the other to the form to be given to the section of the arched rib when the stresses in all parts of it are known.

C. F. F.

Experiments on Portland Cement. By R. Feret.

(Annales des Ponts et Chaussées, March 1890, p. 313.)

Since 1885 the specifications for cement furnished for public works in the ports of Boulogne and Calais have required not only tests of the cement supplied, but also the inspection of its manufacture, and frequent analysis of the raw materials. To assist in fulfilling this requirement, a laboratory was established at

Boulogne, which has now been at work for three years under the direction of the chief engineer of the service. The work of the laboratory is not limited to tests in connection with current contracts, but it is utilized for researches of a more scientific and general character. The present Paper is extracted from a report on the work of the laboratory, and deals with three only out of the many and various objects to which the investigations of the laboratory have been directed; viz., the chemical composition of cement, the fineness of grinding, and the preservation of cement in the interval between manufacture and use.

(1.) The chemical composition of cements may vary from one factory to another without detriment, because the treatment is never exactly alike in two factories, but the cement from one maker ought to be rigorously constant in its chemical composition, for otherwise the mortar made from it will vary from one part to another in its time and manner of setting and hardening. Tests of the cement as delivered do not suffice to detect these variations, and hence the necessity of the course adopted by the Public Works Department in France. The properties of a cement depend less on the simple elements of which it is composed, than on the manner in which these elements are grouped in chemical compounds. Uniformity may be destroyed either by improper preparation of the raw paste, defective calcination, or want of care in sorting the calcined stone. The Author examines the various methods that may be employed at various stages to determine the nature and properties of the cements, and notices that there are often present two or more different compounds capable of setting in or under water, so that the phenomenon may be noticed of a double setting, one rapid, and one prolonged.

(2.) As to grinding, the Author remarks that it is not so easy as is supposed to determine the fineness of a cement. Sieves of the same nominal size are rarely quite regular or similar, and with the same sieve the amount that will pass depends on the violence and duration of the sifting. If the sifting be kept up for a sufficient time, grains of a diameter markedly greater than the dimensions of the meshes can always be made to pass; and with hand-sifting, although the amount passing through the sieve becomes small, there never arrives a time when nothing passes. Accordingly a machine was made for mechanically sifting cement, in which the speed and amplitude of the motion could be varied at will. The results of experiments with it are given in Tables and diagrams. The Author's conclusion is that extreme fineness is most desirable, large grains being of little more value than sand.

(3.) Cement experiments are largely affected by the time and exposure of the cement since its manufacture. Cements from the outside, and from the middle of a bag may give very different results. Care should be taken to empty the bags, and to thoroughly mix their contents before taking samples. The increase of weight by aeration comes about two-thirds from the absorption of carbonic acid, and one-third from absorption of water. While a moderate aeration of cement is beneficial, too great an exposure is deleterious; and the Author thinks an exposure to the air in bags for a period of twenty-eight to eighty-four days, while the tests are being made, as required by Government specifications, is reasonable. He considers the exposure in thin layers, with frequent turning, practised in other countries, only necessary because the raw materials are less carefully chosen, and the sorting of the calcined stone more neglected than in France, so that free lime occurs in dangerous quantities. The Author condemns the addition of plaster-of-Paris or other like matters as a cure for cements too quick in setting, or liable to crack, as has been recommended by some. The Paper extends to sixty-seven pages, and is accompanied by numerous Tables of the results of experiments, and by two plates of diagrams.

C. F. F.

Lallemand's Mean-tide Gauge. By C. Jimels.

(Le Génie Civil, vol. xvii. 1890, p. 212.)

In a previous article[1] a description has been given of the tidal observatory established at Marseilles for the purpose of determining the mean sea-level at that port, in connection with the new general survey of France. The expense of establishing a complete installation of this kind at numerous points on the coast would be too heavy, and so Mr. C. Lallemand has devised a simple instrument which will serve equally well for the special purpose of registering only the mean tide-level, and which is self-contained and inexpensive.

It consists of a water-tight tube fixed in a vertical position, connecting with the sea-water only through a small pipe, having a plug of porous porcelain in its end. The effect of the plug is that the variation of level in the tube is only produced by the slow filtration of water in or out through the porcelain. It thus comes to pass that all variations of comparatively short period—such as those of the daily tides—produce an insignificant effect in the tube, and only those of long period are registered. Only one daily reading of the level in the tube is necessary, and it is made by sinking into the tube a "sounder," carrying a strip of sensitized paper, which turns black when it is wetted. These strips of paper are of uniform width, and being mounted side by side on a sheet of paper, form a diagram of the daily mean tide-level, from which diagram the mean level for any period may be obtained.

This mean-tide gauge has been tested for five years at Marseilles with the self-registering continuous gauge and found to be quite reliable. The paper concludes with a mathematical investigation of the principle of the apparatus, from which it would appear that,

[1] Le Génie Civil, 1890, vol. xvii. p. 65.

even if the porosity of the plug became partially destroyed by deposits in the pores or organic growths, its utility for the special purpose of obtaining a mean-level would not be interfered with.

C. F. F.

Formula for Calculating the Velocity of a Torrent from the Size of the Materials transported by it. By E. Charlou.

(Le Génie Civil, vol. xvii., 1890, p. 170.)

It is difficult, and would in many cases be useful, to be able approximately to estimate the velocity of a stream in time of flood, where no assistance is derivable from a course of detailed observations in the past. The Author, by considering the equilibrium of a pebble in the form of a circular disk of diameter l, which is on the point of motion under the pressure of the current and is only restrained by friction, arrives at the formula—

$$v = \sqrt{\frac{40\,l}{3}} \text{ (in metrical units).}$$

And for the pressure of the stream on a fixed obstacle $F = \frac{40}{3}\,ml$, where m is a coefficient depending on the form of the obstacle.

He finds the results of the former formula in accord with the observed facts as given in Stevenson's "Canal and Civil Engineering."

C. F. F.

Inland Navigation in France. By Daniel Bellet.

(Bulletin de l'Association Française pour l'Avancement des Sciences. Paris Meeting, 1889, p. 1031).

This Paper contains a full account of the work done and money expended on canal and river navigation in France since the year 1814, and especially of the improved results obtained since the year 1879, when some alterations in the law gave a great impetus to water-carriage. Between 1814 and 1852 (thirty-eight years), the State had expended £16,280,000 on the construction of canals, and £4,768,000 on the improvement of river navigation; but in the latter year there was so strong a feeling in favour of railways, that it was generally believed they would altogether supersede inland navigation. During the next few years such works were quite neglected by the State, and some of the most important canals were even made over to the railway and other companies. In 1860 this policy was reversed, many canals, of which concessions had been granted to private companies, were repurchased at a cost of over £5,000,000 (*e.g.* the Burgundy, the Bretagne, the Nivernois, the du Berry, and the Loire canals, and the canal from the Rhone to the Rhine), and the construction of many others was commenced. During the thirty-eight years from 1852 to 1888, the State expended on canals £14,160,000, and on the improvement of river navigation £17,840,000, more than 54 per cent. of which has been spent since 1879.

In 1879 a comprehensive scheme of inland navigation was voted by the Chambers, according to which all the chief canals were to be built with, or altered to, uniform dimensions, so as to allow the canal boats to circulate from one to another without shifting their load. The minimum depth of water was fixed at 2 metres (6 feet 6¾ inches), and the length and width of the locks at 126 feet and 17 feet respectively. The abolition of all taxes on canal traffic followed in February 1880, and these measures have effected so large an increase in the traffic, that with a length of navigation of 7,950 miles, 23,028,436 tons of goods were conveyed by water in 1887, viz., 7,095,223 tons of coal, 6,990,865 of building materials, 3,150,216 of agricultural produce, 1,681,243 of ore and metals, 1,551,025 of firewood, 1,175,227 of manure, and 1,384,637 tons of miscellaneous goods.

The average distance over which these goods were conveyed in 1887 was 83 miles; the number of canal boats was 15,730, with a total tonnage of 2,713,847, manned by 23,141 men, and of these there were 933 with an average of 370 tons per boat. Those of the canals which cross the Belgian and German frontiers carried an international traffic of 3,070,559 tons.

O. C. D. R.

Improvement-Works on the Upper Adige. By G. Turazza.

(L'Ingegneria civile e le Arti industriali, 1890, p. 33.)

The Author's notes upon the improvement-works carried out upon the upper portion of the Adige, from its source to the Italian frontier, call attention not only to the actual works upon the river and its tributaries, but also to the effect upon the districts in the Venetian province through which the Adige passes in its lower course to the sea.

The Adige takes its rise in the valley above Trent, on the flanks of the Pizzo Bianco, 4,800 feet above the sea, at the confluence of the Reschen, Mezzo, and Heide; and augmented by tributary torrents on its way, increases in volume as it passes Meran to Bolzano, where, being joined by the Eisack, it becomes a river. While, in its lower reaches, the current carries along only minutely disintegrated matter, at Trent it still sweeps up gravel, and in the upper valleys brings down pebbles and masses of stone, which, heaped in times of flood upon the adjoining lands, have caused great damage, and destroyed the fertility of extensive regions.

At successive periods during the last three hundred and fifty years, works have been carried out with the object of diminishing the disastrous effects of floods; and the extensive operations of the last few years have comprised the straightening of the channel, the construction, where necessary, of embankments and training-walls, and the provision of a suitable and uniform section for the main stream, and the controlling of the confluence of its tributaries. The floods in the upper valleys have by these means been amply prevented; but, to a great extent, at the expense of the plains below. The flood waters, which formerly came down from Trent to Verona in twelve hours, now pass in less than six hours, and are correspondingly delayed in flowing off by the channels which had sufficed for the slower current. This evil would, to a great extent, have been obviated by the provision of flood-basins at various points; but the only reserve that is at present available is in the bed of the old river, wherever this has been superseded by new cuts, in which cases the upper end is dammed across, and the lower end left open to be gradually silted up by the backwash.

The recent works begin at Untermais, near Meran, with a new cut 8 miles long, between banks 246 feet apart, and shortening the course by about 1 mile. The river at this point formerly spread in an irregular network of channels right across the valley. At all places where new channels have not been excavated, the old banks have been raised by dykes. The second long cut, measuring 2 miles 25 chains, is at St. Florian, and at Ischia-Wolchestein is a further cut of 1¼ mile. At Trent, the construction of the Ala-Bolzano Railway necessitated, some years back, the formation of a new bed, 1 mile 32 chains in length, which has kept the city free from flood from this source; and the old stone bridge of five arches, which considerably obstructed the stream, has since been superseded by an iron bridge in one span of 294 feet. Below Trent there are two cuts, of 3 miles 33 chains and 2 miles 14 chains respectively, and at Cagliano a cut 1¼ mile long. The total result, in a course of 85 miles, has been to shorten the channel by 6¼ miles. The level of the banks was fixed at 2 feet above the highest recorded floods; and in forming new cuts the process was to excavate a gulley upwards along the course of the proposed channel, and then to deviate the stream into this gulley, and allow it to complete the erosion of the new bed.

Of the tributary torrents which have been regulated, the most noteworthy are the Avisio and Fersina. The general mode of treatment has been to construct weirs across the channel near its outlet into the river, so as to slacken the force of the torrent and to arrest the accumulation of detritus in the main stream; but the Author considers that this treatment would have been more effective and more permanent in its results if adopted in the upper feeders and torrents, where the works would also be on a smaller scale, and their failure would be less disastrous. Under the present circumstances, it is only a question of time for the space behind the weir to silt up, and for the torrent to resume, to a great extent, its original character. The weir at Pontealto is an instance of the necessity of continual extension of these structures.

On the Avisio, the outlet of which is widened out between its new banks to about $\frac{2}{3}$ mile across, a weir has been constructed a little further up the valley, at San Giorgio, of which the following are the leading dimensions:—Height, 62 feet 6 inches; width, 263 feet; radial on plan (convex surface up valley), radius 215 feet; vertical back, front batter 1 in 3; thickness at top, and to 3 feet from sill, 13 feet $1\frac{1}{2}$ inch; ditto at bottom, 32 feet 10 inches. The apron consists of an invert 9 feet 10 inches in thickness and 32 feet long, with a dwarf weir at the toe, 4 feet 11 inches in height and 11 feet 6 inches wide, to form a tumbling-bay to break the fall. The foundations are in rough porphyry, in hydraulic cement, the upper parts being finished in limestone.

On the Fersina, the weir at Pontealto, upon which the safety of Trent is largely dependent, has been rebuilt, and extended at various times since the year 1537. Its present height is 154 feet, and it is massively built in to the rock on each side of the narrow gorge. At some distance up-stream is the weir of Cantanghel, 56 feet in height, 13 feet $1\frac{1}{2}$ inch thick at the summit, and 26 feet 3 inches at the base. This weir having recently been injured, and threatening the Pontealto weir with an increased strain, a new weir has been built about 260 feet further below Cantanghel, the summit being about 33 feet lower. Finally, at about the same distance below the weir of Pontealto, a new structure, known as the Madruzza weir, has been erected, under conditions of the greatest difficulty. Its height is about 160 feet, and the external face is vertical; the thickness at base being 18 feet, diminished in successive offsets to 12 feet 6 inches at the summit. The rock in places overhangs the base, and the structure, curved on plan, all the stones being wedge-shaped, abuts on either side on the solid flanks of the ravine, in such manner as to form a continuation of the wall of rock itself.

P. W. B.

The Embankment of the Tiber at Rome in Relation to the Subsoil Water. By R. CANEVARI.

(Annali della Società degli Ingegneri e degli Architetti italiani, 1890, p. 119.)

One of the matters to which the Italian Government first turned its attention upon entering into possession of the capital in 1870, was the great work of the sanitation of Rome, and the development and transformation of the surrounding country. A commission was nominated for the purpose of promptly investigating the subject; and was, after the extraordinary floods occurring in December of the same year, supplemented by a special commission to study the works required for the improvement of the Tiber.

Among the results of this commission, the works for the regulation and embankment of the Tiber are now nearly completed, and considerable progress has also been made with the development of the main drainage scheme. The construction of the river-walls was commenced in 1878, on the left bank; and at the present time this wall is practically completed, from a point near the Piazza del Popolo to the foot of the Aventine at Ripa Grande, a length of over 2 miles (3,735 yards). On the right bank the length of the wall at present carried out is 1,932 yards, chiefly in one section from San Giacomo alla Lungara to Ripa Grande; giving a total length of 5,667 yards of river-wall. In removing the old buildings along the river, it was found that in many parts the walls rested on massive concrete foundations forming the river-wall of the ancient city, encased by oak or chestnut piling in perfect preservation, in several cases carefully framed and joined, and sometimes lined internally with sheet lead.

Prior to the completion of the works, serious and widespread apprehensions prevailed respecting the alteration of the conditions under which the river had previously flowed through the permeable strata upon which the city is built. The plains around Rome, comprising an area of nearly 800 square miles, are intersected by innumerable lines of erosion, breaking the continuity of the surface strata, and affording evidence of a vast accumulation of subterranean water of varying depth, which, stagnating in various localities, was doubtless a fruitful source of miasmatic exhalations. This water is concentrated along the banks of the river, and in the soil of the lower parts of the city; the heights being, on the contrary, deficient in water. Although it was evident that the level of the water in the soil was immediately affected, though with slower oscillations, by the rise or fall of the river, the varying levels of the water at very short distances apart could admit of no explanation in this connection, and would doubtless have to be referred to variations in the permeability of the soil. The level of the subsoil water was also notably above the level of the river; thus at the same time when the Tiber level-was ranging between 21 feet 6 inches, and 17 feet (above sea-level), the water in places on the right bank stood at from 41 feet to 34 feet, and on the left bank between 36 feet 4 inches to 27 feet 2 inches. At mean level of the Tiber the subsoil water-level was from 16 to 20 feet below the surface of the streets in the lower parts of the city. This subsoil water was, wherever practicable, admitted to the sewers, and in many instances utilized for motive power by manufacturers, who altered the levels of contiguous drains to supply subterranean mill-gearing; and all the sewers converged towards the Tiber, into which they freely discharged their contents. The first sign of inconvenience from floods in the river was usually the backwash in the sewers, and the reappearance of their contents in cellars and at the surface of the streets. The drainage has now been systematised by the construction, in connection with the river-walls, of a main intercepting sewer on each side of the river, converging to a point a few miles below the city, on the Ostian road, where, instead of being dependent on the excessive variations of water-level, 23 to 26 feet, within the limits of the city (the *tronco urbano*), the range of level is less than 9 feet.

The chief matter for anxiety in connection with the new works had been the effect which the entire exclusion of the river from connection with the adjacent subterranean water might have on the free dispersal of the latter, causing a rise in the level which could not fail to have disastrous effects. In fact, assuming the discharge of water from the area of the city to be retarded to the extent of no more than 3 feet per annum over the entire surface, the accumulation in that space of time would be sufficient to cover the lower parts of the city, from the river to the foot of the hills, with upwards of 25 feet of water. It is evident that the works have not in any way had the prejudicial effect anticipated; nor, on the other hand, has the level been lowered so as to cause any sinking in of foundations, while the liability to flood has been practically removed. The works may therefore be said to have fully justified the plan upon which they were designed and carried out.

P. W. B.

The Improvement of the Ticino from Bellinzona to Lago Maggiore. By — von Salis.

(Schweizerische Bauzeitung, 1890, p. 80.)

The lower reaches of the Ticino, one of the most important streams on the southern slopes of the Alps, spread out into an irregular network of channels, curving from side to side of the valley according to the cross-currents of tributary streams, or as determined by the geological features of the plain and the adjoining hills, where the water, thrown back from the surface of hard strata, has eroded shifting channels through the yielding alluvial soil. At the point where the river enters Lake Maggiore, opposite the town of Magadino, the various channels absorbed the full width of the broad flat plain; and the tendency of the river, especially under the influence of occasional freshets and floods, has been to spread still further in its destructive agency throughout the valley, threatening all points in its uncertain action. It was accordingly essential to limit, as soon as possible, this variable flow of water; though financial difficulties occasioned the project to be considerably delayed in its execution. The Swiss National Bund guaranteed a subvention of 40 per cent. of the cost, increased later to 50 per cent.; and there was a further cantonal contribution of 20 per cent.; the remaining 30 per cent. being raised (on the "betterment" principle) among the landowners—including the St. Gotthard Railway—favourably affected by the improvement. The area reclaimed is about 5,800 acres, the value of which is set down at about £160,000; as against which the cost of the undertaking is stated at £121,520, or £10 per lineal yard of channel.

The works commence near the Giubiasco station of the St. Gotthard line, about $1\frac{3}{4}$ mile below Bellinzona, where the river is joined on each side by a small stream, and the channel is confined to a fairly regular and somewhat narrow course. From this point to the bridge carrying a branch of the railway across the valley to Gordola, a distance of 4 miles 5 furlongs, the river falls at an average rate of 13·2 feet per mile, while below the bridge to Magadino, a distance of $2\frac{1}{2}$ miles, the fall is only at the rate of 5 feet per mile. In connection with this lower portion of the river, the great range of water-level in the lake is of considerable importance. The high water-level of 1868, for instance, was 24·4 feet above normal low summer-level. It was therefore necessary to construct dams of sufficient height to protect the upper part of the valley from flooding from the lake, while the river-channel itself is of sufficient dimensions to allow of the discharge of 5,297,500 cubic feet per minute (2,500 cubic metres per second), which is ample provision for any sudden Alpine flood. The mean width of the channel is 197 feet, the banks above the railway bridge being a continuation of the faces of the lateral dykes. The same width of channel is kept below the bridge, but the dykes are kept further back. The erosive action of the current itself has been of considerable assistance in the work, and the excavation has not in any case been carried to the full dimensions of the intended channel.

The left bank of the river was the first portion of the work taken in hand, as this was the most threatened in time of flood. Masonry dams were built transversely to the main channel, wherever necessary to stop up the old water-courses, one parallel cut being left open to take flood-waters during the progress of the work. The operations were, in fact, threatened by several severe floods, the water rising on repeated occasions considerably above the normal range. The lateral dykes suffered little injury, but considerable damage was done to the transverse dams, and some delay naturally occasioned. The stone for the masonry dams was obtained from quarries in the adjacent hills.

P. W. B.

The Re-Afforestation of the French Alps. By L. Gonin.

(Bulletin de la Société Vaudoise des Ingénieurs et des Architectes, 1890, p. 45.)

The fertile plains in the south of France traversed by the Rhône, the Garonne, and their affluents, are frequently laid waste by the overflow of their waters. The magnitude of the inundations has been due principally to the increasing development of the torrents, especially those of the Alpine departments, caused by the destruction of the mountain forests and grass lands, and the disappearance of the vegetation by which the soil was protected, which like a sponge retained the rainfall, moderated the flow of the waters, reduced the floods, and acted as a protection against erosion of the soil.

As a remedy the torrents were to be arrested at their source; the materials removed by the waters were to be retained in the valleys or defiles; the formation of ridges and furrows, and the generation of new torrents in the bared places of the hills had to be opposed; vegetation had to be revived and protected from the sheep which find pasture in the mountains. To carry out these objects, two kinds of works were necessary: 1, the correction and regulation of the torrents by establishing a system of dams; 2, the replanting of the ground with wood and grass. The course of a torrent is divisible into three stages: the collecting basin, the outflow gorge, and the settling bed in the form of a cone, in which the eroded matter brought down by the current is deposited. The valley of the Barcelonnette presents one of the most complete types of torrents. The Riou-Bourdoux dam is the most important of those in the valley. Its cone of deposit of the torrent covers an area of 600 acres—an area of desolation. The dam is $26\frac{1}{4}$ feet high above the bed, and has a width of 274 feet. The crown is $10\frac{1}{2}$ feet thick, and the wall slopes at the rate of 1 in 5 to the bottom. The foundations are $18\frac{3}{4}$ feet thick, and $14\frac{3}{4}$ feet deep. The crown of the dam, in horizontal plan, forms a circular arc of $170\frac{1}{2}$ feet radius. In elevation it presents a level platform $65\frac{1}{2}$ feet long, joined to a circular arc at each end, of 112 feet radius, having a rise of 13 feet at each end, and $52\frac{1}{2}$ feet long. They make a total width of $170\frac{1}{2}$ feet, and are finished with an earth formation at each end. The dam is constructed entirely of hydraulic masonry in very large blocks. It is loop-holed by five openings near the bottom, and six smaller holes at a higher level, for the passage of water and liquid mud; but the lower openings alone are in operation, the upper ones being stopped up. They are fenced at the upper ends with cross bars of iron, the purpose of which is to obstruct the passage of stones, which are detained above the dam, and form a solid and resisting alluvion. An alluvion bed has been formed by deposition, reaching upwards of 1,300 yards above the dam, the surface of which is inclined at the rate of 1 in 9; this deposit constitutes a vast platform which lends itself to forest vegetation, and to the protection of the plantations established on the banks. Below the Riou-Bourdoux dam the correction is continued, comprising ten dams and a rectification of the bed.

Besides the great Bourget and Riou-Bourdoux dams, there is a very large number of smaller ones. There are masonry weirs generally of the form of a circular arc in plan, crowned at the summit by a horizontal platform as wide as is practicable and finished at the ends with arcs of circles. The stream is thus spread out into a comparatively thin sheet, and the erosive force of the fall at the foot is minimised. These dams are increased in height from time to time in proportion as the deposit above accumulates. An opening is made through the wall near the base for the passage of water with solid matter in suspension.

For the smaller dams, owing to the want of stone, wood in the form of wattle fences and fascines is employed. According to one mode of construction two rows of stakes, in larch and willow, are planted across the bed of the torrent, with willow branches interlaced, forming the body of the structure. The stakes are bound together by a longitudinal timber laid horizontally a little below the level of the crown. Behind the dam, for its protection, a body of earth and small stones is placed. It is planted with slips of trees, by the growth of which the consolidation of the work is promoted.

In the valley of the Barcelonnette there are nearly 3000 dams distributed as follows:—

	Large dams.	Minor dams, in wood.
1. La Bérarde	9	300
2. Le Riou-Bourdoux	2	1,133
3. Saint Pons	1	123
4. La Valette	4	132
5. Faucon	17	305
6. Le Bourget	26	422
7. Les Sanières	12	494
8. Gaudissart	..	7
	71	2,916

The total expenditure in this valley to 31st December, 1887, in works of correction, dams, auxiliary works, and general charges, amounted to the sum of £110,540.

D. K. C.

The Harbour of Harlingen and the Fairway through the Pollen.

By F. L. Ortt.

(Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1889–90, p. 83.)

The increased importance of the harbour of Harlingen on becoming the terminus of the railway running eastward towards the North of Germany, made an extended accommodation for shipping desirable. The two small harbours in the town had but a depth of 10 feet at high water, and could contain only a limited number of vessels of 300 tons and less. Sea-going steamers could only with difficulty enter the port, which was separated from the deeper channels in the Zuiderzee by a high ridge or sandbank with a depth of merely 10 to 12 feet at high-water. The harbour improvements consist therefore of two parts: 1st, the extension of the dock accommodation; and, 2nd, the deepening of the channel across the Pollen bank.

The existing harbours in the town, being surrounded with buildings, enlargement of these could hardly be thought of, and in 1851 a dock was built outside of the sea-wall protecting the city, 360 feet long and 262 feet wide, giving an additional dock area of about 2 acres. In 1870 the government again decided on an extension, and outside the last work an embankment was formed giving a large new harbour 492 feet wide and 2,624 feet long with an area of about 28 acres, and a depth of 16 feet below high-water mark. A quay wall of basalt was constructed on the former shore line, while the enclosing dam consists of fascine work with a core of sand covered by a layer, 1 metre thick, of puddled clay. This is overlaid by brick rubbish and a coping of basalt set on end. Running at right angles to the masonry quay-wall is a timber jetty on a low dam of fascine work and stone, constructed principally with the object of sheltering the southerly part of the dock from the swell entering the mouth of the harbour. Since the completion of the works in 1877 the southern part of this dock has never been dredged, and in consequence the depth is at present reduced to about 10 feet below high-water mark. In the entrance channel and contiguous parts a depth of from 12 to 13 feet is maintained.

The sandbank of the Pollen, which forms a barrier to the entrance of the port of Harlingen, is situated about 2 miles from the shore-line, and divides the Blaauwe Slenk channel from the roadstead. In 1861, before the works of deepening were undertaken, a channel across, a depth of 11·20 feet at high-water, was sounded, whereas a depth of 15 feet was considered the minimum required. The bottom was found to consist of sand and gravel with layers of peat, fine silt and mud. The situation being exposed and subject to very changeable currents as the tide rises or falls, a simple channel dredged across was obliterated in a short space of time, and it was therefore decided that a dam or breakwater should be constructed alongside of the proposed deepening. After repeated failures of the dredging operations, a commencement was made with the breakwater, laid in a direction parallel to the dredging works about E.S.E. and W.N.W., and consisting of fascine mattresses sunk in position and covered by a layer of stone, reaching to about 4 feet below high-water mark, a width at the top of 20 to 22 feet, slopes of 1 to 1, and a total length of about $1\frac{3}{4}$ mile. Instead, however, of the original channel improving by this construction, another one formed southwards of the dam with a depth of 14 feet, which was soon utilized by the shipping, and then buoyed and marked in 1879. Since then the channels remain in much the same condition, except slight changes in depth and width. The at first desired minimum depth of 17 feet, and bottom width of 164 feet has not as yet been obtained.

The Paper is illustrated with several plans and sections.

H. S.

The Works of the New Commercial Port of Naples.

By Domenico Lo Gatto.

(L'Ingegneria Civile e le Arti industriali, 1890, p. 65.)

The Bay of Naples, a littoral indentation about 10 miles in depth. extends for a length of 16 miles from S.E. to N.W., Naples being situated at the upper end of the bay, with a due south prospect. The range of tides is very small, not exceeding about 12 inches; but the port is exposed to occasionally violent winds from seaward, in a westerly direction from Sardinia, 200 miles distant; south-west, from the coast of Africa, 500 miles across the Mediterranean; and south, 200 miles from Sicily. These winds, apart from their direct influence upon the swell of the waves, have also a reflex action in the heavy surf along the shore of the bay, and the back-wash from the same, extending behind the breakwater or outer pier of San Vincenzo. The south-west is the prevailing wind. Land winds do not often acquire sufficient violence to affect the shipping of the port, though occasionally the south-east wind (*scirocco*), blowing direct into the entrance to the port, necessitates the suspension of commercial operations.

The earliest portion of the port now existing is the Molo Angioino commenced in 1302, and extended to form the pier and quay of San Gennaro, constructed in the early part of last century, and now fitted with warehouses, cranes and all appliances for dealing with the heaviest cargoes. The military port adjoining was commenced in 1577, the old dock in 1668, and the outer pier of San Vincenzo in 1830. Thirty years later, when Naples was incorporated in the Kingdom of Italy, various projects, on a more or less grandiose scale, were put forward, for the extension and completion of the port. It was decided as a matter of primary necessity, that the pier of San Vincenzo, which protects the port from the open sea, should be considerably extended; and in 1880 the scheme of completion of the port was taken in hand, and is now, with the exception of various buildings and railway sidings, carried out to a successful termination. The work has included the extension of the outer pier (San Vincenzo) into upwards of 100 feet depth of water, the construction of an eastern pier to enclose the new commercial port, the excavation of this port to a minimum depth of 26 feet 3 inches, and the construction of an extensive system of quays. The new portion thus enclosed is 79 acres in extent, the old port having an area of 20 acres; and with 146 acres of water in the outer port (apart from the military port) this makes a total area of 245 acres available for commercial purposes. The new quays are 6,562 feet in length; and the old quays which have been altered, and where the depth of water varies from 16 feet 6 inches to 26 feet 3 inches—the normal depth for the new quays—extend to a further length of 4,100 feet. Assuming the annual tonnage as 3,500,000, and the bulk of goods landed and loaded as 730,000 tons, there is a tonnage register of 14,330 per acre, and a quay landing of 70 tons per lineal foot. The corresponding figures for London docks averaging 20,000 tons per acre of water and 110 tons per foot of quay, it will be seen that there is a considerable margin available beyond the basis of the traffic above assumed. The quays are provided with cranes worked by hand or by steam-power, and some by hydraulic power, and there are also extensive warehouses completely fitted for all requirements.

The outer pier where it extends into a depth of water of about 100 feet, consists of a rubble base, with large facing blocks, thrown to an inner face-slope of 1 to 1·15, and on the seaward slope 1 to 1·7. The upper part of the pier is based on a solid bed of concrete, the superstructure being carried up in masonry. The quay is 26 feet 3 inches wide, reduced towards the end to 19 feet 8 inches, the pier wall being about 14 feet in thickness and rising to a height of 24 feet 7 inches above water-level, or 28 feet 3 inches to the parapet. The outer face of the breakwater, from the foot of this wall to the edge of the slope, 14 feet below water-level, is topped with blocks of concrete of 16½ cubic yards each, arranged in irregular rows so as to break the force of the waves, to which, allowing for friction, they oppose a dead weight of 14·2 tons per square yard of exposed surface. This pier will in all probability be extended into about 115 feet depth of water, in order to cover the entrance to the port exposed to the south east, leaving a channel from 1,650 to 1,950 feet wide between its extremity and the east pier head.

The east pier, the depth of which averages 34 feet 6 inches (26 feet 3 inches water and 8 feet 3 inches from water-surface to quay-level), provides a quay 49 feet 3 inches wide, and a space 23 feet wide outside the pier wall. The curvilinear head is designed to protect the outer port from the backwash of the surf, and the transverse or "hammer-head" pier encloses the commercial port, though not itself intended to be used as a quay. The east pier is 1,575 feet in length in a straight line from the shore, the transverse pier being 870 feet, while the distance from this to the head of the curved pier is 788 feet. The quay-walls are provided with all necessary mooring posts, bollards, rings, steps and ladders.

All the materials employed in the work were obtained in the neighbourhood of the bay, and this circumstance was greatly conducive to the economy and expedition of construction. The breakwater was formed of trachytic stone from the quarries of Vesuvius and Monte Olibano near Pozzuoli, part being also obtained from Castellamare. The hydraulic mortar was composed of one part of rich Castellamare lime to two of white Bacoli pozzolana; and the concrete blocks formed with the above are perfectly exceptional for compactness and hardness. For the quays, the mortar was mixed with a species of porous ferruginous scoriæ, known as '*ferrugine del Vesuvio.*' All mixing was done by hand, although the use of machinery had been permitted. The quantity of concrete mixed and thrown into the water averaged 922 tons daily, or 184,500 in the course of the year, so that the 1,300,000 tons required were completed within seven years. Amongst the contract prices the following items may be noted:

		s. d.	£ s. d.
Stone for forming the breakwater.	per ton	1 1 to	3 8
(According to depth of water).			
Rubble masonry in hydraulic mortar	per cubic yard		0 4 6
Concrete, thrown in water	" "		0 6 0
laid in regular masses.			0 10 8
Ashlar masonry in facework (say 9½d. per cubic foot)			1 1 7
" " copings, kerbs, &c. (say 1s. 6¼d. per cubic foot)			2 1 0
Excavation by steam-dredger			0 0 9

P. W. B.

Paris a Seaport. By Gérard Lavergue.

(Le Génie Civil, vol. xvii., 1890, p. 167.)

Various projects for constructing a ship-canal between Rouen and Paris have been discussed, more or less seriously, for many years past, but one in particular, prepared by Mr. Bouquet de la Grye, has attracted special attention, and particularly so in the last few years.

The rapid growth of the port of Antwerp has largely resulted from its draining the export trade of the east of France, and it is thought that if Paris could be made a port of shipment instead of, as at present, Dunkirk, Havre, or Rouen, trade that now flows out through Antwerp could be diverted. This being the object of the proposal, it is clear that the proposed canal can only attract traffic by charging very low rates, appreciably less than those at present in force by railway or barge between Paris and Rouen.

The traffic anticipated by the Author is 5 millions of tons per annum, and it is inferred that the capital cost of the work should not exceed 11 millions sterling, if it is to be a financial success. The project has been laid out under this condition, and every expense excluded which the nature of the expected traffic will not absolutely necessitate. The available depth of the canal has been fixed at 20 feet 6 inches, as ships drawing more than 20 feet cannot at present ascend to Rouen at neap tides, and ships of more than 20 feet draught form only 5 per cent. of the trade of Havre. On the other hand, it seems generally admitted that no seaport can prosper with an available depth of water very much below 20 feet.

With a view, however, to future improvements in the estuary of the Seine, Mr. Bouquet de la Grye provides a depth of 23 feet

9 inches in the locks, so that the canal can be deepened in future by dredging.

The locks are to be only four in number; ship-captains strongly object to numerous locks, while the rise at any single lock is of no consequence to them. The canal is to be 115 feet wide, where straight, and 148 feet on curves with a minimum radius of 5,000 feet. The canal follows the windings of the Seine in the greater part of its course, as it is found that the saving in transport by adopting a straighter course would not suffice to pay for the increased cost. At two points, however, the canal leaves the river, to avoid the necessity of carrying the Western Railway Company's line from Paris to Havre over a swing-bridge.

The total estimate for the work is 5½ millions sterling, and it could be completed in three years.

C. F. F.

The Arrangement and Working of Filter-Beds.

By C. Piefke, of Berlin.

(Zeitschrift für Hygiene, vol. viii., 1890, p. 331.)

The Author states that he proposes, by a consideration of the old filter-beds of the Berlin waterworks near the Stralau gate, and of those recently constructed to the north of the city on Lake Tegel, to glance at the development of sand-filtration during the past thirty years. The Stralau works are described by reference to plans. The area of the beds, enlarged from time to time, amounted in 1873 to 37,067 square metres, in eleven independent subdivisions or basins. Each bed can be thrown out of working, or worked by itself, and the total normal yield per twenty-four hours is 60,000 cubic metres; but on certain days it has been necessary to filter 70,000, and even 80,000 cubic metres of water (15,406,790 to 17,607,760 gallons). There are two separate intakes from the Spree. By lowering the level of the filtered water in the clear-water reservoir, beneath that of the constant level in the filter-chambers, the necessary working head is obtained. The capacity of the filtered-water reservoir is only 2,200 cubic metres (484,213 gallons). A very important department of a filtering establishment is the sand-washing apparatus; the filtering material, the sand, finds itself in a state of constant circulation, and it is the object of this department to ensure that, whatever may be the working speed, there may be no hindrance for want of cleansed sand. Of minor importance are the arrangements for the purification of the water rendered foul by the process of sand-washing, prior to its discharge into the river.

Having described the general distribution of the various sections, the Author proceeds to deal with each in detail. The intake is by means of a chamber constructed in masonry, in front of which the bed of the river is artificially lowered by means of dredging; the water is strained through gratings to remove suspended and floating impurities, the latter being intercepted by a screen of copper-wire, with meshes 10 millimetres square. The suction-pipes have their extremities bent downwards at right angles, and are carried down to such a depth as to be below the water-line, even when the river is at its lowest level. These pipes are provided with clack-valves, to prevent them from running empty when the pumps are not at work. The filter-pumps employed to lift the river-water on to the beds are fully described by reference to diagrams; they should be situated, if possible, in the immediate vicinity of the intake, to avoid lengthy suction-pipes. The office of these pumps is to raise the water from the level of the river to that of the storage reservoir, and where the latter is wanting, to the overflow-level of the filter-beds. In the case of the Stralau works, this lift may at times amount to from 5 to 6 metres. With respect to the filter-basins, the principal parts to be considered are: the construction of the receptacle for the unfiltered water; the arrangement of the layers of filtering material, and the armature for the regulation of the filtering process. All of these points are discussed in detail. The formulas for the stability of the walls enclosing and dividing the basins are given. The Author states that, as the square possesses the smallest circumference of all rectangular figures of similar area, the aim of engineers is, for the sake of economy in material, to dispose their filter-beds as nearly as possible in a series of squares. The consideration of economy may, however, lead to the selection of sizes unworkably large, and the limit of surface found to be convenient is from 2,000 to 3,000 square metres (say 70,000 to 105,000 square feet) for each bed. The floor of the basins is generally formed of a thick bed of concrete, and is extended outwards to form the foundation of the enclosing walls, being provided with a sinking to contain the base of the wall, to keep the same in position. The entire structure is bedded into a compact pocket of clay-puddle, most carefully laid down in about four layers, each stratum being 8 centimetres (3 inches) in thickness. Three of the Stralau beds are completely arched over to guard against frost. The mere arching over of the beds is insufficient for this purpose, and it is necessary to add a layer of soil above the arches, equivalent to the depth to which frost may penetrate into the ground. This superincumbent soil must be carefully drained, so that it may not become water-logged. The depth of the horizontal layers of sand and gravel in the filters varies slightly in different works; attention is drawn by the Author to considerable variations in the thickness of the top layer of sand, which, in the case of the Grand Junction Waterworks, is given by Kirkwood as from 3 to 4 feet. At Stralau the following proportions are adopted:—

	Inches.
Fine sharp sand	22
Coarse sand	2
Fine gravel	6
Medium gravel	5
Coarse gravel	3
Small rubble stone	4
Large rubble stone	12
Total	54

The formation and disposition of the under-drains and the pipes and valves for admission of unfiltered water, and for drawing off the filtered water, are explained by references to the diagrams. In the case of emptying the beds for the renewal of the sand, it is important that the drains discharging into the river should be above the water-level thereof, even in times of flood.

The clear-water reservoir and its equipments are then treated of, and the necessity for providing for a constant circulation of the water in this reservoir is insisted upon. The mode of regulating the speed of filtration by the outlet-valves from the beds is discussed, and the indication of the period of exhaustion is described.

In cleaning out the beds, the water is first run off to the floor of the basin, and not to just beneath the surface of the sand, as was previously the practice, and the layer of filth is removed from the surface of the sand. This, in warm weather, consists mainly of algæ of various descriptions. In the water of the Spree, these algæ are so abundant as to clog the filter in five days, working at a mean speed of 50 to 60 millimetres per hour (1·9 inch to 2·3 inches). The necessity for the removal of a considerable depth of sand, although only just the first few inches in depth present signs of impurities, is insisted upon. The mode of refilling a bed after the sand has been cleaned is described.

The emptying, cleansing, and refilling of a filter occupies a period of several days; and, as at times two beds may be thrown out of working at once, the available filtering area is much reduced. Instances of the difficulties entailed by the simultaneous stoppage of several beds at the Stralau works are given. In the case of these works, where the filter beds discharge direct into the clear-water reservoir, the Author points out the want of a compensation reservoir in order to avoid the irregularities in the rate of filtration, due to the constant fluctuations in the level of the water in the clear-water reservoir. The speed of filtration during different months of the year is shown graphically by diagrams, and the numbers of germs per cubic centimetre, in the unfiltered and in the filtered water, during the months of June, July, August and September, are given in a tabulated form.

The sand-washing apparatus, which consists of revolving drums or cylinders, is described by reference to diagrams, and its effect in purifying the sand is set forth by Tables of bacteriological results. The average amount of purification accomplished is, that sand which contained before washing 6,420 millions of germs per kilogram, had only 61·3 millions of germs per kilogram after treatment—a proportionate reduction of about 100 to 1.

A brief description of the filter-beds on Lake Tegel follows; these are entirely covered, and are arranged radially round the sand-washing apparatus in the centre. These filters are worked at an average speed of 100 millimetres per hour (3·8 inches), and an ingenious regulator, devised by Mr. Gill, the Engineer, is explained by reference to the illustration. An automatic regulator, designed by Mr. Lindley, for the Warsaw Waterworks, is also described. The article is illustrated by five sheets of diagrams.

G. R. R.

On the Flow of Water in Filters.

By — CLAVENAD and — BUSSY.

(Annales des Ponts et Chaussées, March 1890, p. 265.)

The town of Lyons derives its supply of water from wells sunk near the right bank of the Rhone at St. Clair, with headings driven parallel to the river to collect the subsoil water. The sand through which the water passes from the river to the wells is very suitable for filtration, but owing to imperfect knowledge of the laws of underground flow of water, the works have been costly and irregular, and often disappointing. The object of this essay is to determine the rate of filtration under given circumstances.

The loss of head due to friction in flowing water is, according to Prony, $a\,u + b\,u^2$, where u is the velocity, and a and b constants. For a capillary tube (to which a filter is analogous) the second term may be neglected. The loss of head with velocity u, therefore, for a difference of level $d\,y$, is, for vertical filtration, $\left(\frac{u}{g}\frac{d\,u}{d\,y} + \frac{u}{p}\right) d\,y$, where p is a constant. This is equal to $d\,y$. Integrating, determining the constants, and simplifying the results, the expression is finally arrived at for the flow from a vertical filter,

$$q = p\,K\,s_0\,\frac{C + L}{L} - p_1,$$

where s_1 and s_0 are the sections of the streams respectively issuing from and entering the filter, and $s_1 = K\,s_0$, K being < 1. L is the height of the filter, and C the head above it; p_1 is a constant substituted for a function of q, p, C, L and K as an approximation; this substitution is proved by experiment to be permissible in a large number of cases, but not universally. The correctness of this formula is verified by several experiments.

For lateral filtration between a river and a heading whose floor is level with that of the river, $q = mp\,\frac{H^2 - h^2}{2\,L}$, where H and h are the heads of water in the river and the heading respectively, and m a constant, L being the distance of the heading from the river; m is, in practice, always near to unity, and may be put $= 1$ without sensible error.

When the heading is driven at a higher level than the impermeable stratum on which the filtering-bed rests, water will enter the heading through its floor, as well as sides, being siphoned, so to speak, from the river through the filter. The total flow will thus become

$$q = p\,(1 + k)\,\frac{H^2 - h^2}{2\,L}.$$

Determining K according to the results of experiments—

$$q = \frac{p\,C}{2\,L}\,(F + f - C),$$

where C is the difference of level in the river and the heading, while F and f are the heights of the water in the river, above the impermeable bed and above the bottom of the heading respectively.

For a circular well of radius r, whose centre is at a distance L from the river,

$$q = 1 \cdot 3643\,p\,C\,\frac{F + f - C}{\log \frac{L}{r}},$$

and for the semicircular ends of a heading described with radius r,

$$q = p\,c\,(F + f - C) \times \frac{1 \cdot 3643}{\log \frac{L + r}{r}}.$$

There is further a small flow into the heading on the further side of it from the river.

The Paper compares the flow given by these formulas with the results of numerous experiments at Lyons.

C. F. F.

Water-Supply and River-Pollution.

By W. Kümmel, of Hamburg.

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, 1890, p. 377.)

Dr. Dornblüth, of Rostock, having urged that the scheme prepared by the Author for the discharge of the sewage of Güstrow into the

River Nebel, a tributary of the Warnow, from which the water-supply of Rostock is derived, would so pollute the stream as to render it unsuitable as a source of domestic water-supply, the Author brings forward arguments, based on the self-purifying powers of rivers, to prove that the fears of Dr. Dornblüth are unfounded. The various official reports of the Author to the town of Güstrow are quoted, and certain statements made by Dr. Dornblüth as to the condition of the filter-beds at the Altona Waterworks are disproved. The scheme for the sewerage of Güstrow, prepared in 1887, assumed that for the present, owing to the general absence of water-closets, the sewage water would be so dilute that no clarification need be practised, but it was pointed out that should this need arise in the future, it would be easy to provide for the sewage treatment by whatever system should be proved to be the best; the Röckner-Rothe process being fully described, and indicated as that most likely to be applicable, as there was no land near Güstrow adapted for irrigation. On the analogy of the case with that of Schwerin, which discharges its sewage into the Lake of Schwerin, the Author points out that the claim of the Rostock authorities to have the sewage of Güstrow treated by irrigation works could not be sustained. In order, however, to have the purifying power of the River Nebel tested, Professor Uffelmann, of the Rostock Hygienic Institute, has undertaken a series of analyses of the river water above and below the town. The water is being examined by chemical, microscopic, and bacteriological tests, and the results of the examination of fifteen samples, taken at various times, and in different parts of the river, are set forth in a tabulated form. The distance of the flow of water from Güstrow to Rostock is about 81 kilometres (50·33 miles). The whole of the projected set of analyses have not yet been completed, but the Author states that a manifest improvement, due to the self-purifying powers of the river, is perceptible.

G. R. R.

Displacing of a Water-Main without Stopping the Supply.

By T. Stang, Superintendent of the Municipal Waterworks, the Hague.

(Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1889–90, p. 36.)

The extension of the town of the Hague made it necessary to alter the position of the main conduit of the water-supply. An interruption in the service would have entailed great inconvenience, and as the intended change was comparatively slight, the Author resolved to try slewing the main sideways without stopping the supply even for a moment. The main, when flowing full, weighs 260 kilograms per lineal metre (524 lbs. per yard), the length to be moved being 250 metres (273 yards), made the total mass a weight of 65 tons. When the main had been laid bare and found in excellent condition, a trench was dug alongside reaching a little deeper than the underside of the pipe, which was then suspended by chain slings and screw-bolts and nuts to beams laid across the trench. While the nuts were being turned, over the whole length of the operation, and at the same time slid sidewards, the earth on which the main had been resting was slowly dug away, allowing the main to swing sideways. This operation was repeated two or three times till the pipe was in its desired position. During this time the pressure was reduced from 3 to 1½ atmospheres. No leaks of importance occurred in the lead joints, and where slight ones were observed they were easily caulked. Drawings and diagrams accompany the Paper.

H. S.

Extension of a Siphon under the Brenta. By F. Cesareni.

(Giornale del Genio civile, 1890, p. 126.)

In connection with the improvement works on the Brenta and Bacchiglione it has been necessary to extend, so as to pass under the new channel of the Brenta, the old siphon at Le Couche under the Taglio Novissimo (or "newest cut"), by which the drainage of the districts of Consorzio Sesta Presa and Piovado is discharged into the lagoon of Chioggia.

This old siphon was constructed in 1608, and has been in continual use since that date. It is built entirely of brick, and measured 63 feet 2 inches horizontal and 38 feet and 44 feet 1 inch on the up-and-down-stream inclines, or a total of 145 feet 3 inches from face to face. The waterway consists of three arches, each 8 feet 6 inches span, with piers 3 feet 5½ inches in thickness and 2 feet high, and two abutments respectively 6 feet ¾ inch and 5 feet 5¾ inches thick, both widened out at the base to 9 feet 6¼ inches and 9 feet 8¾ inches respectively. The three centre arches are 1 foot 8½ inches in thickness at the haunches and up to the angle of 60°, and 1 foot 3¾ inches at the crown, the spandrils being flushed up level. The foundation is a mass of brickwork 3 feet in thickness, 51 feet 9 inches in width, and 187 feet 11 inches in length, but without piles or other preparation or protection. This omission is all the more singular, as an adjoining structure built in 1602 has a good pile foundation. In the present case some slight subsidence has occurred, causing the brickwork to crack in various places, apparently during the process of construction, but no further injury appeared to have been developed after the mortar had set.

For the purpose of extending this old siphon it was necessary to remove the incline at one end, leaving 113 feet 10 inches of the original work standing. The horizontal portion was then extended—the original dimensions of arches and piers being retained—for a length of 283 feet 3 inches, and a new incline built, 44 feet

5 inches in length, giving a total additional length of 327 feet 8 inches, or 441 feet 6 inches from end to end. The abutments were constructed of equal dimensions, and the new work has been carried up on a massive concrete foundation on piling. In removing the end of the original structure the wingwalls were blown up, but in order not to dislocate the lower portion the arches and other parts of the work were cut out with pick and chisel. In carrying down the excavation for the new foundations it was found that the lowering of the subsoil water threatened the stability of the old work, and it was therefore necessary to put in sheet piling to a depth of about 18 feet between the old work and the new. This effectually stopped further settlement, and the whole work was successfully carried out, the entire cost amounting to a little over £9,000.

P. W. B.

Contamination of Waters in Storage-Reservoirs on the Pacific Coast.[1] By L. J. Le Conte.

The rainy season on the Pacific coast usually lasts from November to May, soon after which the streams generally run dry. There is no water-supply, even in favourable years, for nearly half the year, whilst in a dry year there is no supply at all; and it may happen, that no surface-waters enter the storage-reservoirs during an interval of six hundred days. The dry season, occurring during the summer months, leads to extraordinary deterioration in the quality of the ponded waters.

The Author confines himself to the consideration of the water-supplies of San Francisco and Oakland, which are truly characteristic. The San Francisco supply is derived from three large artificial storage-reservoirs, located in the coast range of mountains, having a united area of water-surface of 1,140 acres. The annual rainfall is from 30 inches to 50 inches. The Oakland water-supply is derived from the storage-reservoirs, having a united area of upwards of 410 acres. During the rainy season, the water in the storage-reservoirs is comparatively good in quality, though there is periodical turbidity due to fine loamy sediment brought in by tributary streams. When the stormy weather is past, the water is clarified by natural subsidence. In the case of San Francisco, the difficulty by turbidity is obviated by shifting the supply to some other source less affected; but for Oakland, the reservoirs are equally turbid about the same time, and the muddy waters pass through the pipes direct to consumers.

About the 1st of May in each year, the surface-waters in the reservoirs have attained to 62° Fahrenheit temperature; and the bottom waters to about 50° Fahrenheit. Vertical circulation had

[1] The original is in the Library Inst. C.E.

ceased, and stagnation begins. Water-fleas and vegetable matter make an appearance. The water becomes warmer; carbonic acid and light carburetted hydrogen gases bubble up from the bottom. The cause of these manifestations has been traced to the fermentation of the immense deposits of mud, averaging 10 feet deep, on the bottoms of the reservoirs—the accumulations of many years. The mud consists of animal and vegetable matters in all stages of decomposition. There is a sudden development of vegetable and animal life—algæ and water-fleas. The vegetable spores pass through the screens and enter the pipes, wherein they die and decompose. Subsequently, sulphuretted hydrogen is evolved from the reservoirs, and the water is deprived of nearly all its free oxygen. About the end of October, when frosty nights set in, the surface-waters are chilled, and sink to the bottom, and so are a check on fermentation. At the same time, the water is actually worse than at any other time during the year. There is no decided relief from bad water until the rainfall begins in November, when the reservoirs are filled again, and the temperature falls to 55° Fahrenheit.

Although the waters of the storage-reservoirs are equally bad in midsummer, there is, on the contrary, a very marked difference in the quality of the water delivered to the consumers in the two cities named, due to the different modes of treatment of the water after leaving the reservoirs. At all the open flumes and aqueduct tunnels, through which the water passes from the reservoirs in the San Francisco system, the flowing water is exposed to the air, the quality of the water improves progressively, until finally, when it passes through pipes to the service-reservoirs within the city limits, the quality is at all times very much better than that of the surface-waters in the storage-reservoirs whence it came.

The experience of the Oakland water-supply is quite the reverse. The water passes from the basins into the pipes, and, as supplied to consumers in Oakland, is always very much worse than that of the surface-water in the reservoirs whence it comes. This fact is explained by the deposit of filthy mud in the pipes, which undergoes putrefaction, and contains active red worms.

The Author concludes that the great deposit of putrid mud on the bottoms of storage-reservoirs is the primary cause of the deterioration in the quality of the water; that the mud should be removed from time to time, and the bottom kept free from animal deposits capable of undergoing putrefaction; that thus the conditions which give rise to excessive vegetable growth would be minimised, and that the use of filter-beds would become practicable. Also, that the quality of the water delivered to the consumers is largely independent of the contamination in the storage-reservoirs, and that the troubles can be traced to turbidity during the stormy months, giving rise to deposits in the pipe system, which, when the water becomes warm, take a putrefactive fermentation.

D. K. C.

The Action of Caustic Lime in the Purification of Sewage-Water. By Dr. H. Weigmann, of Kiel.

(Gesundheits-Ingenieur, 1890, col. 317.)

While admitting that the purification of sewage-water by means of irrigation is the more perfect system of treatment, the Author points out that in certain cases some chemical process has for various reasons to be employed. Notwithstanding the numerous substances which have been proposed, lime still holds the foremost place. The caustic lime combining with the carbonic acid gas, a product of decomposition always present in sewage-water, yields a bulky precipitate of calcic carbonate, which mechanically entangles the suspended impurities, and effects a rapid clarification.

Recent experiments respecting the action of lime have shown this substance to possess such excellent disinfecting properties that it seems that the lime treatment is among the best of the precipitation processes. As one result of the use of lime, it is pointed out that the substances in solution are thereby invariably increased rather than diminished in quantity, though the recent researches of Schreib tend to controvert this theory. In order to arrive at accurate conclusions, careful estimations of the amount of chlorine in the sample, both before and after treatment, are advisable. The Author's experiments have led to the conclusion that from the clarified effluent after the lime treatment there is a considerable evolution of ammonia and other nitrogeneous gases, and he states that though water which has been rendered so strongly alkaline as to destroy all the bacteria therein cannot decompose so rapidly as water teeming with bacteria (which are the active exciters of putrefactive changes), there can be no doubt that, owing to the dissolved lime, an important change takes place in the condition of the organic substances in solution. The Author insists upon the necessity for a rapid separation of the sludge from the water in order to put an end to the changes which take place in the organic matters entangled with the calcic carbonate, and points to the advantages on chemical grounds of passing the sludge through a filter-press as soon as possible after deposition, as is done, for instance, in the works at Halle.

In addition to its powerful action in destroying the bacteria and germs of every kind, there can be no doubt that lime is a strong disinfectant. The tendency of alkaline sewage-water, after it has, by means of carbonic acid gas in the atmosphere or in the river water, parted with its dissolved lime, is to become again rapidly charged with bacteria; but these are by the self-purification powers of running water speedily rendered innocuous or converted into the food-stuff of water-plants, and it is pointed out that the previous lime precipitation has removed all the germs of a pathogenic character, and the new growth of bacteria are probably of a non-dangerous character. G. R. R.

The Sewerage of St. Petersburg. By EMIL. SOKAL.

(Wochenschrift des österr. Ingenieur- und Architekten-Vereins, 1890, p. 135.)

The chief local difficulties met with in preparing a scheme for the sewerage of St. Petersburg, are want of sufficient fall, limited choice of outfall, fear of pollution of the river Neva, and the marshy character of the soil on which the city stands, any excavation of which endangers the neighbouring houses, especially in the old narrow streets. These difficulties however had to be faced, and the problem each year became more urgent, so that the Government were compelled to take up the question of a good water-supply, and a complete and effective system of sewerage. Accordingly in 1880 a project was submitted by Mr. W. H. Lindley, which, after much criticism and examination by engineers, was placed in the hands of a committee of experts, consisting of Messrs. A. Geszwend, Delsal, Domontowicz, Ivanow and Sokolov, and their report is briefly as follows:—

1. Mr. Lindley's system of sewerage was the only one which satisfactorily meets all the requirements of sanitation, since it provides for the speedy removal of all foul water and fæcal matter from the houses, and conveys it to the sea far from the city limits.

2. It is divided into an upper and lower system of drains, the former lying above high-water level of the Neva, and the latter in the area subject to inundation, and therefore corresponds with the topographical conditions of the city.

3. The site of the only pumping station is well chosen with a view to the practicability of pumping the sewage out to sea, and further for irrigating the plain at the foot of the Pulkowa heights.

4. The drains, both as regards direction cross section and fall as well as depth, are adapted to local topographical, geological and climatic conditions, the minimum fall of any main drain being arranged with a view to perfect flushing.

5. A modification of the scheme with regard to the main collecting sewer will be necessary, consequent on the sea canal having been made in the interim.

6. The estimate of cost is correct, the prices corresponding with local rates.

This estimate is based on the results of similar works in Frankfort, Hamburg, Berlin and Warsaw, which vary from £1 to £2 5*s*. per head of population. Taking the highest of these figures, and the number of inhabitants at seven hundred thousand, this amounts to £1,575,000, but to be safe the committee rounded this to £2,000,000, exclusive of the project for sewage-irrigation, which according to Mr. Lindley would amount to £400,000. The money is to be provided by a loan of £2,000,000 redeemable in fifty years. The interest will amount to £110,000, and the working expenses to £10,000 a year, so that this would be an annual charge of £120,000, but it is stated that there will be a saving of £40,000 a year in the maintenance of the existing old drains and in other ways, consequently the yearly charge is actually about £80,000, or 2*s.* 2½*d.* per head of population.

A plan showing the position of the city, together with the upper and lower systems of sewerage, as also the pumping station and the outfall, accompanies the Paper.

W. H. E.

The Drainage of the Foz Marshes.

(Wochenschrift des österr. Ingenieur- und Architekten-Vereins, 1890, p. 189.)

The Foz marshes have an area of about 11,250 acres, and lie between the lower part of the Crau and the navigable canal from Arles to Bouc. Nearly in the centre of these marshes there are two large depressions of the soil, which form ponds and are connected with the above canal, which thus serves for carrying off the water to the sea.

All the flood-waters from the higher lying parts rush down into these ponds through two channels, cut as far back as 1476 by the Dutch engineer Van Ens, consequently the level of the water-surface of these ponds is raised at times to about 2½ feet above sea-level; and since the mean height of the surface of the marshes is 1 foot below the same datum, they are for a portion of the year, completely inundated. In 1881 a Company was formed to carry out the drainage of these marshes, in accordance with a project designed by Nadault de Buffon. For this purpose the whole marsh area was divided into the four following drainage-basins, which were protected by dams, viz.:—

	Acres.
(1.) The Foz basin containing	1,425
(2.) The Galéjon basin	925
(3.) The Capeau basin	3,750
(4.) The Etourneau basin	3,375

A group of pumping-engines will be set up in each basin, and the water will be carried by a special network of channels. The quantity of water to be pumped out is about 1,200 gallons per second, which must be lifted from 1 to 5 feet. In these marshes the soil is of different characters; the higher-lying parts, called "Coustière," consisting of clay and chalk, while the lower parts are peaty; the former can be worked with the plough if special precautions are taken, and then French vines will thrive well in it, but in the latter all such labour is in vain, and the land must be turned into grazing-ground for cattle.

W. H. E.

The Cultivation of the "Crau" in the South of France.

(Wochenschrift des österr. Ingenieur- und Architekten-Vereins, 1890, p. 145.)

The Crau is that great stretch of country covered with boulders and pebbles, which is crossed by the Paris, Lyons and Mediterranean Railway between Arles and Miramas. It is in the form of a triangle, the apex being in the Lamanon Pass of the Alps, and below this area are the Foz marshes, which are themselves bounded by the navigation canal from Arles to Bouc. It is evident that this stretch of country once formed a bight of the sea into which the River Durance directly discharged, and by degrees became filled with the stones brought down by that river.

Attempts to bring this barren land into cultivation have been repeatedly made, and as far back as 1559, Adam de Craponne excavated a canal from the Durance with this object, and another canal was made by the "États Généraux" in 1787. By means of these two canals which supply a volume of 4,400 gallons of water per second, some 37,500 acres were made cultivable, and about twenty years ago, Nadault de Buffon prepared a project which in 1881 was approved by the State, and a Company was formed for the purpose of carrying it out. According to this scheme, the area of the Crau was to be covered with a rich layer of mud from the Durance, and this plan might have answered had the soil to be cultivated been rocky or otherwise unsuitable, but such is not the case, the top stratum, though thin, being sufficiently thick for the growth of plants—the barrenness of the land being due to its dryness and lack of fertilizing ingredients, such as nitrogen, phosphoric acid, and potash. The project therefore was pronounced unsatisfactory, and was modified to the extent of providing for irrigating the soil after the fertilizing mud had been deposited on it. A new contract was then made with the Company, who by experiment found that the most suitable and profitable kinds of cultivation were vineyards and pasture-land.

W. H. E.

The Sahara Desert and the Future of the Oases.

By Edouard Blanc.

(Bulletin de l'Association Française pour l'Avancement des Sciences. Paris Meeting, 1889, p. 866.)

Much additional interest has recently attached to the region of the Sahara oasis in the French portion of Africa, *i.e.* in Algeria and Tunis, which has been rendered accessible by the opening of the Biskra Railway as far as Ain-Çefra, 290 miles south-west of Oran. Numerous artesian wells have had such an effect on the cultivation of the arid plains that it has been found possible to create in the desert a route for civilization, and to bring back life to a country which seemed to have perished for ever. It matters not whether the soil be sand, clay, or chalk, for with water it everywhere produces exuberant and magnificent vegetation. Large numbers of geographical and topographical studies, which have been undertaken by French officers, have proved that in ancient times the land which is now desert must have been well supplied with water for irrigation. The Carthaginians bred cattle and largely employed elephants, which were found within the boundaries of the Sahara Desert, and where these animals could feed there must have been vegetation. There are lakes still existing which were formerly fed by rivers, of which only the dry beds now remain; and in the southern parts of the ancient Roman province innumerable Roman and Berber ruins of large towns (many of which the Author enumerates by name), and of wells, cisterns, aqueducts, and water-dams, built of huge blocks of stone, are everywhere met with, showing that all over these plains the people followed agricultural pursuits. Where there is not now a single olive tree, there are evident remains of oil-presses, and, above all, in the whole of the Sahara, from north to south, and east to west, the country is traversed by dry river-beds as broad and as deep as the largest European rivers. It has become, therefore, a question of the highest importance to ascertain whether it would be possible by any means to restore this desert land to the condition in which it was when Africa was the granary of Rome and the most fertile land of the whole ancient world.

During the last few years a variety of investigations have been made with this view by French engineer officers. They have re-opened ancient wells, but often have found no water, and, when it has been met with, it was always much below, often more than 30 feet below the former bottom of the wells, which proves that the drying up is not merely superficial, but extends to a great depth. The destruction of ancient river-dams and aqueducts has sometimes been supposed to have caused the change; but that is not so, for the rivers themselves have disappeared; neither can the destruction of forests account for so vast a change. The Author would rather attribute it to climatic changes of very ancient date, originating at the period when the Scythian Ocean was dried up, which, in the earliest historic times, covered the steppes of Southern Siberia and united the Caspian Sea and the Black Sea. He is not of opinion that artesian wells can ever supply sufficient water for more than isolated oases in the wild expanse of desert, for the rainfall does not exceed 6 or 7 inches in the southern parts of Algeria, and it is much less in the Sahara Desert, while the surface evaporation is twenty times greater than in France. There are districts, however, as at Oued Rirh in Algeria, and at Oued Melah in Tunis, besides others which are less well known, where it has been ascertained that there are subterranean lakes, and there it would suffice to sink a sufficient number of artesian wells in order to transform the whole surrounding country by luxuriant cultivation. That the same should be possible throughout the Sahara must not be imagined. It is mathematically impossible, and the utmost that can be attempted will be to penetrate the desert by making trans-Saharan routes by means of a succession of artificial oases, the direction of which he proposes to indicate in a future paper.

O. C. D. R.

The Employment of Compressed Air for Sanitary Purposes.

(Gesundheits-Ingenieur, 1890, col. 457.)

It is pointed out that influential companies have recently been established in North Germany, at Berlin, and in South Germany at Augsburg, to provide services of compressed air for any town willing to grant a concession for a term of years to be mutually agreed upon. Negotiations are in progress for such supplies at Würzberg and Bamberg, and works are in hand for this purpose at Fürth and Offenbach. The contract in the case of Fürth, signed in May last, grants a monopoly to Messrs. A. Riedinger and Co. for forty years. The maximum price per cubic metre of air, reckoned per unit of atmospheric pressure, is 1·2 pfennige, or air under a pressure of six atmospheres above normal pressure would thus be about seven times the above price, namely, 8·4 pfennige per cubic metre (420·4 cubic feet for 1*s*.). Powers are taken by the municipal authorities to acquire a share in the profits of the undertaking when the interest on the invested capital reaches 6 per cent. After the eleventh year the town may purchase the complete works on payment of sixteen times the net average rental, but such purchase-money must not amount in any case to less than 15 per cent. above the actual outlay. Compressed air, corresponding to 2,300 HP. effective, has already been bespoken. Two years are allowed for the carrying out of the installation.

As it is certain that in the course of a few years a series of towns will each be furnished with a service of air under pressure, it behoves the sanitarian to consider in what way he can avail himself of this new agent. By means of a diagram, the Author shows how water may, by expansion of air, be raised and made available for fire-extinguishing purposes, and under six atmospheres of pressure a jet can be thrown 40 metres in height. Another diagram is given by the Author, to show how compressed air can be utilized for the emptying of cesspits, and the discharge of the contents into tank-wagons for removal. The Author enumerates many other uses of compressed air, among them being its value for ventilation purposes.

G. R. R.

Experiments on the most Convenient Method of Removing the Air from Dwelling-Rooms in the Winter.

By Dr. V. Budde, of Copenhagen.

(Zeitschrift für Hygiene, 1890, p. 507.)

In the ventilation of dwellings the aim is to disperse as much as possible the fresh air at the time of its admission, and conversely to withdraw the vitiated air as speedily and as directly as possible in order to prevent it from becoming mixed with the fresh air. In actual practice the solution of these problems depends upon a multiplicity of details which the Author states that he has here undertaken to investigate. Whether the apartment is heated by close or open stoves or by hot air from some central apparatus, the tendency of the warm air is to rise towards the ceiling, there to spread itself out, and from thence to descend in currents towards the lower portion of the room, where the outlets are usually placed. The heat radiated in a horizontal direction may be here left out of consideration, as being of minor importance. All the excretions of the human body and the products of combustion have a similar tendency to ascend, in spite of the density of the carbonic acid gas, and these impurities, mixed with the heated air, also rise to the upper part of the room. These facts would point to an exhaust placed at the highest part of the room as the more suitable arrangement, with an up-draught system of heating and ventilation instead of the down-draught system now in vogue. Deny has recently formulated a series of objections to this plan, and has at the same time proposed a different arrangement. He states that when the heated and impure gases just beneath the ceiling come in contact with the cold external walls, these gases contract in volume, increase in density, and stream downwards close against the wall. In lieu of a few scattered openings for the extraction of this cooled and impure air, Deny proposes a perforated plinth or panelled opening all along the face of the cold walls near the floor-level. This collecting channel should be led into a vertical flue, the air in which is made to move with a velocity of from 1·8 metre to 2 metres per second. The air in the collecting chamber should have a velocity of not more than 1 to 1·2 metre per second.

No information is given in Deny's treatise as to whether any practical tests have been made to verify the accuracy of his theories, and in particular whether the volume of carbonic acid present at different levels and in various parts of the room is in accordance with his assumption. As this question is one of undoubted public interest the Author deemed it expedient to undertake a series of experiments under varying conditions. The results of his investigations, in which he was aided by Messrs. Jensen and Struer, are here recorded. The experimental room was 4·68 metres long, 2·59 metres wide, and 3·11 metres high;

its area was therefore 12·1 square metres (130·24 square feet), and its contents 37·7 cubic metres (1321·41 cubic feet). It was heated by means of an open stove in one corner; it had one window with a door opposite to it, and it was furnished with a long horizontal exhaust-flue, and apertures for inlet and extraction of air capable of being opened or closed. The tests were conducted with twelve stearine candles and a lamp, and all the arrangements are described with reference to a plan and section of the room. The temperature observations were taken by five thermometers placed at various levels, being attached to a cord stretched from floor to ceiling in the middle of the apartment. Two anemometers, the formula for the use of which had been accurately computed, and a manometer of special construction were employed. The measure of the pollution of the air was based on carbonic acid gas determinations on the system of v. Pettenkofer. The proportion of carbonic acid gas was estimated in eight different places, and the temperature was at the same time observed in the same places. The results of four sets of experiments A, B, C, and D, are set forth in tabulated form.

The most important point observed was the great difference in volume between the fresh air admitted and the foul air exhausted in each of the four experiments, the latter being in all cases nearly three times the bulk of the former, the fresh air varying from 53 to 61 cubic metres per hour, the foul air extracted varying from 142 to 169 cubic metres hourly. The balance must, of course, be due to natural ventilation by crevices, percolation, &c. Five sets of observations on the contents in carbonic acid gas follow; these are also arranged in a series of tables, and show the proportions of carbonic acid gas, the volume of the gas in the outlet-flue being taken as unity. In two of the experiments in which the panelled collecting-flue on Deny's principle was used, it was found that the air in the exhaust-ventilator was richer in carbonic acid gas than was that in any other part of the room. This plan of exhaustion, however, is only really advantageous when a system of heating is employed, which causes a powerful up-draught and a consequent horizontal movement of the stratum of hot air beneath the ceiling. Among the points insisted upon as the outcome of the experiments are the need of warming the fresh air before it is introduced into the apartment, and the fact that an exhaust-flue at the upper part of the room, while it removes large volumes of heated air, does not extract an equivalent volume of polluted air. The evidence was all in favour of the longitudinal exhaust-flue at the skirting, which extracts the largest volume of polluted air in the most economical way, that is, by ensuring the fullest possible utilization of the artificial heat produced within the chamber. G. R. R.

Railway from Oran to Qçour in the Sahara. By Dr. Bonnet.

(Bulletin de l'Association Française pour l'Avancement des Sciences. Paris Meeting, 1889, p. 888.)

This railway, 290 miles in length, has been constructed nearly due south from Oran on the Mediterranean through a succession of oasis to Qçour, where a French military station has been established in the Sahara desert. It is the only railway in Algeria which penetrates the Hinterland. The desert is not in this part wholly sandy, but generally consists of stony and arid plains, at an altitude of from 2,900 to 3,600 feet above the level of the sea, limited in their extent by mountains of rock rising to a height of 6,000 and 7,000 feet. In winter there are a few small streams of water which unite and form the Oued-en-Namous river, which, after flowing for a distance of 200 miles, disappears in the sand not far from the Qçour. This district consists of four separate oases, each with a village and a mosque, surrounded by thousands of palm-trees, and from 100 to 150 acres of irrigated land cultivated with vegetables and fruit-trees. The inhabitants are chiefly Spaniards and native Jews. The railway is only of strategical importance, for it unites no populous places, but along the route fresh centres of population have been created by sinking artesian wells, for wherever there is water a luxuriant vegetation immediately follows. Possibly the road will be ultimately extended across the desert, passing along the borders of Morocco, through Figuig, Gouràra, Touat and Timbuctoo, until it unites the French possessions in the North of Africa with those in Senegal.

O. C. D. R.

Experiments on the Resistance of Trains on Railways. By — Desdouits.

(Revue Générale des Chemins de Fer, May 1890, p. 271.)

For several years many experiments have been made on the State Railways of France to determine the motive power and resistance of trains, in order to settle the conditions on which the greatest economy of motive power may be effected. The trials were made with trains in service under ordinary conditions.

The power developed in the locomotive was measured by means of the indicator for various speeds and various periods of admission. In one instance—of a passenger locomotive, having 17·3-inch cylinders, 26-inch stroke, with Allan's link-motion—it was shown that, for all degrees of admission, the moving power increased as the speed increased, starting from low speeds, until the maximum power was developed at a speed of about 21¾ miles (35 kilometres) per hour. For higher speeds, and for all degrees of admission, the power decreases very sensibly as the speed is increased. The maximum effective force attained with 70 per cent. of admission at a speed of 21¾ miles per hour, is 11,000 lbs. (5,000 kilograms), for which the "theoretical" effort is 12,480 lbs. (5,660 kilograms). The difference is only 12 per cent., of which, allowing 3 per cent. for the loss of absolute effort due to wiredrawing and compression, there is a maximum of 9 per cent. absorbed by passive resistances. In engines having piston-valves with Walschaerts' gear the passive resistances do not exceed 7 per cent.

From the results of observation, taken together, it is established that the consumption of steam, including moisture, is less than 24·2 lbs. (11 litres) per effective HP. in a passenger locomotive in good condition; with steam of 9 atmospheres, cutting off at 20 per cent., at moderate speed—31 miles per hour. The consumption of fuel of good quality is about 2·68 lbs. per HP. The Author argues that the economy effected by the compounding of locomotives can hardly exceed 10 per cent.

From various data it is deduced that the effective work done per unit of steam, for all speeds, attains its maximum value when the steam is cut off at about 20 per cent. of the stroke. At low speeds an admission approaching 30 per cent. may be practised, or it may be a little less than 20 per cent.; but, for considerable speeds, an admission of from 20 per cent. to 25 per cent. is to be adhered to in order to attain maximum economy.

A passenger engine attains maximum economy, travelling at a speed of from 25 to 30 miles per hour, cutting off at 20 per cent. At a speed of 37 miles per hour there is a loss of 10 per cent. of efficiency; at 43 miles per hour the loss exceeds 25 per cent. These results point to a want of harmony between the best speed for economy and the usual working speeds, and they suggest that an augmentation of the diameter of the wheels is desirable. But this expedient does not afford much scope, and it is more likely that the removal of inside lap, or the provision of inside clearance, would reduce, if not altogether prevent, the diminution of efficiency at the higher speeds.

The total resistance of engines with their tenders, at low speeds of from 2½ to 5 miles per hour, varied from 6·94 lbs. to 10·64 lbs., per ton using colza oil for lubricant; and from 5·82 lbs. to 9·63 lbs., using naphtha oil: having four-coupled, six-coupled, and eight-coupled wheels. The engine and tender weighed together 50 tons, except in one instance 70 tons. The resistance of the mechanism alone varied from 1·87 lb. to 3 lbs. per ton. Tenders alone have a resistance of from 5½ lbs. to 6·2 lbs. per ton; the resistance of the engine alone is from 7 lbs. to 8·8 lbs. per ton.

The Author directs attention to "an extremely important element of resistance"—the reaction of the surrounding atmosphere—the greater portion of which applies directly to the locomotive, the resistance of which, with high speed trains, amounts frequently to more than half the total resistance. Two engines, of which the resistance was measured separately and found to be 19·8 lbs. per ton at 37 miles per hour, were coupled together and again tried. The resistance fell to 14·3 lbs. per ton; the second engine was masked by the first. It is argued that by a suitable adaptation to the front of the engine a saving of from 8 to 10 per cent. of the effective power could be made.

The resistance of carriages and wagons, weighing, empty, 10 tons and 7½ tons respectively, was found to be 3½ lbs. per ton at low speeds. Further deductions are made from numerous experiments. D. K. C.

The Wear of Steel Rails of Different Degrees of Hardness.

By J. W. Post.

(Organ für die Fortschritte des Eisenbahnwesens, 1890, p. 14.)

With a view to testing the relative wear of hard and mild steel rails, the Netherlands State Railways Company laid down in 1882 a number of trial lengths. Before being laid the rails were carefully cleaned and weighed, and their chemical composition and physical qualities were determined. Yearly measurements of the depth of the rails were made by means of a micrometer at fixed marked points. By accurate measurements (made to hundredths of a millimetre) of one hundred and fifty-two rails each at two points, everything possible was done to get useful results; but the amount of traffic over the line (from thirteen to eighteen trains daily) was so small that the results of the measurements were not satisfactory. The slightest canting of the flat-bottomed rail, owing to its wearing unevenly into the sleeper, resulted in the wear not taking place at the centre of the rail-head, but at the side, and in such cases measurement showed no wear at all.

In order, therefore, to determine whether hard or mild steel is to be preferred, the rails were weighed after 26,120 trains had passed over them in 1,833 days. They were first cleaned free from rust and sand with steel brushes, then weighed and replaced in the road. The Table on next page shows the results in the case of sixteen rails of four different qualities.

The result shows that the mild steel rails lost through wear and rust 27 per cent. more than the hard. It also appears that the loss is about inversely proportional to the tensile strength.

The rails when new weighed 68 lbs. per yard, and, assuming that they were worn down to 60¾ lbs. per yard, the hard rails of A and B quality would last about ten years longer than the soft rails of E and H quality at the present rate of wear.

Considering, then, the loss from wear and rust, it is desirable to use rails of high strength; while, on the other hand, the fear of fractures prevents the use of rails of great hardness, although it is yet to be proved that with rails of the same weight per yard,

Steel.	Hard.								Mild.							
Make.	A.				B.				E.				H.			
Composition. Silicon	0·132				0·315				0·117				0·032			
Composition. Sulphur	0·067				0·052				0·080				0·054			
Composition. Phosphorus	0·065				0·087				0·072				0·065			
Composition. Manganese	0·529				0·637				0·702				0·691			
Composition. Carbon	0·400				0·360				0·230				0·190			
	1·193				1·451				1·201				1·032			
Tensile tests. Tensile strength, tons per square inch	41·5				41·5				33·0				30·1			
Tensile tests. Contraction per cent. at fracture	42·2				46·5				49·9				46·7			
Tensile tests. Extension per cent., length 8 inches	17·6				17·9				20·8				21·8			
Rail Mark.	A_1.	A_2.	A_3.	A_4.	B_1.	B_2.	B_3.	B_4.	E_1.	E_2.	E_3.	E_4.	H_1.	H_2.	H_3.	H_4.
Weight of new 29 feet 6-inch rail lbs.	651·4	677·9	664·7	664·7	671·3	677·9	653·7	670·2	662·5	661·4	668·1	666·9	669·1	665·2	662·5	663·0
" worn " " " "	643·7	669·9	655·0	656·3	664·7	670·4	645·9	663·1	653·7	650·8	659·6	657·6	659·2	656·1	652·6	632.5
Loss of weight, lbs. per lineal yard	0·80				0·73				0·97				0·99			
	0·77								0·98							
Number of days in use	1,833								1,833							
" trains per day	14·25								14·25							
Total number of trains	26,120								26,120							
Number of trains for a loss of 1 lb. per yard in weight of rail	26,714								34,005							

fractures are more frequent in the case of hard steel than mild steel. Having these considerations in view, the Netherlands State Railways Company have determined to keep the specification for light rails (60 lbs. per yard) to the same tensile strength as hitherto, namely, at least 33 tons per square inch; but for heavy rails (80 lbs. per yard) to raise the minimum from 33 to 36·8 tons per square inch.

W. B. W.

The Baldwin Four-Cylinder Compound Locomotive.

(The Railroad Gazette, May 2, 1890, p. 298.)

This is an ordinary four-coupled, outside-cylinder passenger-locomotive, with compounded cylinders at each side. The first cylinder at each side is placed over the second cylinder, forming one casting. The cylinders are 12 inches and 20 inches in diameter. with a stroke of 24 inches; the capacity-ratios being as 1 to 2·77. The driving-wheels are $5\frac{1}{2}$ feet in diameter; there are $25\frac{1}{2}$ square feet of fire-grate, and the weight in working-order is 47 tons. The centre-lines of the cylinders, at each side, are $17\frac{3}{4}$ inches apart, and the piston-rods are fastened to a common crosshead, to the middle point of which a single connecting-rod is attached. The centre-lines of the piston-rods are only $8\frac{7}{8}$ inches from that of the crosshead. The crosshead is stiff and substantial, and is found to be amply sufficient to over-rule any inequalities of stress at the ends that may happen in the course of working. Steam from the boiler is distributed by a piston-valve, working horizontally alongside the first cylinder. The piston-valve consists of four separate pistons on one body, each made tight with two packing-rings.

A starting-valve is provided, by means of which, when steam is admitted into one end of the first cylinder, wire-drawn steam is admitted to the other end, whence it passes through the exhaust-ports and passages of the first cylinder and piston-valve to the second cylinder. An augmented power of starting is thus obtained, "sufficient to start the heaviest trains, utilizing the entire adhesion of the engine without undue strain on the piston-rods."

A series of indicator-diagrams, taken from the Baldwin engine, is given in the Paper.

D. K. C.

Compound Locomotives on the Royal Prussian State Railways.

(Annalen für Gewerbe und Bauwesen, vol. xxvi., 1890, p. 103.)

This is a Paper read before the Association of German Engineers by Mr. Stambke, Chief Technical Adviser to the Royal Prussian Ministry of Public Works (Locomotive Department), the subject being treated under the following heads, namely:—

The theory of the compound locomotive.

Why the Prussian Government made trials with such locomotives.

The results obtained.

The conclusions to be drawn therefrom for future guidance.

Amongst other points comprised under the first heading, the writer refers to the known necessity in the compound locomotive of providing a special arrangement for starting, and classes the various systems of starting-gear in use as follows:—

(*a*) In the Von Borries, Schickau, and Bute systems the communication between the receiver and the valve-chest of the low-pressure cylinder is intercepted in order to prevent the fresh steam, which is admitted to the latter for starting, from exerting an obstructive back pressure on the high-pressure piston.

(*b*) By the Lindner method, the back pressure above referred to is got rid of by admitting steam from the receiver to both sides of the high-pressure piston through small ports in the inside flanges of the slide-valve.

(*c*) In the Mallet system live steam is admitted temporarily at starting to both the high- and the low-pressure cylinders.

The trials with compound locomotives were undertaken by the Prussian Government because even the high duty obtained with ordinary locomotives of the standard types hitherto employed had been found insufficient, in view of the daily increasing loads and traffic, and it had become necessary to see whether it were not possible to utilize the available steam more economically.

The saving of fuel, although also of importance, is stated to have been regarded only as a secondary question.

On the 1st December, 1889, there were altogether one hundred and eighteen compound locomotives in use on the Royal Prussian State Railways, and eighty-seven more have since been ordered, comprising ten express, thirty-five passenger, one hundred and thirty-five goods, and twenty-five tank-engines.

After quoting detailed reports from the various Royal Railway Directions, the writer proceeds to sum up the results of the trials of the standard locomotives as against the compound ones, and then goes on to state that the experience on the Prussian State Railways shows that compound locomotives, in spite of certain defects which still exist in them, surpass the ordinary locomotives in the following respects:—

a. In the greater amount of work performed.

b. In economy of fuel.

c. In throwing out fewer sparks.

The experiments have also shown that the compound locomotive runs quite as smoothly as the ordinary locomotive, and that therefore there need be no great anxiety with regard to the cases of small differences in the work done in the two cylinders of different dimensions.

Mr. Stambke lays special stress on the importance of a suitable diameter of the blast-pipe. He states that indicator trials made at

Erfurt have shown that a badly chosen diameter of this pipe can affect injuriously the production of steam, and consequently the work performed by the engine, by a greater amount than can be gained by compounding.

The blast-pipe should, in the case of the compound locomotive, have no larger diameter, in fact, should probably have a smaller bore, in order to draw sufficiently the heat of the fire for the rate of the beats of the exhaust steam, which, in the compound engines, are reduced by half. As strengthening this view, Mr. Stambke quotes experiments on the French Eastern Railway [1] according to which no constant exhaust of air exists in the smoke-box, but each separate beat of the steam is distinguishable, even at the highest speeds. In the graphical diagrams which accompany the Paper, where the exhausts appear as ordinates on the diminishing abscissæ, each beat of the steam appears as a peak with somewhat steep sides.

At lower speeds, as, for instance, when starting, the ordinate returns to zero after each beat of the steam, and it is only when a higher speed is attained that the slopes cut across each other and show a constant rarefaction, the diagram, however, always remaining a jagged one.

The Erfurt trials have also shown that for early cut-off (the position of the valve-gear remaining unchanged and with the regulator fully open) a noticeable difference for the worse appears on the diagrams for both the compound and ordinary locomotives, thus proving that for the small high-pressure cylinder a double-ported (Allen) slide is also indispensable.

In conclusion Mr. Stambke is inclined to think that it will be imperative for the Prussian Government to come to a conclusion, in view of the advantages of the compound locomotive cited above, whether it will not become necessary in the immediate future, to adopt the compound system for all except shunting engines.

F. C. F.

The Shay Locomotive.

(Engineering News, April 26, 1890, p. 386.

This locomotive, the invention of Mr. E. E. Shay, of Bar Harbour, Michigan, is designed for working railways—principally mining and lumber roads—of steep gradients and sharp curves. Mr. Shay was a saw-mill owner, and he transported the logs over a track laid with wooden rails, by means of ordinary coupled locomotives, which frequently left the rails, causing delay and expense. To obviate this difficulty, he designed a locomotive on two bogies,

[1] Revue Générale des Chemins de fer for November, 1889.

the wheels of which are driven by means of toothed gearing. The cylinders—two or three in number, according to the power required—are vertical and inverted, placed at one side of the boiler, and connected to a longitudinal crank-shaft, flanking the wheels of both trucks, and driving them by means of bevel toothed wheels and pinions of cast steel, without coupling-rods. The shaft is in three pieces, connected with flexible couplings, by means of which it is capable of adapting itself to the sinuosities of the line. The bevel wheels are bolted to the faces of the carrying-wheels; the pinions are keyed on the side driving-shaft.

The speed of the Shay engines is usually limited to 15 or 16 miles per hour, as they are geared in the ratio of 1 to 3, to provide the needful tractive force; but they may be geared as 1 to 2, or 1 to 1, and run at a speed of from 30 to 35 miles per hour. A Shay engine weighing 28 tons, geared as 1 to 3, is said to have run a distance of 52 miles in one hour, on the Rome and Columbus railroad.

Two Shay engines were constructed for the Gilpin Tramway Company, of Central City, Colorado, a line about 12 miles in length, to a gauge of 24 inches, with very sharp curves, some of which were of 66 feet radius. The steepest inclines are at the rate of 1 in 17; but the greater number do not exceed 1 in 25. The track is laid with 35-lb. iron rails on red spruce sleepers. Ore is taken from the mines down the inclines to the stamp-mills, and fuel is hauled up to the mines. The first locomotive has two 7-inch cylinders, of 7-inch stroke, and 24-inch wheels, geared as 1 to 2½, weighing 10 tons. The second engine has three cylinders, and weighs 20 tons. Both engines pass the sharp curves with ease. The cars are of iron, about 16 feet long, 4 feet wide; of capacities of 4 tons and 8 tons, on 18-inch wheels, weighing about 1¾ ton. The average train-weight is about 18 tons.

The Crescent Mine Tramway, in Utah, was constructed in 1884; it is 4·79 miles in length. The gradients are from 223 feet to 549 feet per mile; or from 1 in 24 to 1 in 9·6. One incline, of 1 in 11·3, contains four curves, of 50-feet radius. The track consists of rails of 16 lbs. per yard, fished and laid on sleepers 30 inches apart between centres. The locomotive has 9-inch cylinders, of 8-inch stroke, geared 1 to 3, on 24-inch wheels; weighing, in working-order, 15 tons. It can haul from ten to fifteen empty four-wheel mining cars, each weighing 1,300 lbs., over the road, which rises 2,000 feet in 4½ miles, averaging about 1 in 12.

A narrow-gauge line at Slate Run is worked with a 25-ton Shay engine, of three cylinders, by which from eight to ten cars, of 3½ tons each, are hauled over the line. There are inclines of 1 in 12½, one of which is 1¾ mile long.

Upwards of three hundred Shay locomotives have been constructed at the Lima machine-works, of Lima, O., for roads of various gauge, and for various requirements.

D. K. C.

The Cable Tramway at Belleville (Paris). By G. Richou.

(Le Génie Civil, vol. xvii., 1890, p. 177.)

This cable tramway is the first of the kind in Paris, and, owing to the special conditions of the route, has necessitated novel arrangements which have been devised by Mr. T. Seyrig, the engineer of the enterprise, in conjunction with Mr. Bienvenuë, the city engineer.

The street being only 23 feet wide, the line is single, with five intermediate passing-places. There are twenty-four curves, with radii varying from 70 feet to 4,300 feet, and gradients up to $7\frac{1}{2}$ per cent. The difference of level between the two ends of the line is 208 feet. The total length is a little under $1\frac{1}{4}$ mile. In previous cable tramways, both in America and England, a continuous double line has always been employed.[1] The curves in that case present no difficulty, but, with both ropes in one tunnel, the same arrangements for supporting and guiding the ropes are inapplicable.

The rails are of the girder type, weighing 96 lbs. per yard, and held by clip-bolts to the ends of yokes, spaced 3 feet 3 inches apart. The yokes are built up of angle-bars riveted together. They carry Z-shaped slot-rails with vertical webs, weighing 54 lbs. per yard. The opening of the slot is $\frac{7}{8}$ inch. The tunnel has vertical walls of masonry, 1 foot thick, resting on a concrete floor 6 inches thick. Its internal dimensions are $13\frac{3}{4}$ inches in width, and $24\frac{3}{4}$ inches in height. The reverse curves at the passing-places have 70 feet radius and 60 feet of straight length. The carrying-pulleys have an outside diameter of 12 inches, and a groove $1\frac{1}{2}$ inch deep. They are placed $2\frac{1}{4}$ inches each side of the centre line of the rails, and 33 to 36 feet apart. The cable is 1·18 inch in diameter. The grip consists of a fixed jaw to which, at one end of it, is hinged a movable jaw, which is made to rise and fall by a lever actuated from the platform of the car by means of a screw and hand-wheel. The cable is picked up and let go by the usual arrangement of an elevating pulley to bring the cable to the level of the grip, a deviation being made in the rails which carries the grip round the elevating pulley. There are two Corliss engines, of 50 HP. nominal each, with steam at 100 lbs. per square inch. The speed of the engine is 60 revolutions; that of the driving-shaft, 23; that of the rope, 7 miles per hour. The tramway is to be worked by a contractor until 1910, on lease at a rent of £2,000 per annum, subject to the approval of the agreement with the City by the Government. Further details are to be given in a succeeding article.

C. F. F.

[1] The Author is mistaken here. Single lines of cable tramway with the up and down ropes in one tunnel have been built both in America and England. —C. F. F.

Notes on Modern Boiler-Shop Practice.
By Assistant Engineer ALBERT C. ENGARD, U.S. Navy.

(Journal of the American Society of Naval Engineers, May 1890, p. 129.)

The methods employed by Messrs. Cramp in the building of large modern boilers, with thick plates for high pressures, are described.

The plates are, in the first place, pickled in a wooden bath containing a 5 per cent. solution of sulphuric or hydrochloric acid. After remaining in the bath for about six hours, they are removed and thoroughly scrubbed with hickory brooms, while a strong stream of fresh water is played upon them. They are then immersed in a bath of lime-water to neutralize any remaining acid, and again washed with clean water. All holes are drilled, and the edges of the plates are planed and bevelled for caulking. The shell plating is bent cold to the proper curvature in the rolls. The flanging is done by a Tweddle hydraulic flanger, the plate being heated to a bright cherry-red. A length of about 8 feet can be flanged at each heat. Furnace mouth-plates are flanged in cast-iron dies at a single heat.

After the flanging of tube-plates, &c., is completed, they are re-heated, and the plates are straightened on a cast-iron surface-plate, and finally they are annealed by cooling in the open air from a cherry-red heat.

The riveting is performed by a Tweddle hydraulic riveter, using a pressure of 1,500 lbs. per square inch on the flange, which gives a stress of about 90 tons on the rivet. The stay-tubes are screwed into both tube-plates and expanded, the ends in the combustion-chamber being beaded over.

S. W. B.

Experiments with Boiler-Plate Materials made at the Royal Technical College, Berlin. By — RUDELLOF, Head-Assistant.

(Mittheilungen aus den Königlichen technischen Versuchsanstalten zu Berlin, 1889, p. 97, 6 tables.)

This report consists of comparative experiments on Thomas cast iron, basic Martin cast-iron, and welding-iron, with a view to their employment as fire-plates. The experiments were made on behalf of the Rolling-Mills Company, of Peine, and consisted of:—

(*a*.) Eight tension-tests; four with, and four across the grain, two of each being with annealed, and two with hardened specimens.

Eighteen bending-tests; nine with, and nine across the grain; two of each being with annealed, two with hardened, two with red-hot, and three with blue-hot specimens.

(*c.*) Eight punching-tests; four with, and four across the grain; one of each being annealed, one hardened, one hammered red-hot, and one blue-hot specimens.

(*d.*) Forge-test (hammering).

All the specimens, except the two plates of Thomas iron, were procured by the College as follows:—Two plates each of Siemens-Martin iron from the Mining and Foundry Company at Hoerde, and from another—which latter, regarding the experiments as inconclusive, did not wish its name to appear.

The two plates of welding-iron were procured from Jacques Piedbœuf, of Dusseldorf.

The purpose for which the plates were required (fire-plates) was mentioned in the orders for them, and the following composition was suggested for the basic Martin iron:—Carbon, 0·08 per cent.; phosphorus, 0·05 per cent.; manganese, 0·40 per cent.; without, however, insisting on these proportions. The Hoerde Company stated that the plates supplied by them contained:—Carbon, 0·115 per cent.; phosphorus, 0·025 per cent.; manganese, 0·36 per cent.; sulphur, 0·051 per cent.

Private experiments at their own works had convinced them that plates with 0·05 per cent. of carbon were too weak, while similar plates with 0·16 per cent. carbon stood the test perfectly, and the best American boiler-plates contain from 0·14 to 0·175 per cent.

The quality of the welding iron was that known as "Prima fire-plate," and such plates are made 0·56 inch thick, 5 feet long, and 3 feet 4 inches wide. The specimens were cut out and marked with great care, following a uniform plan (shown in the drawings) for all except the welding-iron, which the maker told them would be injuriously affected by further heating.

Preparation of the Specimens.—Those intended for tension-tests were first cleared of the rolling skin. Those for the punching-tests had bored in them two holes, of 0·8 inch diameter and 6 inches apart, and the burr produced by the boring was carefully removed with a file. Pains were taken to make the centres of these holes coincide with the centre of the strip (16·8 inches long by 2·4 inches broad). Those for the bending-tests were cut to 6 inches by 1·6 inch, and the edges rounded off with a file. The hardening and annealing were carried out in the ordinary way; an open charcoal-hearth being used for the punching, and a coke-heated cupola for the tension- and bending-tests.

Method of Experimenting.—The tension-tests were made on the Werder testing-machine, advancing the load by ½ ton at a time within the limit of elasticity, and after by 1 whole ton at a time. The breaking-load was finally adjusted to within 5 cwt. The flow of water into the hydraulic cylinder was regulated so that the bar under test stretched about 1 per cent. per minute.

The punching-tests were made by driving steel spikes, with a taper of about 5 per cent., into one of the holes with a sledge-hammer, until one side or other gave way. Those which were tested hot were not bored, but punched with a 6-inch drift, and in opening out the hole the iron was re-heated in an open charcoal-fire, as soon as it showed, after a few blows, a dark edge round the pin.

The bending was carried out in a screw-press, the test-piece being slowly bent round a pin of 1 inch diameter, and then forced together until it showed rending or complete fracture.

The forge-tests were made on strips of 2·8 inches wide. One end was first beaten out hot to about two and a half times its original breadth. The other end was cut off; then one half was bent over hot, and when cold was hammered out at the end till cracks appeared. The other half was doubled over hot about two inches from the end, and then hammered out at a bright red heat. The sledge-hammer used throughout was the same one, weighing 18 lbs.

E. L. W. H. S.

On Reducing the Internal Wastes of the Steam-Engine.

By R. H. Thurston.

(Advance-Proof Transactions of the American Society of Civil Engineers, 1890.)

Great losses are due to waste of heat internally in steam-engines, by the alternate absorption of heat by the metal surfaces of the cylinder covers and piston, and the ejection of that heat later to the condenser, or into the atmosphere. According to Mr. Thurston's invention for obviating such waste, an effective non-conducting skin is provided for the internal surfaces of the cylinder, formed integrally with the castings of which the engine is composed. The idea is to expose the internal parts of the engine—the covers, the two sides of the piston, the internal surfaces of the steam-passages—to the action of a suitable solvent for converting these surfaces into highly carbonized material, which is a comparatively poor conductor of heat. It is not proposed so to treat the rubbing-surfaces that are in a high state of polish, in virtue of which their capacity for taking up heat is greatly lessened.

One of the best methods of treatment for this purpose is the removal of the iron by oxidation, by subjecting it to the action of a dilute acid, say sulphuric acid in water. Thus the graphitic surface became fairly dense and compact. The spongy surfaces so prepared may be filled with a non-conductor, as drying oil, or shellac.

Tests of this system were made by Mr. P. M. Chamberlain, in the Sibley College laboratory, on a steam-cylinder, the cover or "head" of which was of Tuscarora iron, 1 inch thick. The outer face was smoothly polished, the inside surface was smoothly faced in the lathe, with an ordinary finishing cut. The inner face was treated variously, and was subject to a course of fifteen tests for the quantity of heat transmitted through the head into a calibrated calorimeter. In the first and second tests, the inner surface of the head was greasy; for the third, fourth, and fifth, it was the same, and washed with benzine and dried; for the sixth and seventh, oiled with lubricating oil; for the eighth and ninth, washed clean with benzine; for the tenth, eleventh, and twelfth, after exposure to nitric acid for sixteen hours, oiled with linseed oil; for the thirteenth and fourteenth, similarly treated with hydrochloric acid, and oiled after twelve hours' exposure; for the fifteenth and sixteenth, sulphuric acid 1, water 2, for forty-eight hours, then oiled and allowed to dry during twenty-four hours. The variation of resistance to the transmission of heat was not notable until the last pair of tests were made, when it became evident that treatment with drying oil, even after so short a period of exposure to acid, and so short a time allowed for drying, had an exceedingly important effect in reducing conductivity, and preventing storage and transmission of heat.

The saving of otherwise wasted heat thus brought into evidence is calculated to be 40 per cent., and this should be a measure of the proportion by which internal cylinder-condensation should be diminished, Dr. Thurston estimates that with more prolonged treatment, the cylinder-waste may be reduced by at least one-half, which, in ordinary practice, means a saving of from 10 per cent. to 20 per cent. of all the steam used.

D. K. C.

The Distribution of Energy. By J. LAFFARGUE.

(L'Electricien, 1890, p. 393.)

The Author considers and compares the principal methods of transmitting and distributing energy under the following heads. Transmission by (1) ropes and pulleys; (2) pressure-water; (3) hot water; (4) steam; (5) gas; (6) compressed air; (7) rarefied air; (8) electricity.

Taking these in order: Up to distances of 1,000 yards (1) gives good results, the efficiency being given as 96 per cent. for about 100 yards and 90 per cent. at 1,000 yards. (2) Is probably at present the most extensively used in towns. No exact details seem obtainable of the expenses connected with this mode of transmission, though the price in London to the consumer is given as nearly 2*d.* per HP. hour. (3) Only one example exists of distribution by hot water, viz., Boston, U.S., where water is distributed at a temperature of 400° Fahrenheit[1] by means of pipes. These pipes being led into the consumers' premises, and, being arranged in flow and return, are used to heat the houses and to raise steam for power purposes. No details of costs are given. (4) Again, only a single example exists, viz., the steam distribution in New York. No results have been published of the efficiencies or costs. (5) The distribution of power by gas is well known, and will probably be still further adopted. It is, however, susceptible of great improvement, the present motors being troublesome and expensive. (6) Compressed air has up to the present been a most important vehicle for power transmission. The Author refers to an earlier article on this subject in the 'Electricien,' February 1st, 1890, and to an article by Mr. Henri Dechamps in the 'Revue Universelle des Mines et de la Metallurgie." The loss in the conduit itself is very considerable, and tables are given showing the loss for various pressures and velocities of air in the pipes. The Author concludes that on a large scale distribution by air-pressure cannot be seriously considered. (7) Rarefied air has never been practically adopted as a means of transmitting power. (8) The Author devotes considerable space to the consideration of electrical distribution of power, and cites the various advantages in the way of cheapness of motors and adaptability to present requirements, and concludes by exhibiting two tables showing the cost per HP. of the plant for distributing power, and the working cost either with steam- or water-power prime movers, of the four principal systems, electric, hydraulic, pneumatic, teledynamic. The Author's conclusions point to the use of cables up to about 1,000 yards, after which electricity has in every point the advantage.

LL. B. A.

Transmission of Power by Manilla Ropes. By J. H. Gregg.

(Journal of the Association of Engineering Societies, New York, 1890, p. 110.)

This Paper, which was read before the Western Society of Engineers, contrasts the English system of separate ropes for transmitting power from the prime mover to line shafts with the American system, in which one continuous rope is employed, independently of the number of grooves in the sheaves, with an automatic tension-carriage for taking up slack and giving tractional force, which is dependent on the weight applied to the pull-back. The sheaves for American rope-gearing are of two kinds, drivers and idlers, or carrying-sheaves, distinguished by

[1] Corresponding to about 250 lbs. pressure per square inch.

the form of the grooves, which for drivers include the angle 45°, and for idlers are semicircular in section.

Mr. Gregg quotes a safe formula for ordinary practice, constructed by E. D. Leavitt, jun., for the horse-power of driving-ropes, as follows:—

$$\text{HP.} = \frac{G \times D \times R}{200} v.$$

G = circumference of rope.
D = diameter of sheaves in feet.
R = revolutions per minute.

The annexed Table was calculated by means of the above formula:—

ROPE-TRANSMISSION OF POWER.

Speed in feet per Minute.	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000
Diameter of Rope.	Horse-Power.								
Inches.									
$\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{3}{4}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{2}$	$6\frac{1}{2}$	7	$8\frac{1}{4}$	9
1	$3\frac{1}{4}$	$4\frac{1}{8}$	$6\frac{1}{2}$	8	10	11	13	15	16
$1\frac{1}{4}$	$5\frac{1}{8}$	$7\frac{1}{2}$	$10\frac{1}{4}$	13	15	18	20	23	26
$1\frac{1}{2}$	$7\frac{1}{2}$	11	15	18	22	26	30	34	37
$1\frac{3}{4}$	10	15	20	25	30	35	40	45	50
2	13	$19\frac{1}{2}$	26	33	39	46	52	59	65

The margin of safety, according to this Table, appears to be considerable. The Chicago Arc Light and Power Company run successfully fifty light dynamos with two $\frac{3}{4}$-inch ropes, travelling at a speed of 3,516 feet per minute, and transmitting 50 HP., or about four times as much as would be calculated from the Table.

The average breaking-strength of the manilla rope is about 10,000 lbs. per square inch of section.

D. K. C.

The Use of Motors for Small Powers in Large Towns, especially Berlin. By OTTO LEONHARDT.

(Mittheilungen aus der Praxis des Dampfkessel- und Dampfmaschinen-Betriebes. 1890, p. 35.)

The number and variety of motors used for small industries in Berlin is very great, such motors being chiefly steam- and gas-engines.

Since November 1, 1887, gas used for purposes other than illumination has been supplied by the town authorities at a price 20 per cent. lower than previously, and this has been followed by a considerable increase in the number of gas-engines employed.

In Berlin at the end of March 1888 there were 555 gas-engines, developing 2080·5 HP.; at the end of March 1889 there were 667 gas-engines, developing 3000·75 HP. This corresponds to an increase of 20 per cent. in the number of engines, and 50 per cent. in the power developed.

The number of engines of small power during the period in question, up to 1 HP., increased by 17; up to 2 HP., increased by 27; up to 3 HP., increased by 2.

According to official reports gas-engines are employed in eighty-four different trades.

The increase in the number of steam-engines used for small powers cannot be so accurately stated, because, in the first place, it is difficult to draw a line between great and small industries; in the second place, steam is employed in many places for other purposes than the production of power. At the central electric lighting stations alone in Berlin about 8000 HP. is at present required, and when the stations still in course of erection are completed, this will be increased to 18,400 HP. In the future, when electric motors will be extensively adopted for small powers, the development of the latter will be obviously dependent on the existence of steam-engines of large power. The number of new steam-engines erected in the year 1888–89 was certainly enormously in excess of the number of gas-engines. In Berlin water-motors are very little used, and cannot, on account of their costliness when driven by the town water-supply, as well as for other reasons, compete with steam. This is not, however, everywhere the case; in Zurich, for instance, the number of these motors rose from 157 in 1887 to 172 in 1888. The Author arrives at the conclusion, from the examples given, that the assistance of mechanical power can be advantageously employed for small as well as large industries.

G. R. B.

Experiments upon the Inflammability of Mixtures of Fire-damp and Air.

(Le Génie Civil, vol. xvii. 1889, p. 238.)

After the catastrophe at Saint Etienne a sub-commission, consisting of Messrs. Mallard, Le Chatelier, and Chesneau, was appointed to make tests upon mixtures of fire-damp and air, and these were carried out at the "École nationale supérieure des Mines." From the results already obtained, it appears that explosive mixtures of this kind are not fired by such sparks as are produced by pickaxes working on hard rock. This conclusion was obtained from the following facts. Pure C_2H_4 was prepared with apparatus used in the tests made at Sevran-Livry by means of acetate of soda and lime heated together in iron retorts, then washed in water, and collected in a gas-holder of a capacity of 222·5 cubic feet. The explosive mixtures were made by conducting the gas into a Bunsen burner with several jets, which were directed into a wooden box placed against masonry work, opposite blocks of sandstone or porphyry imbedded in the masonry, and arranged so that when struck with the pick the sparks produced would fall into the box. The quantity of gas admitted to the burner was regulated so as to obtain, by direct lighting, an instantaneous flame from the hole in the box to the inlet of gas at the burner corresponding to the most explosive mixture. The picks used were those of mild steel with a removable point used at Saint Etienne, and those of iron used at Anzin. The Commission first repeated the experiments previously made at Saint Etienne with mixtures of ordinary illuminating gas and air in the apparatus described. Ignition was easily obtained when the sparks were large enough, and remained glowing for an appreciable time, and this state could be obtained at almost every stroke of the pick. The sparks consisted of metallic particles burning in air, and giving true globules of magnetic oxide. With mixtures of fire-damp and air no case of combustion was obtained, although more than a hundred tests were made under conditions which would have caused ignition with illuminating gas and air. These opposite results are due to the sluggishness of ignition of fire-damp as compared with illuminating gas.

Besides the ordinary picks with steel or steely iron points, the Commission tried picks made of steel containing 13 per cent. of manganese, and also some of aluminium bronze containing 8 per cent. of aluminium and 2 per cent. of silicon. The sparks from the manganese steel were larger and hotter than those from the iron, and ignited the mixtures of illuminating gas and air more easily, yet they never ignited the mixtures of fire-damp and air. The picks of aluminium bronze were almost equal to iron in hardness, and gave no sparks.

Experiments were then made on an explosive mixture of air, illuminating gas and fire-damp, with the result that, when the combustible gases were mixed in equal volumes, the sparks sometimes ignited the mixture, but no ignition took place when the proportion of fire-damp to illuminating gas was 3 to 1. As the most exact analyses of natural fire-damp show it to consist of C_2H_4, with the addition of air, and only 3 to 4 per cent. of other gases, it is fair to conclude that explosive mixtures of fire-damp and air cannot be ignited by the sparks produced by picks working on hard rocks.

E. R. D.

A New Method of Carbon-determination in Iron.

By O. Petterson and A. Smith.

(Stahl und Eisen, 1890, p. 720.)

This method depends upon the use of potassium bisulphate for rendering the iron soluble. The sample, weighing from 6 to 12 grains, either as a single piece of thin sheet or plate, or in filings or borings, but preferably the former, is heated with molten bisulphate of potassium, and completely disintegrated in from five to twelve minutes, the iron being converted into ferric sulphate, with the production of an equivalent quantity of sulphur dioxide, and the conversion of the combined carbon into carbon dioxide, while the graphite remains unchanged in the form of brilliant crystalline scales, which exactly resemble natural graphite when examined by the microscope. The gaseous products are carried by a stream of air freed from carbonic acid into a mixture of baryta water and soda-lye, forming sulphite and carbonate of barium. The former salt is oxidised to sulphate by a slight excess of permanganate of potassium, after which the carbonate is decomposed by nitric acid, the carbon dioxide is collected and measured in a special form of eudiometer, and from its volume the combined carbon is calculated.

The melted potassium ferric sulphate is a white mass containing the graphite, which is liberated by solution in weak hydrochloric acid, and may be collected on a platinum and asbestos filter and weighed. It is then burnt by heating in a glass tube, through which a current of air and nitrous oxide vapour is passed for a few minutes. The filter, when completely cleared, is then weighed, and is ready for a fresh operation. The eudiometer in which the carbonic acid is measured is illustrated by a sketch, but not specially described. The whole apparatus is made by Mr. F. Muller of Bonn.

In decomposing the barium carbonate it is necessary to use a stream of hydrogen in order to remove the last traces of carbonic acid from the solution. This is done by placing in the flask in which the decomposition is effected, a small piece of aluminium wire wrapped round with platinum wire, and this serves the additional purpose of preventing bumping towards the end of the operation when the liquid is freed from air.

H. B.

On a Method of Protecting Puddlers from the Heat of the Furnace.

By M. H. KOPPMAYER.

(Stahl und Eisen, 1890, p. 613.)

At the Menden and Schwerte Ironworks in Westphalia a method has been adopted for protecting the workmen at the puddling and heating furnaces from the heat radiated from the interior and the casing plates. It consists of a rectangular iron screen hanging from an overhead rail, which can be made to cover the whole working side of the furnace, or can be pushed aside when not required. The lower end is bent over into a gutter, which has a slight fall in the direction of its length, and the upper edge is provided on the inside, that nearest the furnace, with a pipe bored through with small holes about $\frac{3}{4}$ inch apart, which is in connection with the service-pipe supplying water for cooling the sides of the bed When in use the inside of the plate is kept constantly wet from the supply pipe, the small jets trickling down to the gutter at the bottom and running away to the cooling bosh at the side. A notch at the bottom is left for the passage of the rabble, and a short inclined plate is provided for the cinder to run over; but with these exceptions the whole surface is screened by the water-cooled plate. At the time of balling-up, the water is shut off and the screen is run to one side, when the furnace is accessible in the ordinary way. This arrangement, which was first applied experimentally to a few furnaces, has worked so satisfactorily that it has been fitted to the whole of the puddling furnaces in the works, as it is found that the puddlers, being protected in great part from the exhausting effect of the heat, can work full time even in the hottest summer weather. A sketch of a similar application to the doors of heating and open-hearth furnaces is also given by the Author.

H. B.

A New Modification of the Open-Hearth Steel Process.

By F. KUPELWIESER.

(Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1890, p. 262.)

In 1888 the Author published some calculations showing that in the open-hearth process the use of molten iron from the blast furnace would be attended with considerable saving of fuel, especially when the amount of scrap in the charge is much diminished, as in the pig and ore process. The heat of fusion of white pig-iron being 260 calories, and the make of steel where ore alone is used, or with a very small amount of scrap, being about equal to that of the pig-iron, the heat brought into the bath by the fluid metal would be at least 260,000 calories per ton. If this has to be furnished by the combustion of fuel of a calorific value of 7000, as the Siemens furnace only utilizes about 25 per cent. of the heat developed, the amount required will be at least 3 cwts., and proportionally more with fuel of lower heating power. Since the above date this method has been adopted and regularly worked at Witkowitz in three furnaces, where, owing to local difficulties in carrying the iron from the blast furnaces, an empty Bessemer converter previously heated, was used as an intermediate reservoir. Subsequently the process has been modified by blowing the blast-furnace metal in the converter for two minutes, when the bulk of the silicon and manganese are removed, rendering it more suitable for the basic-lined furnace. The chemical changes are shown in the following analysis:—

——	Metal from Blast Furnace.	Metal blown two minutes.
Silicon . . .	0·95	0·26
Manganese . .	1·77	0·75
Carbon . . .	3·39	3·03

The amount of heat developed in the blowing is theoretically as follows:—

Per ton of 1,000 kilograms.			Calories.
From	6·9 kilogram	silicon	42,860
„	10·2 „	manganese	15,500
„	10 „	iron	8,750
			67,110

About one-half of this is, however, lost by radiation, so that the amount added to the metal does not exceed 10 per cent. of that brought from the blast furnace; and as this is subject to further diminution by the losses experienced on the double transfer to and from the converter, the loss and gain, of heat, probably about balance each other; at any rate, the heat added has no particular influence on the working of the open-hearth furnace. The charges at present consist of 90 per cent. cast-iron, 10 per cent. scrap, together with the necessary amount of ore for tempering, and some lime for dephosphorizing. The work is done very rapidly; the three furnaces take from fifteen to eighteen charges, or an average of seventeen, in twenty-four hours, and the fuel used varies from

10 to 12 per cent. of the weight of the ingots produced—a result which the Author considers as unattained by any previous method of working.

H. B.

A New Method of Recovering Tin from Tin-plate Scrap.

By B. SCHULTZE.

(Dingler's Polytechnische Journal, vol. 276, 1890, p. 279.)

The solvent action of acid ferric salts upon metals is well known, but the property has not hitherto been utilized in the treatment of tin-plate waste, for which purpose it answers perfectly. The solvent used may be either acid ferric sulphate, acid stannic sulphate, dilute sulphuric acid, or dilute hydrochloric acid, but in the two latter cases ferric hydrate, in the form of heavily-rusted scrap iron, must be added. The tin, when dissolved, is precipitated by metallic iron, for which purpose, however, the solution must be perfectly neutral, and contain only protoxide salts, as the smallest excess of acid in the presence of persalts prevents the reaction. This condition is attained by passing the solution through a mixture of iron rust, metallic tin, and metallic iron, when the following reactions take place:—

(1) $Fe_2\,O_3\ 3\,H_2O + Sn\,O\,SO_3 + 3\ SO_3\ H_2O = 2\,Fe\,O\ SO_3 + Sn\,O_2\ 2\,SO_3\ 6\,H_2O$.

(2) $Sn\,O_2\ 2\,SO_3 + Sn = 2\,Sn\,O\,SO_3$.

(3) $2\,Sn\,O\,SO_3 + 2\,Fe = 2\,Fe\,O\,SO_3 + 2\,Sn$.

The process, as practised, includes three principal operations:—

1. The solution of the tin.
2. The precipitation of the tin.
3. The treatment of the waste liquor.

When acid ferric sulphate is used, the tin-plate cuttings are placed in iron baskets and lowered into the solution contained in an open wooden vat. The tin covering is completely stripped off the iron in a very few hours. The basket is then lifted out, the contents washed in water and picked over by hand, to separate portions still covered with tin, while the remainder which is clean malleable iron, is pressed into balls for the heating furnace.

The partially-stripped portions are either returned to the dissolving bath or put aside to rust, in order to obtain material for the neutralizing vat.

When the solution is saturated, as evidenced by its no longer acting upon fresh tin-plate scrap, in which condition it contains mainly stannous and ferrous sulphates, probably a little stannic oxide and some free acid, it is passed to the neutralizing vat containing metallic tin and iron rust, where the excess of acid is neutralized and the persalts are reduced as shown above.

When an acid stannic solution is used, the method of proceeding is similar, the only difference being in the nature of the solvent.

Instead of these solutions, dilute sulphuric or hydrochloric acid may be used in conjunction with ferric oxide or its hydrate, but with these the action is somewhat slower, from six to twenty-four hours being required to remove the tin completely.

The precipitation of the tin from the neutral stannous solution is effected by running it into vats containing clean metallic iron (scrap previously freed from tin). The reaction goes on slowly, the tin separating as grey metallic powder or in brilliant crystalline grains; but the reduction is complete, the exhausted solution showing not the slightest trace of tin. The precipitate, when washed and cleaned from iron by dilute sulphuric acid, is either melted or used for making tin salts. The green vitriol liquors from the precipitating vats are concentrated by allowing them to drop slowly over a large heap of cleaned iron scrap, which causes a rapid evaporation and a deposit of ferrous sulphate on the metal. This may be washed off and purified as commercial copperas by recrystallizing, or it may be used for forming the acid liquor for dissolving fresh quantities of tin.

When the tin-plate cuttings are varnished, the surface is cleaned by heating them with strong sulphuric acid at a temperature of 100° Centigrade, which destroys the varnish in a very short time, leaving the tin surface exposed. When zinc is present, it should first be removed by treatment with dilute sulphuric acid as long as hydrogen is evolved.

The plant and materials required are both simple and inexpensive. From 1 to 6 cwt. of chamber acid, worth from 1*s.* to 12*s.*, are consumed per cwt. of tin obtained, worth £4 10*s.* to £5, in addition to 25 to 40 cwt. of iron, worth from £1 17*s.* to £4. The amount of coal required is inconsiderable. Both tin and iron are obtained in the highest state of purity.

H. B.

The Lewis and Bartlett Bag-Process for Collecting Lead-Fume.

By F. P. Dewey.

(Advance Proof. Transactions of the American Institute of Mining Engineers, Feb., 1890.)

This process, which was originally used in the production of zinc-oxide for paint, has been adopted at the Lone Elm Leadworks at Joplin, Missouri, for collecting fume produced in smelting lead-ore in the Scotch ore-hearth, which is afterwards converted into a white powder suitable for paint by a second smelting operation. The ore, a very pure galena, containing a small proportion of zinc blende and only about 1 oz. of silver per ton, is dressed up to about 73 per cent. of lead, and smelted in a hearth with coal and quicklime, in such a manner that only about two-thirds of the lead is reduced, the remainder being converted into fume and slag, in the proportion of 1 of the former to 2·8 of the latter. The fume is drawn by an exhausting-fan through a settling-chamber and a long iron flue to a bag-house, containing a number of suspended woollen bags, which filter it from the uncondensable gases. These bags are made of cloths woven from unwashed wool, which is found to resist acid fumes better than other material. They are 33 feet long, and 60 inches in diameter when new, but after being some time in use they lengthen to 35 feet and contract to 38 inches. The condenser-house contains eight hundred bags, costing about 37*s.* 6*d.* each. These are grouped in series, connected with hoppers in which the separated fume or blue powder collects, and is removed at intervals of about ten days.

This substance is an exceedingly fine blueish-grey powder, consisting mainly of oxide and sulphate of lead in about equal parts (43 to 45 per cent.), from 6 to 10 per cent. of sulphide of lead, and some carbonaceous matter and hydrocarbons, when removed and piled in heaps on the ground, is fired by a few pieces of burning oil-waste. In about ten hours the lead sulphide and carbonaceous matters are entirely oxidised, and the loose blue powder is converted in pinkish-white coherent crusts, which are then purified by being subjected to a second volatilizing process in a furnace known as a slag-eye. This resembles an ordinary brick slag hearth, 2 feet square and about 6 feet high, with a charging-door 4 feet above the ground. There are eleven 1½-inch twyers, four being at the bottom, and the other seven about 6 inches below the charging-door. The throat is covered by a flue, 7 feet high and 4½ feet broad, common to the three furnaces, two of which are worked at a time.

The furnace is filled with coke up to the charging-door, upon which the materials to be smelted are thrown. These consist mainly of the ore-hearth slags, the burnt blue powder, and coarse fume from the cooling fumes. The principal object being to volatilize as much of the lead as possible, the furnace and flue are kept very hot, a highly-heated flue being necessary to produce paint of a good colour. A certain portion of the metal is, however, reduced, and, together with the slag, runs into a basin containing charcoal, which acts as a filter for the lead, while the slag passing into water is granulated in the usual way. The highly-heated fume is drawn by an exhausting-fan through a series of iron cooling-pipes. The first two of these are cylinders, 7 feet in diameter and 20 feet high, lined with firebrick, and traversed by the 18-inch pipe supplying the twyers. The air in its passage takes up heat from the fume, cooling the latter, and is raised to a temperature that the hand will just bear. The cylinders are followed by four siphon-pipes, 3½ feet in diameter and 20 feet high, with their lower ends set in brickwork, through which the gases ascend and descend four times, and become sufficiently cool to pass through the fan and on to the bag-room.

The second bag-room, called the paint-house, is 40 feet wide, 90 feet long, and 45 feet high. It has three rows of hoppers, nine in a row, with twenty bags above each hopper. Each bag has 168 square feet of surface, giving a total filtering surface of 88,704 square feet for the five hundred and twenty-eight bags in the house.

The final product, or white paint, is a pure white impalpable powder. It passes from the bags into the hopper, from which it is shoveled out into a box upon wheels, and weighed into casks containing 500 lbs. Two packers are employed, who wear sponge respirators when at work.

The composition of the paint averages—

Lead sulphate	65 to 65·5
Lead oxide	25·8 „ 25·9
Zinc oxide	5·9 „ 6·0
Carbonic acid	1·5 „ 2·0
Water	0·7 „ 0·9

The deposit in the last bags of the last row is of a finer grain than that from the first in the first row, but no distinction is made, all being packed together.

The average product of two furnaces per day is seventeen barrels, or 8,500 lbs. They are kept at work from fifteen to thirty days, but when first started with cold flues the product for four to five hours is discoloured, and is turned into the blue-powder room. The first twenty-four hours' work of the paint-room at starting is also inferior in quality, and sold as such.

The fans used are of iron, 6 feet in diameter and 3 feet wide, and run at 290 revolutions per minute.

The proportion of different products obtained from an experiment with 57,324 lbs. of mineral, supposed to contain 68 per cent. of lead, was as follows:

From the ore hearth:—

	lbs.
Pig lead	25,549
Slag	11,140
Blue dust	5,000
Blue powder	13,690

From the slag eye the materials charged were:

	lbs.
Slag	11,140
Blue powder	13,226

Which yielded

	lbs.
Pig lead	8,798
Poor slag	4,030
Paint	14,387

The price realized for the paint was 3½ cents per lb., when pig-lead was selling at 3·35 cents.

H. B.

Delta Metal. By L. Glaser.

(Annalen für Gewerbe und Bauwesen, vol. xxvi., 1890, p. 245.)

This metal, the invention of Mr. A. Dick, is an alloy of copper, zinc, and iron. The process of manufacture is as follows:—When iron is heated in molten zinc, the latter dissolves about 9 per cent. by weight of iron; the exact point of saturation, which may even exceed this amount, is dependent upon the temperature at which the zinc is maintained during the process. In order to obtain uniform results, it is thus important to keep the zinc at a constant temperature, viz., the cherry-red heat of iron, at which heat zinc absorbs 8·5 per cent. of iron. This alloy of iron and zinc is cast into bars, and is then admixed with certain quantities of copper, or copper and tin, in accordance with the purpose for which it is required. In order to effect the deoxidation of the oxides present in the alloy, a proportion of copper manganese is employed; this substance being used either in the exact amount necessary to combine with the oxygen, or an excess of the copper manganese is used, so as to retain a certain quantity of manganese in the alloy. The delta metal is as soft as wrought iron, as strong as steel, and possesses a beautiful golden-yellow colour. It can be forged at dull redness; drawn into wire, welded, and, if used for casting, runs freely and gives a fine grain on fracture. It is very little changed on exposure to the atmosphere, and does not rust or become coated with verdigris, and resists in a most extraordinary way the effects of acids and salt-water. By means of a graphic diagram, the superior strength of delta metal, when compared with copper and its various alloys, is shown. The experiments of Professor Unwin are quoted as indicating that at high temperatures the delta metal, both rolled and cast, is much stronger than copper, brass, gun-metal, or phosphor-bronze. Tensile, torsion, and compression tests are set forth in a tabulated form; the average breaking-weight being 58·8 kilograms per square millimetre (37·33 tons per square inch) when submitted to tensile strain.

The metal melts at 950° Centigrade, and has a specific gravity of 8·6. The Author directs attention to many purposes for which this alloy has already been employed. An illustration is given of a cog-wheel which was submitted to very severe tests by Colonel Locher, the engineer of the Mount Pilatus Railway, and which, under stresses of 21,000 kilograms, showed a spread in the teeth of 12 millimetres, and broke at 21,500 kilograms. In a foot-note attention is drawn to the suitability of delta metal for the fire-boxes of locomotives.

G. R. R.

The Copper- and Silver-Production of Mansfeld in 1889.

(Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1890, p. 275.)

The output of the different mines producing copper schist in 1889 was 511,323 metric tons, which was raised at a cost of 33*s*. 7*d*. per ton, against 469,716 tons at 35*s*. 2*d*. in the preceding year. This was derived from an area of 1,459,360 square metres (360·6 acres), or about 31 square feet of ground exhausted per ton of mineral. The area laid out for working at the end of the year was 2,763 acres, but of this about one-eighth was inaccessible owing to an influx of water which drowned some of the deeper levels.

In the coarse metal fusion 502,750 tons of schist yielded 39,588·4 tons of coarse metal, the corresponding figures for 1888 being 472,120 tons and 38,087 tons. The metallic yield after allowing for rich slags and other additions to the furnace charges, corresponded to 3,292 per cent. of copper and 0·0194 per cent. of silver (6·3 oz. per ton) in the ore, against 3·33 and 0·0195 per cent. in 1888. The silver in the copper was 0·590 per cent. (192·74 oz. per ton) against 0·585 per cent. in 1888.

Nearly 4,500,000 of moulded blocks and slabs of various kinds for building purposes were made from the coarse metal slags, in addition to 17,500 cubic yards used for road-making.

In the calcining works 37,543 tons of coarse and 432 tons of fine metal were roasted, giving 16,583 tons of chamber acid of 50° Baumé; 1,529 tons of the latter were concentrated to 1,203 tons of 60° strength, and 4,929 tons in the Faure and Kesslers pan apparatus to 3,179 tons of sulphuric acid of 66°.

The burnt coarse metal, 41,376·8 tons, yielded on second fusion 21,039·5 tons of fine metal, averaging 75 to 75·7 per cent. of copper, and 0·44 to 0·446 per cent. of silver, and 315 tons of bottoms containing 95·3 to 96·88 per cent. of copper, and 0·947 to 0·961 per cent. of silver.

The total cost of the coarse metal, roasting, and fine metal works was £256,172 18*s*. 9*d*.

In the desilverizing works 20,991 tons of ground and sulphatized fine metal yielded 87,127·5 kilograms of precipitate, or 86,850 kilograms of bars, 999 fine, or 86,714·48 kilograms of fine silver, which was 8018·29 kilograms above 1888. The yield of fine silver per ton of fine metal was 4,131 kilograms, against 4,210 kilograms in 1888. This corresponds to a total saving of 89 to 94 per cent. of the silver.

The total desilverizing cost was £34,214 5*s*. 2*d*. (about 3*d*. per oz. of fine silver).

The production of refined copper was 15,330 tons, at a total cost of £22,706 18*s*. 4*d*. The sales amounted to 15,925·25 tons, which exceeds that of any previous year; but the price, in consequence of the collapse of the French syndicate, fell from £72 18*s.* 6*d.* in 1888, to £56 3*s.* 6*d.* in 1889.

84,821·97 kilograms of silver were sold at £6 6*s.* per kilogram, against 78,688 kilograms in 1888.

The hammer- and rolling-mills at Rothenburg and Eberswald turned out 1543·8 tons of sheets and 134 tons of pans and bottoms, 178 tons of round and 11 tons of square rods.

H. B.

Mining and Metallurgical Products of Russia in 1887.

By S. Kulibin.

(Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1890, p. 231.)

I.—Mining Products.

(a.) Mineral Coal and Bitumen.

	Tons (metr.)
Bituminous coal	4,040,084
Anthracite	455,163
Lignite	43,905
Asphalt	11,136
Petroleum	1,727,031

(b.) Salt and Non-Metallic Minerals.

Rock salt	261,613
Glauber salt	2,476
Phosphorite	7,062
China clay	6,095
Sulphur	4,945

Salt was made from brine to the amount of 1,767,314 tons.

(c.) Metallic Minerals.

Gold ore (wash dirt?)	22,142,895
Platinum ore "	1,012,004
Lead and silver ores	37,887
Copper ore	108,185
Zinc ore	37,897
Tin ore	1,737
Cobalt ore	1·25
Mercury ore	7,465
Manganese ore	58,269

The total number of mines at work was two thousand three hundred and sixty-seven, employing one hundred and thirty-four thousand two hundred and forty-three hands, and seven hundred and fifty-four steam-engines of 18,713 HP., and ten water-wheels of 123 HP.

II.—METALLURGICAL PRODUCTS.

	Tons.
Pig-iron	613,184
Platinum	4·4 (140,800 oz.)
Gold	34·9 (980,214 oz.)
Silver	15·4
Lead	991
Copper	4,995·6
Tin	10·2
Zinc	6,788·4
Mercury	64·3

There were one hundred and eighty-nine blast-furnaces blowing, seventy with cold and one hundred and nineteen with hot blast, of which thirty-two were fired with coke, five with anthracite, and one hundred and fifty-two with charcoal, for a total working period of nine hundred and fifty-seven thousand four hundred and twenty-six hours (equal to an average of two hundred and eleven days per furnace). The ore smelted was 1,278,852 tons, made of the following items:—

	Tons.
Magnetite	256,464
Brown iron ores	689,280
Spathic and other ores	274,355
Cinder and scrap	58,753

The total make of wrought-iron was 478,830 tons, which was produced in five hundred and thirty-seven hearth fineries and six hundred and twenty-four puddling furnaces. The forges and mills, one hundred and seventy-seven in number, included four hundred and forty-five balling furnaces, four hundred and forty-seven heating furnaces, five hundred and forty-five water-power helves, three hundred and thirty steam-hammers, and four hundred and ninety-nine rolling-mills. Steel was made in thirty-three works, containing thirty-three puddling furnaces, seventeen Bessemer converters, seventy-seven open-hearth furnaces, and two hundred and ninety-two crucible furnaces. The total production was 112,876 tons, classified as follows:—

	Tons.
Blister steel	1,646
Puddled steel	3,899
Bessemer steel	69,350
Open-hearth steel	47,327
Crucible steel	3,534

H. B.

The Use of Aluminium in the Construction of Instruments of Precision. By W. P. Blake.

(Advance proof. Transactions of the American Institute of Mining Engineers, Feb. 1890.)

The Author advocates the use of aluminium in the construction of portable instruments of precision. He points out the great advantage which aluminium has over brass in its resistance to corrosion by air or moisture. It does not require a coating of lacquer as all brass instruments do, and its lightness is highly advantageous in mine-surveying instruments. Probably, however, it could be improved for general instrument work by the addition of a small proportion of silver, as commercial aluminium is rather soft for wearing parts. An alloy consisting of 95 per cent. of aluminium and 5 per cent. of silver is much harder and more rigid, and works better under tools. It is but little heavier than aluminium, its specific gravity being 3·2, and that of aluminium being 2·6. It is whiter than aluminium and withstands corrosion nearly as well; the evidence presented by the surveying instruments exhibited at the meeting at which the Author's Paper was read, is sufficient to show that aluminium and its alloys have great merit as materials for the construction of instruments of this kind.

B. H. B.

Some Tests on the Efficiency of Alternating-Current Apparatus. By Messrs. Duncan and Hasson.

(The Electrical Engineer, New York, 1890, p. 158, 2 Figs.)

This was a Paper read before the American Institute of Electrical Engineers. The Authors remark, that several Papers have already appeared on the efficiency of transformers, but they know of none on alternating-current dynamos, except the account of those made by Dr. Hopkinson and Professor Adams, on a De Meritens machine used for lighthouse work, and the converter tests have given very various results. The apparatus, of which the efficiency forms the subject of this Paper, consisted of a Westinghouse 750-light No. 1 dynamo, with a No. 2 exciter, and an outfit of 40 light converters, the whole presented to the Johns Hopkins University, by the Westinghouse Electric Company. The plant consisted of a 75-HP. Armington and Sims engine, driving a dynamo and exciter through a Latham transmission dynamometer. The engine, dynamometer, and dynamos were secured to heavy parallel timbers, and the converters banked on a wooden framework, at a distance of 30 yards from the dynamo, their primaries being permanently secured to the dynamo circuit, and a switch and ammeter placed in this circuit. The secondaries were taken to a switchboard, and then to glow-lamps mounted on racks. The energy in the secondary circuit was measured by means of a Cardew voltmeter and a Thomson ampere balance; as it is not customary to put converters in parallel, each had its separate lamp-circuit. Before making an efficiency test, the potential difference in the primary was regulated, there being a Cardew voltmeter in that circuit, and a separate measurement of the potential difference and current in each secondary circuit was made. When the test was in progress, the voltmeter and ampere balance were used in one circuit, and the currents and potential differences in the others were calculated from the readings in this circuit, together with the previous measurements. Both the voltmeter and ampere balance were accurately calibrated, the former being checked after each test, and the latter had its constant determined with continuous and alternating currents, both of which gave the same result.

A Table is then given of the HP. absorbed by the apparatus at varying electromotive forces, and a Table of the efficiency at varying loads, from which it appears that the electromotive force of the exciter is approximately 100 volts, and of the dynamo 1,110 volts, changed to 50 volts in the converters. In these cases the efficiency with half-load was 65·4 per cent., and with full load, 78·3 per cent.; the efficiency of a 40-light converter separately was 94·8 per cent., and of a 20-light converter with full load, 90 per cent., and with half load 83·3 per cent. The efficiency of the converters was measured by placing them in a metal calorimeter, between the double walls of which water was allowed to flow. The temperatures of exit and entrance were observed, as well as the weight of water which passed through; at the same time the current and potential difference in the secondary circuit of the converter were measured. Two points should be noted in the Tables: the very large amount of power absorbed in the core of the armature, and the very small loss in the converters on open circuit; the dynamo losses, due to reversals of magnetism and eddy currents at the electromotive force used in the test, amount to 6 HP., while the energy due to the same cause in the sixteen converters is only 1·6 HP. Another striking feature is the almost constant ratio of primary and secondary currents over a considerable range. The maximum efficiency is about 78 per cent. It would seem that the losses could be divided into a constant part, and one varying with the current.

A Table is given of the number and sizes of converters supplied by a local Company for two 2,500-light dynamos, and a diagram of load. From this the Authors estimate that the test-plant would supply 23–40 lighters, and there would be a loss of 10 HP. in the dynamos, and about 3 HP. in the converters, or altogether about 13 HP. From the Table there would be 750 lamps supplied; and, taking the data from the load-curve, the average load would be about 1,300 (*sic*). This corresponds to about 20 HP., and the efficiency of the plant for twenty-four hours would be $\frac{20}{33}$ = 61 per cent., less, say, 2 per cent. for loss in lines, so that the final efficiency would be 59 per cent. A continuous-current dynamo supplying the same outfit of lamps, with a maximum loss in the mains of, say, 15 per cent., would have a greater average efficiency. To show the disadvantage of the alternate current for domestic supply, the Author says it would be necessary to have a converter of at least 20-light capacity in each house; the constant loss would be 100 volts, so that in twenty-four hours there would be a loss of about 3 E.HP., corresponding to, say, 45 lamp-hours. The actual number of lamp-hours used is about 30 in twenty-four hours, so that the efficiency of the converter would be about 30 per cent. The efficiency of large converters will be greater than the smaller ones of the same design, and working at the same temperature, but the output per lb. of metal would be less.

E. R. D.

The Hagen Secondary Battery. By Dr. E. Lieg.

(Elektrotechnische Zeitschrift, p. 298, 1890, 3 Figs.)

Secondary-battery makers have two chief ends in view; firstly, to obtain the most permanent method of fixing the active material to the plates; and, secondly, to diminish the dead weight. A plate which fulfils the former requirement would last a very long time; for all the minor difficulties which previous types of secondary batteries have shown, such as buckling of plates, can be put right by mechanical means. Every loss of active material from the frame means a loss of capacity; if this loss can be made good by renewal, the same capacity is obtained for some time; indeed, in special types it is said that the capacity is greater during the first period of use, yet this is attained at the cost of permanence of the frame, and therefore of the whole cell; or, on the other hand, the plates have not been fully formed, and are completely formed only at the purchaser's expence; such increased capacity is never to be regarded as a structural improvement. The second aim referred to above, namely, the lessening of dead weight in the plates, is of special importance in portable batteries, but should not be attained at the expense of the first. The Author considers that the Hagen type shows considerable improvement over earlier forms of secondary batteries. The frame for holding the active material may be made of any of the alloys now used for such a purpose, and consists of two halves formed of ribs, crossing each other at right angles, thus leaving square openings. Each rib is in form a triangular prism, with the base outwards; contrary to the usual custom, the halves are not cast solid along the inner angle of the ribs, but are some little distance apart, and merely held together at the crossing points of the ribs by short crossbars; the whole frame is cast in one piece. In this manner a light but strong frame is obtained, which is not only able to hold a larger quantity of active material, but holds the same permanently, for it is prevented from falling by the ribs of triangular section. The proportion of the weight of the frame to that of the active material is, in plates for stationary work, as 1 : 1, but for special purposes it can be reduced to the proportion 40 : 60. The plates for stationary work develop, in an eight-hour discharge, about 4·5 ampere hours per lb. weight of the filled plates, and about 18·1 ampere hours per lb. of active material. The electromotive force of discharge is, for the first half of the discharge, constant at from 1·98 to 2 volts per cell, and then falls gradually to 1·88 volt; after that it falls so quickly that the discharge should previously be stopped. A stationary battery of 160 ampere-hours capacity, and several smaller portable sets, have been in use for three years; the latter were used for lighting baggage-cars without springs. In spite of the fact that the former battery was frequently uncharged for a long time, and was at times half dry, and in other cases had to supply current up to 100 amperes for soldering experiments, the plates show no change, neither loss of active material nor buckling. These results led Mr. Hagen to add to his lead rolling-mills the manufacture of secondary batteries of this type at Kalk, near Cologne.

E. R. D.

On the Storage of the Alternating Current. By Dr. Föppl.

(Elektrotechnische Zeitschrift, 1890, p. 305. 8 Figures.)

The Author begins with the statement that in recent years the assertion has often been made that it was impossible to store up the alternating current; this doubtless is true in the present state of the science, but is quite inapplicable with reference to future possibilities. It is evident that the energy of an alternating current can be changed into mechanical work by means of a motor, and this mechanical work can in countless ways be changed and stored up. Practically, storage in accumulators is the only method in use to-day which comes into the question. It would then be necessary to build a machine consisting of an alternate-current motor with a continuous-current dynamo, and similar to the well-known continuous-current transformer. If an alternating current were supplied to the motor, the direct current produced by the dynamo could be stored up in an accumulator, and when the alternating current ceased to flow into the motor, then direct current would flow from the accumulator to the dynamo, and cause this to act as a motor, and an alternating current would flow in the outside circuit. The chemical energy of the accumulator which originated in the alternating current, is thus changed back to alternating current again, and this process can doubtless be called a storage of the alternating current. The several transformations necessary, however, cause considerable loss; it would then be a step in advance if the alternating current could be stored direct in a battery. The Author has worked out a process with this end in view. The curve of potential difference at the terminals of the alternator is a sine-curve, and for each part of the outer circuit in which there is no opposing electromotive force, as for instance, from induction, this curve may, by a suitable choice of scale, be treated as the current curve. To enable such an alternating current to be used for charging an accumulator, it is first necessary to divide the curve into positive and negative halves, by a cut-out every time the curve crosses the neutral line. For this Patten had an arrangement and Gaulard a similar one previously, both of which consisted of a commutator which resolved the current into two parts, so that one was a pulsating positive current, and the other a pulsating negative current, both being constant in direction. Such a pulsating direct current cannot however be used to charge an accumulator in the ordinary way, for though the current would flow into the battery at its maxima, the battery would discharge into the mains during the minima of the current, so that no constant charge could be given to the accumulator. The Author was not aware of Patten's experiments when he began to give his attention to the problem. He has found that in order to charge an accumulator in this way the terminals on the accumulator must be so arranged that the opposing electromotive force of the battery shall vary in the same way as the potential difference during each alternation on the alternate-current main. If, then, the number of cells in the battery, or, to put it otherwise, the electromotive force of the battery be represented by a line, and its extremities be considered as the terminals to which the leads are fastened, then if it be assumed that these points move simultaneously towards the opposite end of the line, the potential difference will at first be, say a positive maximum, gradually decrease to zero, and then increase to a negative maximum, and so on.

In this way, by making the time of swing of the accumulator terminals to correspond with the curve of the electromotive force on the charging-leads, the accumulator can be charged. So that the alternating current may be changed into chemical energy direct, and conversely when the charging-current ceases. An alternating current, with the same number of alternations per second, would flow from the accumulator into the leads. There is only one marked difference between this process and the ordinary mode of charging with a direct current; in the latter case the whole length of battery is flowed through by a current of constant quantity, while in the former the current only flows through that part of the battery lying between the terminals at that instant; so that obviously, the centre part is being charged uninterruptedly, but by a current of varying quantity; the cells in the middle of the battery must therefore be of greater capacity than those at the ends, and this may be attained by using larger cells or coupling several in parallel.

The Author proposes the term "alternating-battery" for such an arrangement. Having given the above theoretical description of the process, he proceeds to explain the method of carrying it out in practice. The simplest method would be to arrange a row of contacts upon a frame of insulating material, and to cause two movable contact-pieces to slide over the surface of the fixed contact-strips; each single contact-strip would be coupled up to a suitable point on the battery. An improvement upon this would be to place the row of contact-strips upon the surface of a cylinder, and to replace the movable contact-pieces by ordinary collector brushes. In order to obtain the necessary connections by a simple rotary movement of the brushes, the row of contacts merely requires doubling, each row occupying half the circumference, and both being arranged in opposite directions, the end contacts of like polarity are then common to both rows. With this arrangement the rotating brushes turn once for each complete alternation of the current; this movement can be obtained by toothed gearing from the armature shaft, or from a small motor synchronised with the main machine. The brushes can, of course, remain fixed while the commutator rotates, as it is merely the relative movement which is required.

The coupling up of the commutator strips with the corresponding points of the battery can be accomplished by the use of ring-shaped rubbing-pieces. In order to diminish the speed of the commutator the battery can be coupled up 4 or 6, or $2n$ times to its circumference. Such a commutator could be arranged upon the armature of the alternator itself, as is done with the large direct current machines with internal poles recently built. The Author then points out the main objections which can be raised against the system. In connection with sparking at the commutator, he shows the similarity between the commutator here used, and that employed in an ordinary direct-current machine. The brush at one instant in the direct-current machine is touching two commutator bars, and therefore short circuits an armature coil, while, in the case under consideration, a portion of the battery is short circuited. This difficulty can be removed, or much lessened by inserting a non-inductive resistance in circuit. The second difficulty is that, with a changing load, the electromotive force curve changes, and as the commutator is arranged for only one curve some slight difficulties occur; the self-induction of the armature of the alternator lessens these, if the sole duty of the machine is to charge the batteries, if not some of the cells become more fully charged than others, until equilibrium is attained. The Author believes this method will be of great use in alternate current working. The commutator can be arranged on the armature of the alternator, and there a change of load will make no difference; also the alternate current battery can be used to excite the field magnets. The number of poles used in the alternator may be lessened; for, by a suitable arrangement of commutator, the current from the battery will give a higher number of alternations per minute, and really act as a transformer as well as a reservoir of power.

E. R. D.

Transmission of Electric Energy at Domène (Isère.) By —. FORIS.

(Le Génie Civil, vol. xvii., 1890, p. 209.)

The paper-mill of Moutier, in the department of Isère, has been the object of an interesting application of electrical machinery, which has now been in operation since September 1889. The power is derived from the Domènon, a stream flowing into the Isère. The available fall is 230 feet, the water being led to the turbine-house in a conduit of steel plate 760 yards long. The available energy amounts to a maximum of 300 HP. The dynamos generating the current revolve at 240 turns per minute, and those which are actuated by it in the mill at 300, giving out a maximum of 200 HP.

The length of the line is 3 miles, and its resistance (including dynamos) 6·8 ohms. The past winter was so severe that all wheeled traffic was impossible for four months; but in spite of the constant ice and snow which covered the wires and insulators, the current was never interrupted for a moment, nor have the thunderstorms of the early summer caused any injury or interruption. There is a telephone-wire carried on the same posts as the conductor, which enables the necessary communications to be kept up. The machines work night and day, and require only four attendants, two at the generating station, and two at the receiving station.

C. F. F.

The Electric Current as a Traction Increaser. By ELIAS E. RIES.

(The Electrical Engineer, New York, vol. ix. 1890, p. 432.)

As the Author was probably the first to call attention to the direct action of the electric current in increasing tractive adhesion, and there have been recently numerous communications contradicting the existence of such action, he deems it incumbent on him to clearly restate the requirements for obtaining the increase in adhesion arising from the passage of a current between the wheel and the rail on which it runs. His experiments have shown that friction between two conducting surfaces is very much increased by the passage of a current of low electromotive force and large volume, and is, indeed, a function of the number of amperes flowing through the circuit, as well as of the nature of the metals in contact, and is certainly caused by the local and instantaneous heating at the points of contact, this heating being, indeed, when the current is of sufficient density, capable of producing incipient welding of the two surfaces. The conditions to be secured are therefore briefly as follows:—(1) The current must be of sufficient volume to produce appreciable heating at the point of contact; (2) the electromotive force must be as low as possible, a high electromotive force having a tendency to diminish the friction; (3) the metals in contact should be iron or steel; (4) there should preferably be rolling contact between the surfaces. The Author thence proceeds to show how very far all those who hold views opposed to his have departed in their experiments from these four conditions.

The Paper closes with an account of further experiments made on a small model car, as well as on actual locomotives running on the Philadelphia and Reading Railroad. In the former case, with the rails so greased that without the current the car would not mount a 6 per cent. grade, the application of the current at once sufficed to secure the ascent, without the slightest slip, of a 25 per cent. grade, and, with additional current, even of a 50 per cent. grade. On the locomotive, the circuit from a special dynamo was connected to the forward and rear pair of drivers, the axle-boxes being insulated for the purpose, so that the current could pass along either rail from one pair to the other, and thus not be interrupted by the joints between the rails, which, as usual, were not directly opposite. When the current was applied, the locomotive was able to start and raise to full speed a train of twelve loaded cars, with their brakes down, without a single slip, though the engineer had been instructed to do his utmost to make the wheels slip. The load moved by the engine was estimated to be equivalent to a train of one hundred and ten cars; the effect on a long incline of 185 feet per mile was also very marked, the consumption of coal being reduced to half, owing to the absence of the rapid exhaust consequent on the slipping of the drivers.

Examining the conditions that maintain in the usual practice of electric railways, it is shown that there is probably a slight increase in the friction resulting from the small volume of current and high potential employed, but that the full benefit of this effect would be obtained only by a current of large volume obtained from a special source on the car, or other such similar means, so that this can be varied quite independently of the motive power, to suit the circumstances at the moment.

F. J.

Electric Lighting of the "Eastern" Railway Station in Paris.

By Max de Nansouty.

(Le Génie Civil, vol. xvii., 1890, p. 145.)

Since 1882, the Eastern Railway Company of France has had under consideration the question of lighting their terminal station in Paris, in connection with a contemplated enlargement of the station. Electric lighting was only decided on after prolonged enquiry and careful trials, and the installation described in the present Paper has been in use since November 1889.

The entire service comprises one hundred and five arc-lamps of 35 carcels each; twenty-five of 20 carcels; two hundred and twenty glow-lamps of 16-candle power, and one thousand two hundred and eighty of 10-candle power. The three-wire system of distribution is used, the main conductors being fed from eleven principal centres, from which each department of the service can be independently controlled, and at which arrangements are made by which a constant tension in each circuit is maintained. The system is so arranged that in each circuit the electromotive force cannot vary by more than two volts, while the number of lamps in circuit varies from one to its maximum. The 35-carcel lamps require (allowing for the absorption of the opal globes) 7 amperes of current; the 20-carcel lamps, 5 amperes. The glow-lamps, of 16 and 10 candles, absorb respectively 1 ampere and $\frac{3}{4}$ ampere. The electromotive force on each of the two branches of the 3-wire circuit is 75 volts. The energy required is 153,000 watts. The installation comprises three dynamos of 100,000 watts, driven by three Weyher and Richemond engines of 140 HP. each. Two engines and dynamos are sufficient for the service, one being in reserve. The arrangements are such that the spare dynamo can be introduced into the circuit, and one of the others withdrawn, without affecting the lights or interrupting the current. There are four boilers of the Belleville type, one being always out of use. Steam is produced at 170 lbs. pressure, and expanded to 114 lbs. The engines make 150 revolutions per minute, and each drives by a belt one dynamo at 300 revolutions. Each dynamo is capable at this speed of giving out a current of 1,200 amperes at a tension of 85 volts. The magnetic field is produced by two vertical electro-magnets, shunt-wound. Each electro-magnet has ten coils, of 190 turns each, of wire 3·4 millimetres in diameter, giving a resistance of 6 ohms.

The armature is a Gramme ring, formed of 442 insulated disks of sheet-iron of 1 millimetre thickness, mounted on a bronze pulley keyed to the shaft. On the ring thus formed are wound wires of 0·366 millimetre in seventy sections. Each section is formed of twenty-four wires, giving a total cross-section of 252·48 millimetres for each half-ring, and a density of current of 2·35 amperes, when the total current is 1,200.

The entire resistance of the armature is 0·0018 ohm. There are ten brushes, carried by an adjustable support.

The Paper is accompanied by numerous illustrations and diagrams.

C. F. F.

Electric Lighting of the State Hospital at Urban.

(Electrotechnische Zeitschrift, 1890, p. 375. 4 Figures.)

The State Hospital at Urban is lighted entirely by electricity by the firm of Naglo Brothers, and has no gas fittings at all. It is said that this is the first attempt to provide so large an institution with electricity alone, but by the method used any chance of the light failing seems out of the question. Firstly, the machinery and mains are divided into two separate parts in order to increase the safety of working, and besides this a secondary battery of considerable size is also installed. A failure of a single engine or dynamo would therefore have no effect upon the lighting. The complete failure of one of the two systems of distribution could only cause the extinction of part of the lamps in each room. The engines are in the basement of the administration building, and the steam is brought from the neighbouring boiler-house, in which are placed six boilers for this purpose and for heating the buildings. The isolated buildings of which the hospital consists are connected by roomy underground passages which serve for the reception of the steam heating-pipes, and for the water-mains, and electric-light leads, and are also used for the transport of patients and corpses. The whole plant consists of two Swiderski compound steam-engines, each of 75 HP., and making 130 revolutions per minute. Each engine drives a dynamo by belting direct. Both dynamos are ring-armature machines developing 400 amperes at 100 volts, or 300 amperes at 150 volts, and are easily accessible on separate foundations, which are isolated with cork to prevent the sound travelling. The battery-room adjoins the engine-room, and the separating wall is used for the switch boards and instruments. The accumulators are on the Tudor system by Müller and Einbeck of Hagen. There are 124 cells coupled two in parallel, so that the whole battery can supply a current of 350 amperes, and has a capacity of 2,200 ampere-hours; the cells rest on low wooden frames. The copper leads from the cells are supported on porcelain insulators on iron bearers, and pass through the wall adjoining the switch-board, and are insulated from it by hard india-rubber tube, which in turn are run in with asphalt so as to be acid-proof and air-tight. A description of the switch-board and instruments follows, of which it may be noted that the ammeters on the battery circuit are provided with current-direction indicators, so as to show whether the battery is being charged or discharged. An automatic switch is used which works within a range of 3 volts, so that with an increase or decrease of 1·5 volt a cell is switched in or out. A small independent switch-board is used for the arc-lamps. A relay is used which, at a potential difference of over 112 volts, or under 106 volts, sets an alarm-bell ringing. The battery switch is arranged so that the electromotive force of each single cell can be read. The mains are almost entirely of bare copper bars, carried on porcelain insulators, so arranged that a row of them one above the other is carried by iron bearers which are fixed to the T bearers which carry the roof of the passage. Where the two mains enter the isolated buildings the joints are brought together in a cast-iron box provided with lead fuses mounted on slate. In the wards the lamps can be burned at full or half power, or turned out. The operating theatre in the middle of the court, besides being fitted with arc-lamps, is also provided with apparatus for electro-cautery, which uses an electromotive force of 3 volts, and can be fed from the leads; for this purpose a resistance coil is arranged in the operating theatre. The electromotive force can be regulated by hand so as to avoid damage to the instruments, and also small lamps can be fed from this circuit to light up hollow parts of the body. The vibration of the plant is not felt in the rest of the building owing to the cork insulation.

E. R. D.

The Automatic Registration of Vibration-Curves by Means of Photography.

(Elektrotechnishe Zeitchrift, 1890, p. 356, 1 Fig.)

More and more use is continually being made of self-recording apparatus in technical experiments, and it is especially useful where the movements are small, or in cases where the vibrations take place too rapidly to be observed with the naked eye. The apparatus in common use consists of a pencil carried by a light arm and arranged to press upon a rotating cylinder covered with lamp-black. In cases where the changes take place at regular intervals, making it absolutely essential that the cylinder should rotate at a constant speed, an electric chronograph, regulated by a tuning-fork, is used; this method has given good results, but in cases where light arms and a pencil have to be moved by very small forces it is not reliable. In such cases it is advisable to use optical methods by the employment of a mirror-galvanometer and lamp, and photography for fixing the curve. In this way the curves for changing electric currents were discovered at the University of Liége. The apparatus consisted of an aperiodic galvanometer with a movable coil of great inertia of the Duprez-d'Arsonval type. The ray of light from an electric lamp was thrown upon the registering cylinder by means of a small concave mirror fixed to the movable part of the galvanometer, and by the aid of a lens; the cylinder had been previously covered with a sheet of paper sensitized with a gelatine preparation of silver-bromide. Simultaneously equal periods of time were marked off on the cylinder by means of a second ray of light thrown on to it from a concave mirror fixed upon a tuning-fork worked by electricity. This method was extremely successful, the photographic record being obtained from a spark produced by a Ruhmkorff coil of ordinary size. The spark was made to pass between the end of a magnesium wire and the point of a lamp-carbon, the length of arc being less than 1 millimetre. The sensitized paper may be fixed either upon a cylinder, as described above, or upon a special frame. The regular occurrence of the spark was obtained by the electricity of the spring used in the automatic circuit-bearer, and the distance between the images of two sparks represented corresponding intervals of time. The breaks of the circuit were produced by an electric tuning-fork of known number of vibrations. In the battery-circuit were placed the primary coil and the tuning-fork coil.

As the ends of the secondary coil were fixed to the terminals of a Leyden jar, a white spark was obtained in a fixed position, and in order still further to shorten the image of the spark, a double concave lens was placed in the path of the ray of light. A diagram is given which was obtained in the manner described, and the curve represents the changes of the magnetic field in the air-space of an electro-motor. A straight insulated wire was fixed to the armature parallel to the axis, and ended in rings which were fixed in the armature-shaft, but insulated from it, brushes pressed upon these rings, and were connected to a galvanometer of the type referred to. The ordinates of the curve are proportional to the induced current, and represent the intensity of the field cut by the rotating wire. The time intervals between the ordinates represent hundredths of a second.

E. R. D.

On an Optical Pyrometer.[1] By — Mesuré.

(Comptes-rendus Mensuels de la Société de l'Industrie Minerale, 1890, p. 129.)

This instrument, known as the *lunette pyrometrique*, is used at the S. Jacques steel-works, Montluçon, for determining the temperature of ingots or other masses of metal in the heating furnaces. It is essentially a polariscope arranged for parallel light, having a quartz plate cut perpendicularly to the principal crystallographic axis interposed between polarizer and analyzer in order to produce circular polarization. In such a combination the rotation of the plane of polarization varies directly as the thickness of the quartz plate, and nearly inversely as the square of the wave-length of the light, or the rotation is greater for the more refrangible rays at the blue end of the spectrum than for those of the red end. As, however, the proportion of the former rays becomes larger with increased heat, it is evident that the angular deviation of the plane of polarization may be used as a means for comparing the tem-

[1] A description of this pyrometer has already been given in vol. c. p. 506. The present article, by the inventor of the instrument, gives fuller and more correct information.

perature of luminous bodies. In practice, however, it has been found necessary to use a greater thickness of quartz than in ordinary polariscopes, as a plate of one millimetre produces only a deviation of two or three degrees between bright red and strong white heat. The most convenient thickness is found to be 11 millimetres, in spite of a certain overlapping of the extreme colours, owing to their being turned through more than a semicircle.

The rotation is measured by a divided circle attached to the analyser, the zero point corresponding to the position of total extinction when the quartz plate is removed.

At the highest temperatures the sensitive or passage tint is nearly the same as that of solar light, *i.e.*, a neutral violet, which changes to red or blue by a very small rotation of the analyzer in one or other direction; but at lower temperatures, where the blue light is feeble or entirely absent, it is a greyish yellow changing to red or green, while at the lowest luminous heat, when the light is sensibly monochromatic, the operation is made upon the extinction of the red rays. For these lower temperatures, the light being feeble, a condensing lens is used in front of the polarizer, but no useful observation can be made at a dull red heat.

The following is the scale of rotation corresponding to different temperatures:—

Heat.	Degrees C.	Angular Duration °
Incipient cherry red	(800)	33
Cherry "	(900)	40
Bright cherry red	(1,000)	46
Orange yellow	(1,100)	52
Yellow	(1,200)	57
Bright yellow	(1,300)	62
Welding white	(1,400)	66
Brilliant white	(1,500)	69
Solar light		84

The value of the instrument is, however, less for absolute measurements than for comparing the temperatures of different bodies, or as a means of judging of the exact heat necessary for a particular operation where it has since been determined by a previous experiment.

The instrument only indicates correctly when it is acted upon by the light due to the incandescence of the body under examination, and care must therefore be taken to observe only such portions of the latter as are screened from the illuminating effect of flame or very highly heated surfaces, otherwise the results will be affected by the reflection of some of this extra light, and will be too high. In cases where the substance is of low conductivity the luminosity diminishes very rapidly in cooling, and therefore observations made on substances when drawn from the furnace must be quickly taken.

H. B.

Report of the United States Policy Board.

(Proceedings of the United States Naval Institute, vol. xvi. 1890, p. 1.)

A Board consisting of six naval officers and one naval constructor, under the presidency of Commodore W. P. McCann, was constituted by order of the Secretary of the Navy on the 16th July, 1889, and received instructions to report as to the policy which should be pursued by the Naval Department in the construction of a fleet to meet the future wants of the United States. The following questions were submitted for their consideration:—

(1) How many years should be allowed for the building of the fleet?

(2) What should be the number of vessels of which the fleet should be composed when completed, both for cruising and for coast-defence purposes?

(3) What classes of vessels should be built, both for cruising and coast-defence purposes?

(4) What should be the size and general features of each class of vessels?

(5) What proportion of the entire fleet projected should be constructed annually?

(6) What additional percentage should be constructed annually?

(7) What number and classes of vessels should be asked for at the coming session of Congress?

(8) What will be the annual cost of construction and the aggregate cost of the fleet as recommended?

The report was presented on the 20th January, 1890. The Board first computed the probable number of ships of war of foreign powers which, allowing for probable alliances, might operate against the United States. These vessels they divide into two classes:—

(1) Vessels which have a sufficient coal-supply to enable them to operate without recourse to a naval base near the American coast. It is assumed that a vessel cannot be employed in service at a greater distance from a base than one-third of her coal endurance.

(2) Vessels which could only be able to operate so far from their home base, on the condition that coaling stations were available.

They consider that, in the event of war, the United States should make an immediate and supreme effort to capture and destroy all such coaling stations, as by so doing she would enormously reduce the possible number of vessels which could be brought against her. The Naval Programme is framed with this object in view, and it is proposed to provide especially for the construction of a number of heavy ships suitable for the attack of fortified places within 1,000 miles of the nearest naval depot.

It is recommended that the following ships should be added to the navy:—

Battle-ships of great coal-endurance	10
" limited " "	25
Cruisers of 4,000 tons and over	24
Torpedo cruisers of about 900 tons	15
Special cruisers for China service of about 1,200 tons	5
Rams	10
Torpedo depot and artificer's ships	3
	92

Besides one hundred first-class torpedo-boats, of about 65 tons displacement, and numerous second-class torpedo-boats.

The battle-ships of great endurance would constitute the basis of a fleet which might be detached in whole or in part for distant service, and for the purpose of cruising against the enemy and for attacking points on the other side of the Atlantic.

The battle-ships of limited endurance would serve the purpose of keeping their ports open and destroying an enemy's coaling stations. Three subdivisions of this latter class are recommended, all having the same general characteristics of speed and manœuvring power, so that they might work in combination.

The 22-knot protected cruisers are calculated to capture or destroy the fastest merchant vessels in the world.

The 20-knot cruisers are to serve the same general purpose, and have the same armament, but are to receive a greater amount of protection on a less displacement.'

The question of protection for the guns and crews of all these cruisers has received special attention. The development of rapid-fire guns, and the large number now carried, renders it absolutely necessary that the guns' crews should be protected, or they could not remain at their guns. It is believed that within certain limits the weight assigned to such protection is far more useful than the same weight in additional guns.

The tonnage of the ninety-two vessels proposed would amount to 491,550 tons displacement, and the approximate cost is estimated at £68,762,500 sterling.

The following summary gives the distribution of the elements of the fleet, including all vessels built, building, appropriated for, and recommended by the Board:—

Battle-ships of great endurance.—Thirteen vessels of an aggregate tonnage of 120,450, and total cost of £16,850,000.

Battle-ships of limited endurance.—Twenty-five vessels of an aggregate tonnage of 179,200, and total cost of £27,522,500.

Harbour defence and rams.—Seventeen vessels of an aggregate tonnage of 62,320, and total cost of £11,125,000.

Cruisers of all classes, including gun-vessels and dispatch-boats. —Sixty-eight vessels, aggregate tonnage, 225,500; total cost, £28,615,000.

Torpedo, depot, and artificer ships.—Three vessels; aggregate tonnage, 15,000; cost, £1,625,000.

Sea-going torpedo-boats.—One hundred and one boats; tonnage, 6,565; cost, £1,641,250.

Reliance is placed on the development of an auxiliary navy of fast well-built merchant steamers. After an examination of the shipbuilding resources of the country, the Board concludes that the whole of the ships could be completed in fourteen years. A prominent feature in most of the designs is the use of woodite, a light water-excluding material, composed essentially of cork and rubber. It is largely relied upon, in connection with coal and patent fuel, to maintain the stability in vessels not heavily armoured, and whose sides may be perforated by gun-fire. In the vessels designed to take a large amount of gun punishment, the guns of 5 inches and upwards, not protected by heavy armour, are given completely localized protection, being mounted in low barbettes of 2½ to 3½ inches thickness, with equivalent complete shields, entered by doors in rear, carried by and turning with the piece. In such vessels without a casemate, the barbettes are continued to the armour deck by thick cone and tube bases. The tubes open into passages below the armoured deck, and the ammunition is to be passed up through the tubes and cones. The largest guns to be carried are of 13 inches calibre, weighing about 60 tons. These will all be mounted in the middle line, in turrets above redoubts, with a single-loading position.

The machinery will consist of triple-expansion engines and cylindrical boilers, working under forced draught. The heating surface per I.HP. will vary from 1·8 to 1·95 square foot. In the vessels of great coal-endurance, two sets of engines will drive each screw.

The report concludes with a detailed description, with illustrations, of each design.

S. W. B.

Machinery of the United States Torpedo Boat "Cushing."

(Journal of the American Society of Naval Engineers, vol. ii., 1890, p. 215.)

This vessel, designed and built by the Herreshoff Company for the United States Navy, is of the following dimensions:—Length, 137·5 feet; beam, 15·05 feet; draught, 5·2 feet; displacement, 105 tons. Two sets of vertical quadruple expansion engines drive twin screws. The low-pressure cylinder area is divided into two, thus making five cylinders upon each shaft. The diameters are 11¼, 16, 22½, 22½, 22½ inches respectively, and the stroke is 15 inches. Each cylinder has a separate valve-chest, and a double piston-valve. The columns are steel rods, 1½ inch in diameter, braced diagonally, and they form the cap-bolts of the main bearings, which in turn are secured to a bed-plate consisting of a single sheet of wrought steel, $\frac{3}{4}$ inch thick, with openings cut through it for the passage of the cranks.

There is one surface-condenser, of 1,052 square feet of cooling surface, through which water is circulated by the speed of the vessel when in motion, and by a centrifugal pump when at rest. The pumps are worked by independent engines. There are three single-acting, vertical, single-trunk, bucket air-pumps for each engine, 10 inches in diameter, and of 5 inches stroke; they have no foot-valves, the bucket and delivery-valves being flat annular rings of composition, $\frac{1}{4}$ inch thick. Three single-acting plunger feed-pumps, driven by the same engines, are $2\frac{7}{8}$ inches in diameter, and have a stroke of 5 inches. The pumping-engines are $3\frac{1}{2}$ inches in diameter, and 5 inches stroke. They are geared down 3·2 to 1, the pumps making 240 strokes per minute at full speed.

There are two Thornycroft water-tube boilers, one forward, and one aft of the engine-room compartment, which were manufactured by Messrs. Herreshoff from drawings furnished by the patentees. The heating-surface of each boiler is 2,375 square feet, and the ratio of grate to heating-surface is 1 to 60.

The weight of the boiler with water is 11 tons. The working-pressure is 250 lbs.; steam can be raised from cold water in about half an hour. A speed of 22·5 knots was maintained during a three-hours' trial, when 1,720 IHP. was developed. At full-speed, with $2\frac{3}{4}$ inches air-pressure, 2 lbs. of coal were burned per I.HP. per hour; and at 0·5 inch air-pressure the consumption was 1·7 lb. per I.HP. per hour.

S. W. B.

Experiments on the Perforation of Armour Plates by Means of Self-Registering Projectiles.

By Captain DE LABOURET, French Marine Artillery.

(Memorial de l'Artillerie de la Marine, vol. xviii. 1890, p. 279.)

The Author begins by remarking that these researches have been undertaken mainly on account of the difficulties hitherto encountered in providing sufficiently for the subdivision of time to subject a phenomenon so rapid as the passage of a projectile through an armour-plate to analysis. The whole time of the passage being only some ten-thousandths of a second.

The Author enters very minutely into the details of the experiments,[1] showing the method of estimating and calculating the

[1] In order to understand the experiments, it is necessary to give a very brief description of the self-registering projectiles by which they were made.

The self-registering projectile of Colonel Sebert is a hollow projectile, in the longitudinal axis of which is a steel bar square in section, but terminating at each end in cylindrical gudgeons resting in the plugs which close the ends various corrections and allowances which it is necessary to make in the recorded results, to bring them into the form required to give a true estimate of the relations between the times, spaces, velocities, and accelerations.

The experiments discussed in this article are three in number, made with projectiles of about 29½ lbs. weight, fired from a (10-centimetre) 3·90-inch gun, against a forged-iron plate of 3·90 inches thick, with a striking velocity of 366 metres, or 1,165 feet per second, on March 2nd and November 28th, 1889, at Sevran-Livry.

The results are shown graphically in Figs. 1, 2, and 3.

Fig. 1 shows the results obtained on March 2nd, and shows the velocity of the projectile and the resistance of the plate, as a function of the penetration.

Fig. 2 shows the same for the projectiles fired on November 28th.

Fig. 3 shows the velocity of projectiles and resistance of the plate, as a function of the time.

The total time registered was about twenty-five hundred-thousandths (0·00025) of a second, and the corresponding penetration about 2·8 inches.

In all these curves are indicated two successive maximum values of the acceleration.

The maximum value of the resistances in Fig. 2 are greater than those in Fig. 1, which is caused by an improved method of treating the observations, by virtue of which it was possible to denote the time to the one hundred-thousandth of a second, whilst the unity of time in the experiment of March 2nd was four times as great. By this more perfect division of the time, the representation of the phenomena became more complete, and thus the curve of November 28th is more exact than that of March 2nd.

The Author then remarks that the experiments of November 28th show that a plate of 4 inches thick appears to have opposed to a ogival-headed projectile of the same diameter, viz. 4 inches, fired with a striking velocity of 1,167 feet per 1 inch, a resistance increasing until the point of the projectile reached a depth of 0·58 inch, at which moment the resistance indicated was 1,900 tons.

of the internal cavity. Thus the steel bar is not affected by the rotations of the projectile. On this steel bar, one side of which is covered with lamp-black, is a movable mass which moves freely along the bar which serves as a guide. This mass carries a small tuning-fork, the two vibrating branches of which carry steel points, which, vibrating with their respective branches as the mass moves along the bar, describe a series of undulations on the lamp-black surface. The intersection of these curves with the centre line of the bar make known the relative positions of the moving mass and the projectile at each interval of time represented by the vibration of the tuning-fork.

From these curves have been obtained the curve of the space passed through by the projectile as a function of the time, and from this again the curves of the velocity and of the acceleration of the projectile end as a function of the time.

The branches of the tuning-fork are set in vibration by means of a small wedge inserted between them while distended, and which is liberated by its own inertia on any sudden change of velocity in the projectile.

Fig. 1.

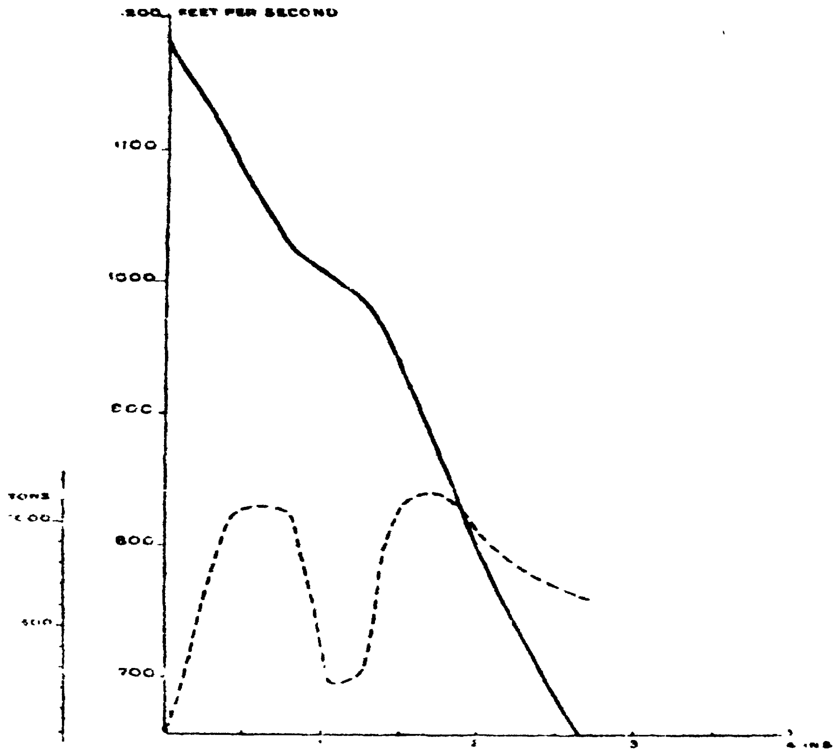
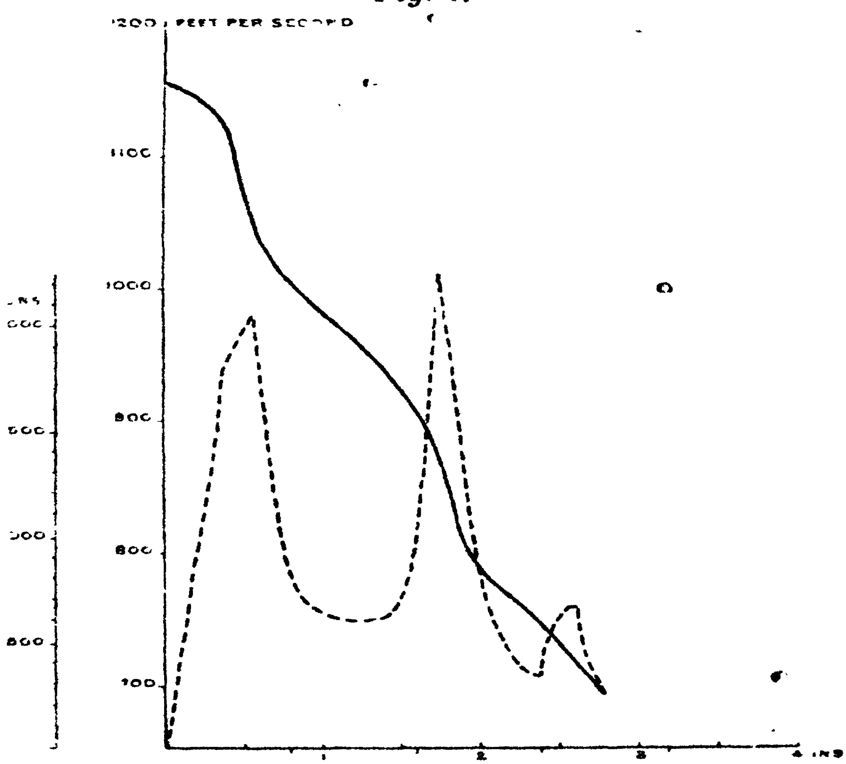

FEET PER SECOND
1100
1000
800
700
TONS
4 INS

Fig. 2.


1200
1100
1000
900
800
4 INS

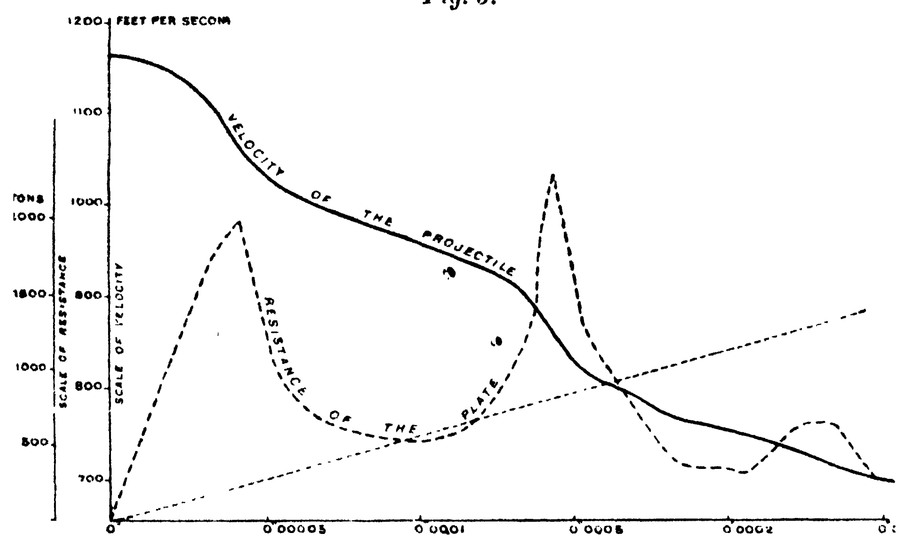
The resistance then decreases to 550 tons for a penetration of 1·2 inch; this again increases, and attains a second maximum of 2,190 tons at a penetration of about 1·90 inch, or when the point of the projectile has reached to about the middle of the plate. From this point the resistance decreases rapidly to a penetration of about 2·4 inches, when there occurs a third maximum of minor importance.

The time of penetration to a depth of 2·80 inches was as follows:—

		Second.
On March 2nd	. . . .	0·00024
On November 28th—first experiment	. . . . .	0·00027
„ second experiment	. . . .	0·00026

and the total time in passing right through the plate was about 0·000397 second.

Fig. 3.



The Author then explains the phenomena revealed by these experiments:—

1. The formation of waves of displacement, forcing the molecules of metal next the surface of the projectile to take a velocity approaching that of the projectile, and in an opposite direction, and thus causing the first maximum of resistance.

2. A yielding of the entire plate in transmitting to its supports the force of the projectile.

3. The formation and tearing away of the disk in the back of the plate coinciding with the time when it became immovable with respect to its supports, and thus giving rise to the second maximum of resistance.

4. After the tearing away the disk it is carried away by the projectile into the sand backing, thus causing an increase of the resistance until the projectile is entirely free from the disk.

The Author concludes by stating that further experiments are necessary to verify the above hypothesis, and is of opinion that the self-registering projectile is an instrument capable of furnishing useful indications with regard to the phenomena, however sudden and violent they may be, which accompany perforation of plates by projectiles.

J. A. L.

Meteorological Observatory at the top of the Eiffel Tower.

By MESSRS. RICHARD BROTHERS.

(Bulletin de l'Association Française pour l'Avancement des Sciences. Paris, 1890, p. 367.)

At precisely 300 metres above the level of the ground a platform is placed, 5 feet 4 inches in diameter, which has been fitted up as an observatory. The lightning conductor passes down through the centre, and the observations are transmitted by electricity to the Palace of Liberal Arts, a distance of 890 yards from the tower. The apparatus in the observatory consists of a maximum and minimum, and an ordinary thermometer; anemometers, raised on three iron tubes to a height of 13 feet, which mark the direction, the force, and the velocity of the wind; two barometers, and a rain guage. Double venetian blinds, strongly built of iron, enclose the platform on all sides but one.

O. C. D. R.

Process for Manufacturing Ammonium Chloride from the By-Products of the Manufacture of Gas and Metallic Chlorides.

By — DUBOSC and — HEUZEY.

(Bulletin de la Société Industrielle de Rouen, 1889, p. 439.)

This process has for its object the conversion of the ammonia present in ammoniacal gas liquor into ammonium chloride (sal ammoniac), by treatment with metallic chlorides. Such gas-liquor contains various compounds of ammonia, such as the sulphide, carbonate, cyanide, as well as free ammonia. On account of the emission of sulphuretted hydrogen, the ammonium salts cannot be treated with free hydrochloric acid. The Authors therefore propose to treat the liquor with a mixture of ferric and calcic chlorides, in suitable proportions. The advantage of using both chlorides in conjunction is that the precipitation is more rapid, and the desulphurization more complete, than when each is used separately.

In carrying out the process, the liquor is first freed from tar by allowing it to settle for forty-eight hours. It is then mixed mechanically with solutions of ferric and calcic chlorides, with which double decomposition takes place. After the lapse of twelve hours, the clear solution of ammonium chloride is drawn off and concentrated by evaporation. The concentration takes place in large iron pans, covered with hoods of silicated wood, coated with plaster. When sufficiently concentrated, the solution is run into wooden vats, where crystallization takes place. If cubical crystals of the chloride are required, about 5 per cent. of a strong solution of ferric chloride is added to the liquid. The crystals are afterwards allowed to drain, and dried by artificial heat. Ammonium sulphate may be transformed into the chloride by means of various metallic chlorides, some of which give, by double decomposition, insoluble sulphates, while others form soluble sulphates.. In the first case the treatment is simple. The ammonium sulphate is dissolved in a minimum quantity of water, and poured into a vat, in which has been previously placed a quantity of the metallic chloride, sufficient for complete decomposition. The insoluble sulphates formed are separated from the solution of ammonium chloride either by means of special filters or by a filter press. The deposit of sulphate is, in the case of sulphate of lime, used as an artificial manure. The liquid is treated as above for the production of crystals. When ferric chloride is used as a decomposing agent, the liquid is concentrated until about 95 per cent. of the ferric sulphate produced has crystallized out. The remainder of the iron is then precipitated by means of ammonium sulphide, and after further purification by barium chloride, concentration and crystallization take place as before.

W. F. R.

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