# Canadian Magazine of Science and the Industrial Arts.

## Patent Office Record.

Vol. 12. NOVEMBER, 1884. No. 11.


*Communications relating to the Editorial Department should be addressed to the Editor,* HENRY T. BOVEY, *Ontario Avenue, Montreal.*

*The Editor does not hold himself responsible for opinions expressed by his correspondents.*

*No notice will be taken of anonymous communications.*

## THE CONNECTION BETWEEN CHINESE MUSIC, WEIGHTS AND MEASURES.

Chinese music can now be heard by all who desire to hear it at the Health Exhibition, and more may be learned on the subject from the pamphlet published by the Commissioners for the Chinese department. A curious account of the common origin of Chinese weights, measures, and musical notes is contained in a paper read some years ago before the German Asiatic Society of Japan by Dr. Wagener. The story is based on native legends, and is also to be found among the Jesuit "Mémoires concernant les Chinois." Dr. Wagener says there is not the slightest doubt that the Chinese system of weights and measures is more than 4,600 years old; and it is a highly remarkable circumstance that, quite irrespective of the fact that it is more scientific and exact, it possesses all the advantages for which the French metrical system is so much praised. In the first place, it starts from a basis supplied by Nature; secondly, tne decimal arrangement is almost consistently employed throughout; thirdly, linear and dry measure proceed directly from the same unit as the measure of weight; and lastly, what the metrical system does not do, it regulates in the simplest manner the relations of musical notes, which latter form the starting point for the whole system of weights and measures. The following account of the origin of this system (says Dr. Wagener,) contains fact and fancy mingled, but it is easy to distinguish between them. In the reign of the Emperor Hoang-ti, who ruled over China in the twenty-seventh century before Christ, the scholar Lyng-lun was commissioned to complete the musical system which had been discovered 250 years earlier, and particularly to lay down fixed rules for making musical instruments. Naturally he had to commence with the bamboo, which had already been long used to give the note for other instruments. He therefore betook himself to the province of Siyung in North-Western China, where, on the northern slope of a range of high mountains, a species of bamboo grew, which, on account of its uniformity and its structure, being neither too hard nor too soft, was exceedingly suitable for a wind instrument. He cut one down and tried it. Tradition says that it gave the same note as his own voice when he was excited by no emotion; and the rippling of the sources of the great Hoang-ho, or Yellow River, which were in the vicinity, followed in the same tone. At the same time the fabulous bird Fung-Hiang, accompanied by his mate, flew to the place. Both perched themselves on a neighbouring branch, and commenced a song, in the course of which each of the birds gave six separate notes. These are the notes which are called the six male and six female tones in the scale discovered by Lyng-lun, and which correspond to the ancient doctrine of the male and female principles in Nature. As a matter of course, the deepest of the male notes was tho one already discovered by the philosopher himself. He now endeavoured to reproduce the other notes with the help of bamboo pipes, and succeeded. His task was now to lay down fixed rules as to the length of the pipes, as that thenceforth they could be easily constructed everywhere. For this reason, and also because such a scale of notes depends upon slight differences of length, and there were scarcely at this time instruments to divide great lengths, he necessarily arrived at the notion of passing from the less to the greater, and of laying down an adequately small natural unit for his measurements. That could be nothing else but a grain of seed; and now the point was to get seeds of the greatest possible uniformity. He chose a sort of millet, the *Sorghum rubrum*, the seed of which is of a dark brown colour, and which is said to possess ths advantages of greater hardness and uniformity than that of the gray and other kinds. The seed is pointed at the onds, and from one point to the other the length is somewhat than id the direction at right angles. Lyng-Lun now fixes the length of the pipe, which gave the key-note at 81 grains of the seed placed lengthwise in a row. But when the grains were placed breadthwise it took 100 grains to give the same length. Thus the double division of 9 + 9 and 10 + 10 was naturally arrived at. According to the dimension in question, it was called a musical or an ordinary foot, the latter being introduced with the decimal subdivision as a measure of length. The breadth of a grain of seed was 1 *fen* (a line), 10 *fen* = 1 *tsun* (an inch), 10 *tsun* = 1 *che* (a foot), 10 *che* = 1 *chang*, 10 *chang* = 1 *ny*. In subsequent times the line was divided into tenths, hundredths, &c. Lyng-lun also laid down rules for the breadth as well as for the length of the pipe, because although the note is essentially dependent on the length, it is nevertheless necessary for its purity that the pipe should be neither too broad nor too narrow. He therefore fixed the circumference on the inside at 9 grains laid lengthwise. With these dimensions, namely, a length of eighty-one grains, and an internal circumference of nine, the pipe which gives the keynote contains just 1,200 grains, and this volume accordingly was made the unit of dry measure, and was called a *yo*; 2 *yo* = 1 *ko*, 1 *ko* = 1 *cheng*, 10 *cheng* = 1 *ten*, 10 *ten* = 1 *hu*. So fay we see how the units of length and dry measure were connected with the musical keynote. The twelve notes of the scale are all derived from the keynote, and are to a certain extent comprehended in it. Hence if the 1200 grains contained in the pipe are divided among the twelve notes it gives to each a hundred, and the weight of these hundred grains was made by Lyng-lun the unit of weight. This was divided and subdivided on the decimal system until a single grain became the lowest weight of all. At a later period even the coinage became connected with this system, for one of the weights, the *leang*, corresponding to our ounce, became the weight of metal put into a coin, so that the modern *tael*, in which mercantile quotations are found every day in the *Times*, is merely an ounce of silver, and is thus directly connected with the musical scale. Finally, says Dr. Wagener, it appears from this account that, in China, weights, measures, coinage, and the tuning of musical instruments have been derived quite consistently from a constant unit supplied by Nature herself, and that the essentials of this system are over 4600 years old.--*Nature.*

## EXPERIMENTS UPON AUTOMATIC SPRINKLERS.*

BY G. J. H. WOODBURY.

(*Continued from page* 299.)

### SENSITIVENESS.

Any method of measuring the sensitiveness of sprinklers is confessedly an artificial one; and, in the endeavour to apply uniform conditions, the sprinklers are subjected to exposures which bear little analogy to those met with in a mill fire.

The writer has made some trials of sprinklers where measured quantities of fuel were ignited in a building equipped with sprinklers; and, notwithstanding that the utmost care was taken to preserve uniform conditions, the results were exceedingly variable and of no value, unless to serve as a basis of comparison between two sprinklers tried simultaneous'y. These test fires possess a commercial value, where it is desirable to show to possible purchasers that automatic sprinklers would extinguish a sharp fire kindled beneath them. Ovens heated with a large gas flame have been used to demonstrate various merits of automatic sprinklers; but the heat applied to the oven is variable, because both the pressure and calorific value of gas is constantly changing. The temperature of such an oven varies in different parts of the oven at the same time. These oven tests are of use to those engaged in the manufacture of sprinklers; but neither a bon-fire in a room, nor the gas-oven half a yard in either dimension, has the elements of precision necessary for this work.

With the purpose of employing a method which would give precise results, the following apparatus was devised for the object of learning the relative sensitiveness of automatic sprinklers under pressure: A box of thirty cubic feet capacity, measuring three by four feet, and two and a half feet deep, was swung top downwards over a large table. A Parmelee sprinkler-head projected through the centre of the table, and was connected with a piece of four-inch pipe about two feet long, which was beneath the table, and capped at both ends. Water was placed in the lower end, and connections were made with a steam supply and a steam gauge. This arrangement served to furnish a supply of saturated steam at any desired pressure, and therefore the quantity of heat and its temperature could be known and controlled. The sprinklers were screwed into a frame-work of fittings which was placed on the table, so that the sprinklers under trial were about two feet above the table. The sprinklers were filled with water at the temperature of the room, and weights applied in such a manner as to be equivalent to a water pressure of fifteen pounds to the square inch upon the sprinklers. Electric apparatus was attached, so that when any sprinkler opened, a bell corresponding to each sprinkler would ring in an adjoining room. On making a trial, the box was lowered upon the table, and the temperature increased very slowly to 112 degrees, and then the valve was opened and steam blown through the Parmelee sprinkler-head into the box. It required two minutes to increase the temperature within the box one hundred degrees, and the circulation of the steam was so rapid that thermometers inserted through orifices in various parts of the box varied less than one degree from each other. Although this was not the heat proceeding directly from a fire, yet it enabled the use of constant conditions; and the results with any one sprinkler, as given in the record, do not vary from each other more that would correspond to varying masses of solder in the joint.

A cubic foot of steam at 212 degrees contains 2 6-10ths times the amount of heat that a cubic foot of air does at the same temperature, but in these experiments the influx of steam heat was a constant, and in the rapidity of its results corresponded to that which might be expected from air at a much higher temperature.

Whenever one sprinkler opens upon a fire, it is probable that in many instances, other sprinklers are opened by the steam generated as a result of the application of the water upon the fire, rather than by the air directly conducting the heat of the fire; and in such instances this method must represent the facts in the case.

Accepting these results as accurately representing the relative sensitiveness of these sprinklers when exposed to steam, the question naturally arises as to the analogy between this action and its cause and the actual mill fires, and the consequent operation of sprinklers. In fact, the steam method probably gives results as different from a mill fire as one mill differs from another.

In a fire on light stock in process of manufacture, such as a card or picker room, the difference between the sprinklers at either end of the list would probably be greater than here stated, while a fire of any kind would reduce the difference to a point that the two kinds might be quite nearly alike in the time of the action.

If the temperature produced by the fire rose so slowly that the heat could be conducted through the metal of the sprinklers into the soldered joint as fast as the temperature of the room increased, then the relative sensitiveness of the diverse types of sprinklers would be diminished. A sealed sprinkler, with its soldered joint next to the water, is assuredly the strongest form of construction; and, in order to produce a sensitive sprinkler, with its joint away from the water, it is necessary to introduce complications in the way of valves, deflector joints, and links; and he who utilizes these mechanical makeshifts to the least disadvantage, produces the best sprinkler. A sprinkler joint should be rather narrow in the direction of sliding open; and as far as necessary for strength, increase the width; because, when a sprinkler is in the act of opening, the least particle of water which reaches the partially opened joint at once seals it in that position, and it requires an exceedingly fierce fire to melt open a sprinkler with leaking water trickling over the soldered joint.

The Parmelee sprinkler is shown to be about the least sensitive head on the list, and the least in capacity of discharge; and yet the whole experience with the Parmelee sprinklers has been a success, and we have no record of a fire getting away from them. If such is the fact with this sprinkler, what results may we not expect from the latter forms of sensitive types of sprinklers?

### BURSTING STRENGTH.

The results were obtained with a pump used in the graduation of hydraulic gauges. The piston was slowly moved by means of a screw, and the pressure applied steadily and without any violent motion. The effect of a pressure applied rapidly upon a solder joint is different from that of a lower pressure remaining constantly upon the sprinklers, and still less destructive than a constant water hammer. Save in three

* A paper read before the British Association at the recent Montreal Meeting.

instances, the sprinklers yielded elsewhere than at the soldered joint. One of the three sprinklers was a Parmelee, and the other two Burritt sealed sprinklers.

This shearing strength per square inch amounted to 2,449 pounds in the Parmelee, and 4,534 and 7,254 in the Burritt sprinklers. Sensitive sprinklers, with any considerable elements of elasticity in their construction, become tight after leaking down to a point at which the elasticity of the sprinkler equalled the water pressure.

These results show that the solder does not weaken on account of age or pressure. An examination of sprinklers which have opened at ordinary temperatures warrants the opinion that such instances have been produced by imperfect soldering, freezing, excessive strains caused by screwing a valve to its seat, or by expansion of the sprinkler with rise in temperature.

In some sensitive sprinklers the elastic springs, or the flexibility of some of its members, limit the stress on the solder to the force which can be transmitted by the spring; and sprinklers of this form have not given trouble by reason of yielding of the soldered joint from this cause.

The methods of applying the fusible alloy by sealing caps over automatic sprinklers, and thus producing a joint exposed to contact with the water, were not used until after numerous attempts to produce sprinklers containing a valve secured to its seat by a rigid arrangement of parts, with the soldered joint away from contact with the water, had resulted in failure.

Subsequently, Mr. Frederick Grinnell solved this problem by placing the valve in the centre of a flexible diaphragm. As a result of this construction, the water pressure upon the diaphragm tends to keep the valve tight, as long as the levers remain in place; when the resistance against the water pressure is removed by the fusion of the solder, then this same water pressure opens the valve. This new mechanical movement, using the same element of hydrostatic pressure to keep the sprinkler open or shut, as needed, and also to relieve the inelastic solder from strains due to water hammer, is comparable in simplicity and importance to the celebrated invention of Elias Howe which pierced the sewing machine needle near the point.

In the Grinnell sprinkler, the joint is reinforced by a wire bent at right angles, and soldered against the joint, making a compound soldered joint lying in three planes. In the Brown sensitive sprinkler, the thrust of the spring against the yoke is taken by a pin driven through the yoke, and there is no direct stress upon the solder until it melts and allows the parts to slide laterally. The Walworth sensitive sprinkler differs from others in the use of an oval link instead of a soldered joint. The system of levers is such that a water pressure of one pound to the square inch exerts a force of one-fortieth of a pound on this link. The area of cross-section of one of these links is one-fortieth of a square inch. The yielding of the lever at the side limits the tension which is placed upon the link.

At this date we have not the benefits of experience respecting the endurance of this link; but one of these sprinklers, with the tension on the link as great as the stiffness of the side rod would permit it, has been in my possession for three months without any indication of the solder yielding.

OPENING TEMPERATURE OF SPRINKLERS.

The temperature at which sprinklers opened was ascertained by connecting the sprinkler to fifteen pounds' water pressure, and placing it in the middle of a large steam kettle. The water was agitated with a dasher, and heated so slowly that fifteen to thirty-five minutes were required to melt the sprinkler-joint, and the temperature could be noted to an accuracy of about one-quarter of a degree.

Sprinklers with hard solders were melted in a similar manner in a kettle of oil. When a sprinkler opens, the solder is not fluid, but either in the granular state that precedes fusion, or in a thick viscous condition, the form varying according to the solder and the pressure applied.

Therefore it is important that the parts forming a joint should slide easily on each other. These sprinklers, where the joint is formed by a conical sleeve must open with more difficulty, because the two surfaces of the joint must be separated as the joint opens, requiring greater force than mere sliding, or the opening of the sprinkler delayed until the temperature increases to a higher point, and renders the solder perfectly fluid.

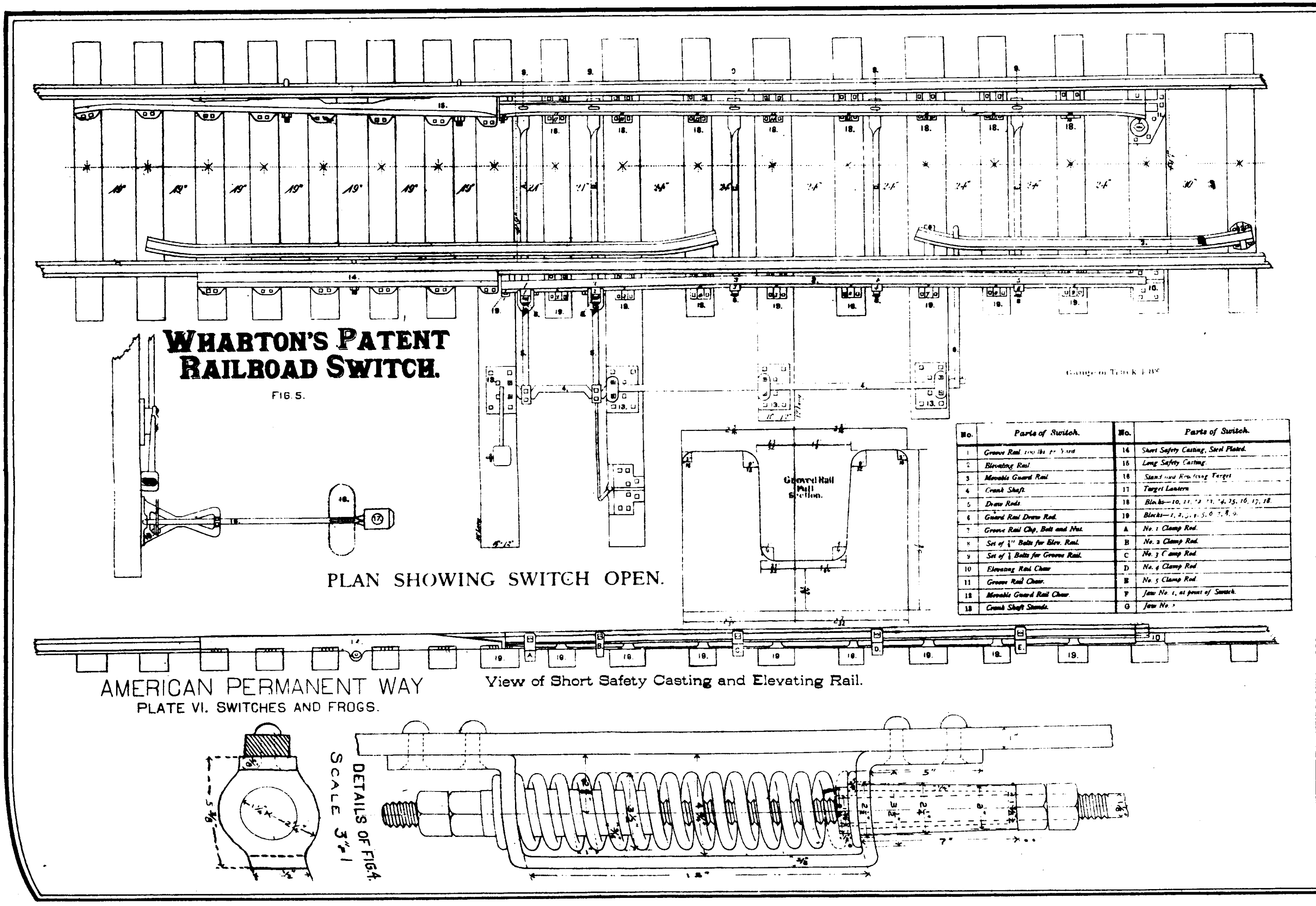
Those engaged in the manufacture of the earlier Parmelee sprinklers used rather harder solder than is the present practice. The very first sprinklers were sealed with the more fusible solder, and later "212" and "250" (so called) solder were used. Two lots of sprinklers, as given in the table,—one in present condition since 1879, and a portion of another lot which had been in use since 1872,—gave as their opening temperatures 163 and 168. On comparison with the results given for later sprinklers, it will be seen that the solders have retained their low-melting points. There were but a few of the earlier sprinklers introduced into the mills, and so many of them have been changed that it is not an easy matter to obtain a full supply of them for these experiments.

The alloy which melts at about 150 is not considered strong enough for use in sprinklers, and there cannot be considered to be a demand for such a sodder, while those now in use prove to answer the requirements of such work over highly combustible material. The operation of the automatic sprinkler, of the valve, or "sensitive" type, is interfered with or wholly prevented if the sprinkler is severely corroded; and it is suggested that such moving or sliding portions of sprinklers be protected with some of the heavier petroleum oils, which would prevent rust without cementing the sprinkler. It is essential that no mixture containing an animal or vegetable oil be used.

N.B.—This paper was accompanied by Valuable Tables of the results of tests, &c.

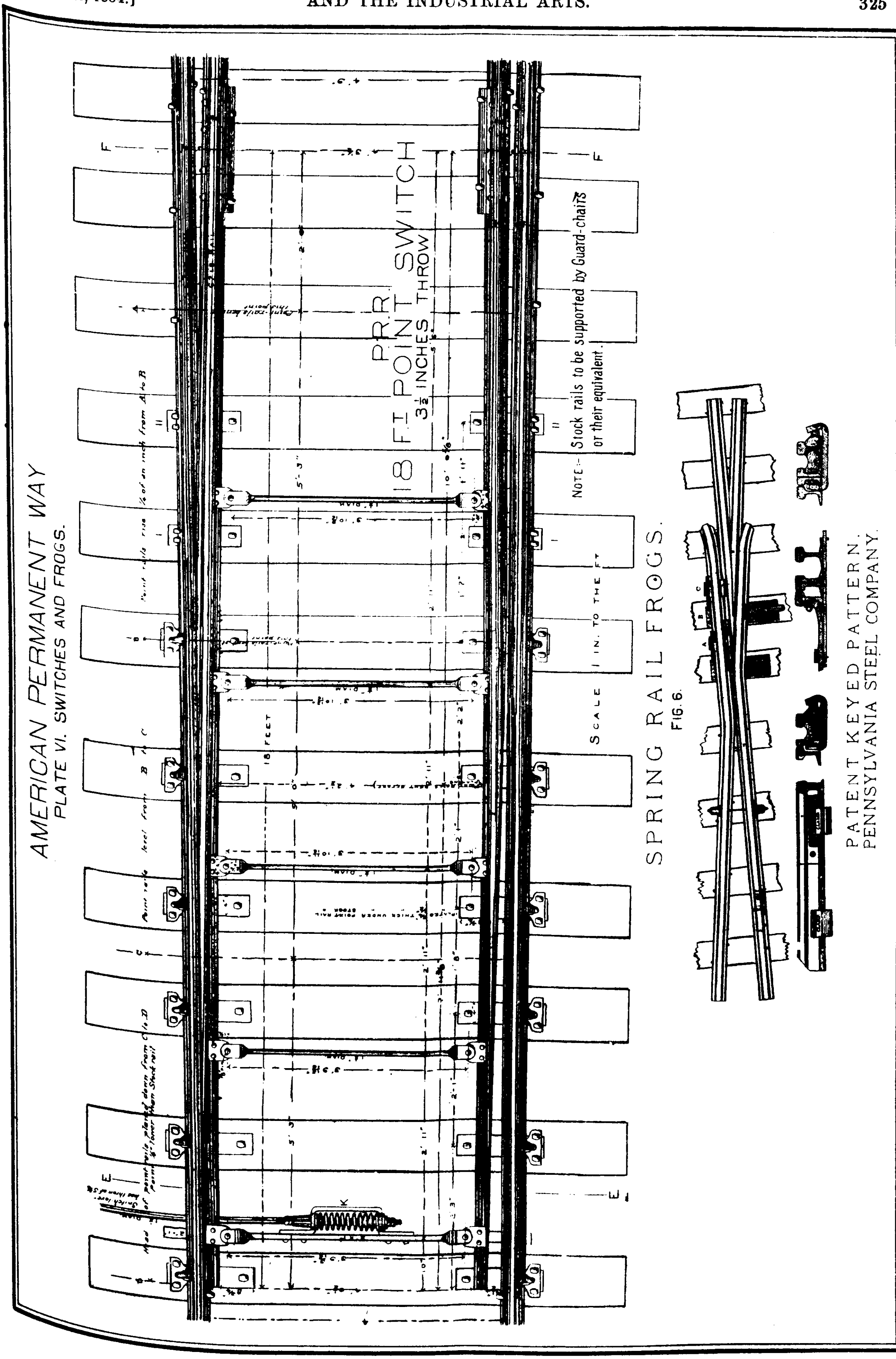
WOODEN WATER PIPE.—At a Meeting of the Engineer's Club of Philadelphia, it was stated respecting a Wooden Water-Pipe that:—The section of spruce was originally about 14 inches in diameter at the large end and somewhat smaller at the other, having a wrought-iron band about 1½ in. wide, 3·8 in. thick at one side and tapering to a thin edge at the other, so that it could be driven on or into the end of the log near the outer circumference. A piece of iron pipe 4 in. internal diameter and about 12 inches long, tapered to a thin edge at each end, served to connect the ends of the two adjoining logs, which were driven over it end to end, and prevented from splitting by the iron bands around the ends of the logs. In some cases no interior iron coupling pin was used; one log was tapered at one end and driven into the next one, which was prevented from splitting by the exterior iron band. The 4-in. pipes, so far found, were of yellow pine, spruce and oak, of about 12 feet lengths, and from 12 to 24 ft. in diameter and supposed to have been laid between 1795 and 1805; the depths at which they were found varied from 2 to 8 feet below the surface of the street. The outer bark and heart wood of the spruce logs were generally sound, while the inner bark and sapwood were decayed, except where the soil was dry, gravelly or porous, when the greater part of the wood was decayed and the iron badly corroded. A specimen of red oak from a log adjoining the spruce one was decayed on the under side, but other portions looked nearly as fresh as if recently laid.

This is very useful information, and those interested should make a note of it.




| No. | Parts of Switch. | No. | Parts of Switch. |
|---|---|---|---|
| 1 | Groove Rail, 100 lbs per Yard | 14 | Short Safety Casting, Steel Plated. |
| 2 | Elevating Rail | 15 | Long Safety Casting. |
| 3 | Movable Guard Rail | 16 | Stand and Revolving Target |
| 4 | Crank Shaft. | 17 | Target Lantern |
| 5 | Draw Rods. | 18 | Blocks—10, 11, 12, 13, 14, 15, 16, 17, 18. |
| 6 | Guard Rail Draw Rod. | 19 | Blocks—1, 2, 3, 4, 5, 6, 7, 8, 9. |
| 7 | Groove Rail Clip, Bolt and Nut. | A | No. 1 Clamp Rod. |
| 8 | Set of ¾" Bolts for Elev. Rail. | B | No. 2 Clamp Rod. |
| 9 | Set of ¾ Bolts for Groove Rail. | C | No. 3 Clamp Rod. |
| 10 | Elevating Rail Chair | D | No. 4 Clamp Rod. |
| 11 | Groove Rail Chair. | E | No. 5 Clamp Rod. |
| 12 | Movable Guard Rail Chair. | F | Jaw No. 1, at point of Switch. |
| 13 | Crank Shaft Stands. | G | Jaw No. [illegible] |

AMERICAN PERMANENT WAY
PLATE VI. SWITCHES AND FROGS.


AMERICAN PERMANENT WAY
PLATE VI. SWITCHES AND FROGS.
P.R.R.
18 FT. POINT SWITCH
3½ INCHES THROW
NOTE:- Stock rails to be supported by Guard-chairs or their equivalent.
SCALE 1 IN. TO THE FT.
SPRING RAIL FROGS.
FIG. 6.
PATENT KEYED PATTERN.
PENNSYLVANIA STEEL COMPANY.

## AMERICAN PERMANENT WAY.*

BY JOSEPH M. WILSON.

(*Continued from page* 298.)

The term "switch" is an American word, and indicates any arrangement of movable rails used for the purpose of transferring a train from one track to another. In the stub switch, where the lines of rails separate, each pair of the four rails are brought as closely together as will just allow the flanges of the wheels to run between them. The last pair of rails of the single track are then connected together to gauge by bars, and have only the rear ends fixed to the ties, the other ends being made so as to swing back and forth horizontally, by means of a lever, in front of either pair of the diverging lines, so that a continuous connection can be made with either one or the other. The ends of these movable rails, which are called switch rails, rest on slide plates which receive and partially secure them, limiting their movement, or the "throw" of the switch, to the distance between the rails of the diverging lines. A small opening or space must always be left between the end of the switch rail and the next rail, to allow not only for expansion and contraction under changes of temperature, but also the creeping of the rails under service, both of which causes tend to close up the space and hold the switch rails so tightly in place that they cannot be moved and the switch opened. But the want of continuity in the track, causes severe shocks and jars to passing trains, not only uncomfortable to passengers, but also battering down the ends of the rails, rapidly destroying them and the ties below, and causing much trouble. In addition to these disadvantages, inherent in the form of switch, it possesses no elements of safety. If placed for the wrong track, a train approaching from the side of the diverging lines must be derailed.

The great advances which have been made in the scientific operating of railroads in this country, and the vastly increased traffic, demanding greater comfort and greater safety, have necessitated some form of switch that would pass trains smoothly and easily, free from the shocks and jars experienced with the old form, easily operated, without risk of being locked by changes of temperature or creeping of rails, and, at least on the main tracks, of a switch that, even if set wrong, would not derail a train. These wants have been met by the Split or Point switch.

The split switch, as made in America, is of the same type as has been used almost altogether in Europe, but there may be some differences in details, or in the application of the principle. This form of switch consists simply of a movable pair of split or tapering rails, which are fastened to the two inside rails of the four that come together, the outer rails being fixed, and connected and made continuous with the single track from which the divergence takes place; these split rails at the opposite ends are free to be shifted sideways and move with each other, being tied together to a certain fixed distance apart by rods, this distance being made so that only one of them can be in contact with a fixed rail at the same time, the other being separated from the fixed rail by a space, called the "throwing" of the switch, sufficient to pass the flanges of wheels of trains. The free end of the pointed rails is called the "toe" and the fixed or pivot end the "heel" of the switch. At the heel, the fixed distance from the adjoining rail must be enough to pass wheels easily. It is essential that the point when pressed up against the fixed or "stock" rail as it is called, should leave no projection that a wheel approaching the switch could run against. For some years it was customary to make the points quite blunt, and to cut a recess into the side of the stock rail for the point to fit into; but as now made, the point rails are tapered down to a thin wedge and shaped so as to fit very closely to the stock rails, resting on them and having the thin point also tapered for a short distance from the end, so that there will be no risk of the wheels touching the point rails until they reach a thicker part. Nothing has to be done to the stock rails and no changes of temperature or creeping of rails will affect the point rails. The throw of the switch is usually made about 3½ or 4 inches, to avoid any danger of the open end of the point being struck by the back of a wheel, although less throw would answer. Sometimes short guard rails are used in front of the points to protect them. The two point rails require to be connected together by rods or bars, which should be as low to the surface of the cross ties as possible, and rigid vertically, while flexible to some extent sideways to allow of self adjustment.

Split switches are made by a number of firms, each of which usually has some special patent or detail of its own in the style which it builds. Fig. I, Page 328 shows the split switch as made by the Pennsylvania Steel Company, which will very well illustrate the type. The form of connecting bar is also shown. The two arms of the bar are rigidly attached to the webs of the rails, and are secured together in the centre by means of two flat plates, which lay on each side of them and are rivetted together through a separating block. The arms having only one rivet in each, can adjust themselves between the plates, about this rivet as a pivot. The paint rails of this Company are made 15 feet long, being one-half of a 30 ft. rail. They are planed and tapered down without being heated, and are shaped so as to completely fit the stock rails and to rest on the flanges of the same throughout the whole length of the tapered portions, in such a manner that the point rails receive substantial support if required, although the wheels do not come in contact with them until they have passed the extreme end. The slide plates under the point rails are of wrought iron, quite plain except near the point, where they extend also under the stock rails and have the ends turned up to hold rail braces.

When a train approaches a split switch by the heel, it is called a "trailing switch", but if the toe or point is approached first, then it is called a "facing" switch. Single point switches are sometimes made, but only one movable point rail, the other being fixed like a frog point, but this is not a good arrangement. If the movable point rail is placed inside the curve diverging from the main line, then when it is set right for the diverging line it acts not as an ordinary point rail but as a guard rail, for which is is not suitable; also no matter which way the switch is placed, the supports to the threads of the wheels is not as much as two point rails give, and the stock rail alongside the fixed point wears out the same as a wing rail in a frog wears out at the frog point. One of the greatest dangers with the split switch, that of loose wheels working in to catch the end of the open point is doubled in the single point switch, for a loose wheel catches easily on the end of a fixed point, as on an open point, and when the point in such switches is open, there are two places where there is a liability of trouble. In this connection it would be well to say, that split switches should always be made trailing lf possible, never facing the travel if it can be avoided. On single track lines, with travel in both directions, it is not feasible to carry out this precaution, but on double track lines the matter should never be overlooked, as it may prevent serious accidents. If a trailing switch be operated by a spring or weight, so that in case the switch is wrong for an approaching train, the flanges of the wheels advancing from the fixed rail on to the movable point rail, can overcome the resistance and move the points into their proper position, thus avoiding a de-railing of train, then the switch becomes a self-acting "safety switch."

Mr. William Lorenz who has for a long time been Chief Engineer of the Philadelphia & Reading Railroad. designed a simple and practicable form of self-acting split switch, with a spring securely holding the points against the stock rail, so that the switch was safe for all trains approaching, facing the switch, at the same time that it was self-acting, as a trailing switch. His switch being the type of all of these, his name is deservedly attached to them, and they are known as the "Lorenz Safety Switch." Fig. 2, Page 328 shows the Pennsylvania Steel Company's improved pattern of this switch. The general arrangement is the same as already described, except as it regards the spring, whieh is steel, double coiled, and is generally arranged in a yoke on the side of the front connecting bar, where it can be conveniently reached for adjustment. The length of the points is fifteen feet, and the throw is three and a half inches, the switch stand throwing four inches to give proper compression to the spring. In the original Lorenz pattern the points were usually made much longer, even up to 30 ft.

A shorter pattern of safety switch is made for yard service the point rails being as short as seven feet six inches, with a flange way at the heel of only two inches.

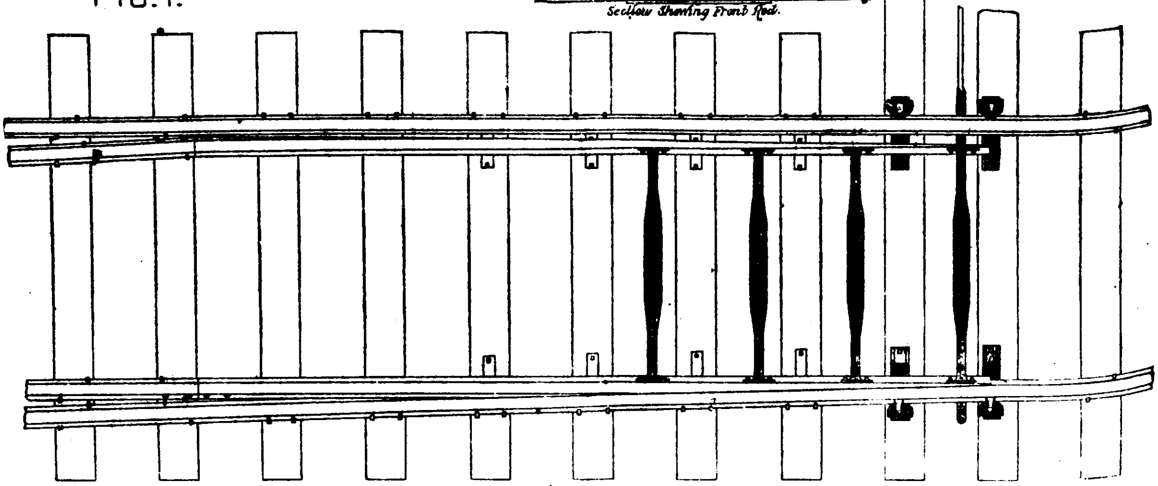
The Pennsylvania Steel Company also make an Automatic Switch Stand, (see Fig. 3, Page 328) which by the combined operation of a weighted lever and gearing, holds the switch with a solid rigid throw, and renders it absolutely safe for all "facing" trains. at the same time giving a signal indicating the position of the point. It also acts automatically as a safety switch for trains trailing over it from either track. When acting in the latter way, the first pair of wheels over the switch set it right, so that the remaining wheels do not have to open the switch, each for themselves, as in the safety switch with springs.

Fig. 4, Page 328 shows an 18 feet Point Switch as used by the Pennsylvania Railroad, but it must be understood that this does not represent the latest pattern, as some improvements have lately been made on the design which it has not been possible to obtain in time for this paper.

Fig. 5, Page 329 shows Wharton's Patent Switch, the great principle of which is always to preserve an unbroken line in the main tracks, under all circumstances, and to carry a train off, on to a siding, without any break in the continuity of the rails. This is accomplished in the following manner: The switch rails and a movable guard rail are connected together, the inner switch rail being shaped like the letter U, and having one side, next the rail, terminating in a point, which when the switch is set for the side track, laps under the main rail and guides the wheel away from it. The guard rail acts also to draw this wheel away from the main line, so us to insure the point being cleared by the flanges. The result bring the tread of the wheel upon the outer switch rail, which at the end is flush with the main rail, but gradually rising, lifts the wheel in a distance of about 4½ feet, until it can pass over the top of the main rail. Each end of the longitudinal shaft of the operating machinery has a crank, one connected with the guard rail and the other with the switch rails, and the angles of these are so arranged with reference to each other, that while the crank holding the switch is on the dead centre or a little below it, that at the other end is at such a position as to be easily acted on by the movable guard rail. Any lateral pressure therefore, against the switch when it is use, tends to hold it in position. If the switch should accidently be left closed, the

# SPLIT SWITCH

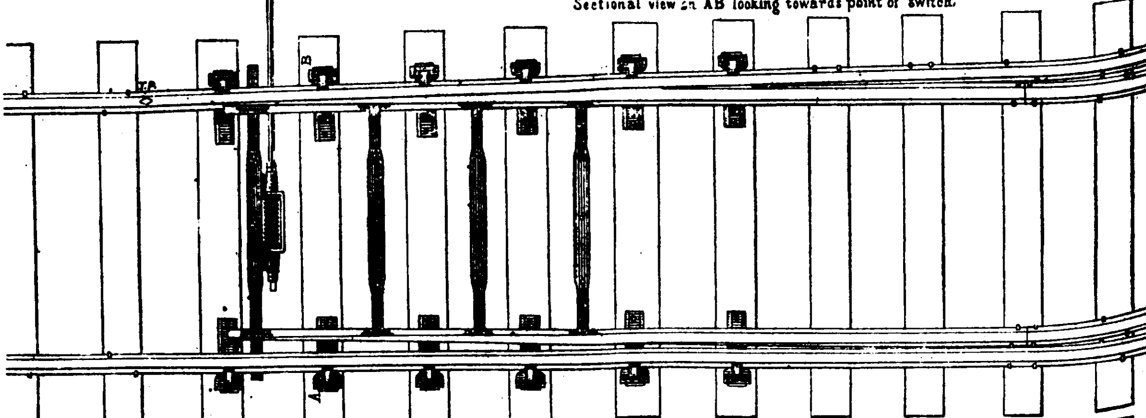
FIG. 1.

# LORENZ SAFETY SWITCH

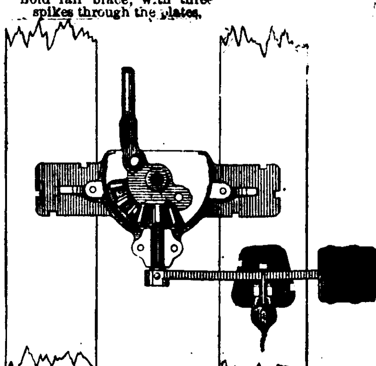
FIG. 2.

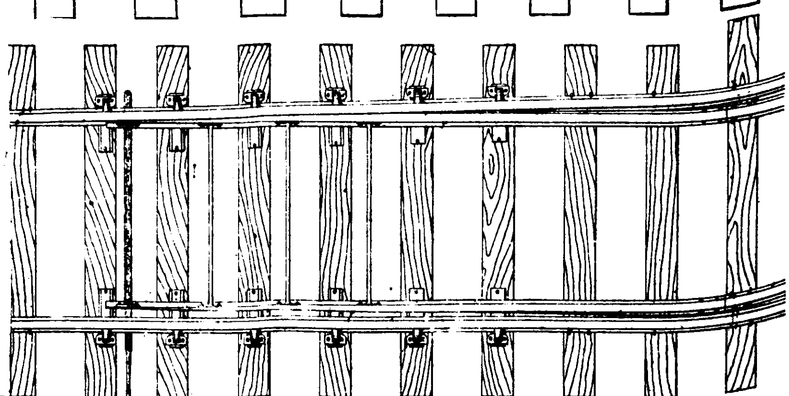
Sectional view on AB looking towards point of switch.




*P. S. Co. Patent Plate.*

With end of Plate turned up to hold rail brace, with three spikes through the plates.





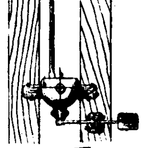
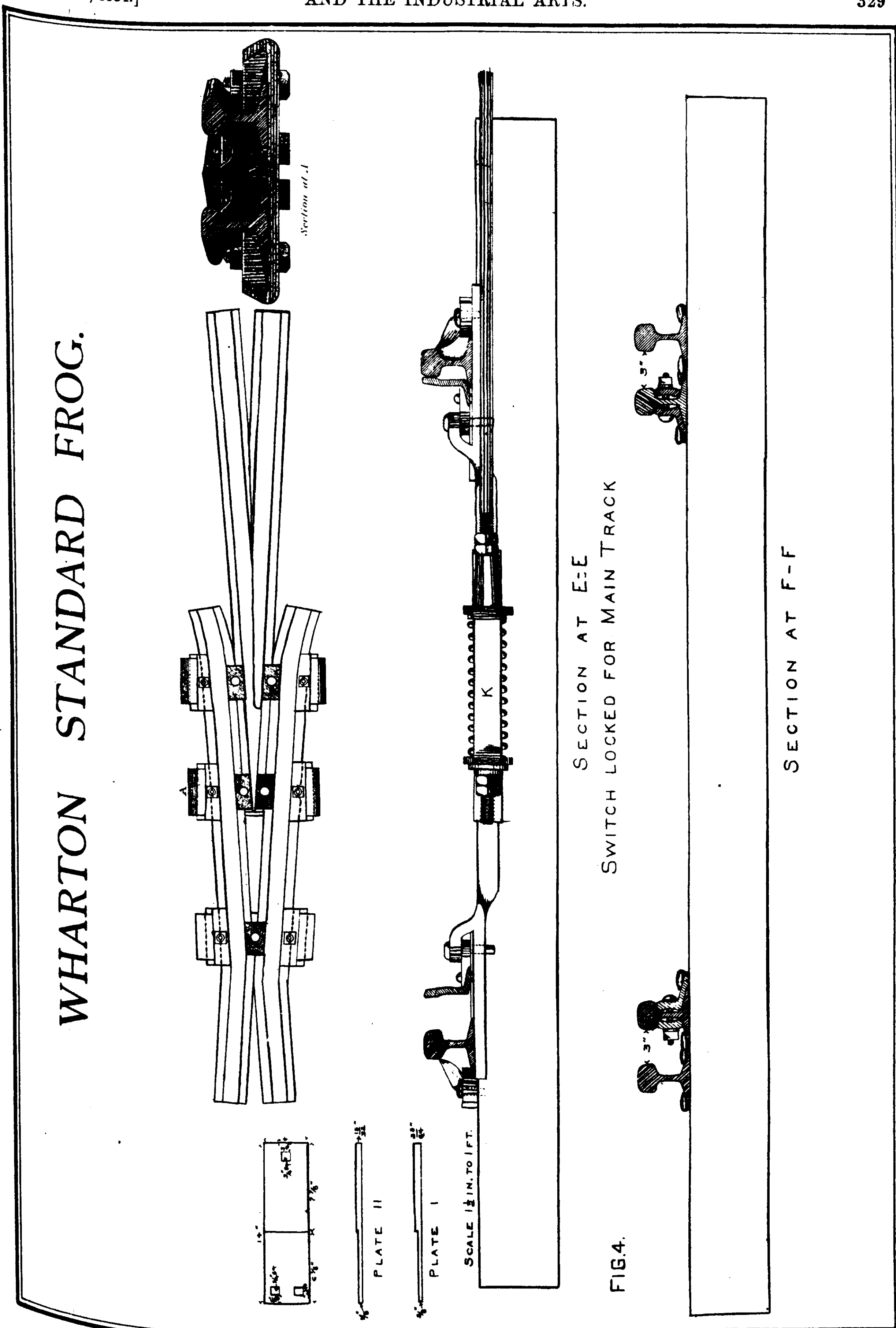


FIG. 3. THE AUTOMATIC SWITCH STAND.

IMPROVED FORM PATENT CONNECTING BAR.

PENNSYLVANIA STEEL CO.


WHARTON STANDARD FROG.
Section at A
A
K
SECTION AT E:E
SWITCH LOCKED FOR MAIN TRACK
SECTION AT F-F
FIG.4.
PLATE II
PLATE I
SCALE 1½ IN. TO 1 FT.

first wheels of a train on main line, acting on the guard rail, operate the switch, placing it all right for main track. These switch are rather expensive but have given great satisfaction where used. Their employment depends upon the question as to whether their increased expense, complication, multiplication of parts, etc. are more than compensated for by their increase efficiency over the simpler safety split switch.

The Wharton Switch Company also manufacture a safety split switch, with the guard rail attachment for throwing it right for main line, by the action of the wheels of a train, when left wrong.

When one rail is crossed by another rail, unless under some such arrangement as the Wharton switch, the rail crossed must have an opening or slit in it to allow the flanges of the wheels to pass through. The arrangement that provides for this is called a "frog." The earliest forms of frogs were of cast iron, then they were steel plated, afterwards cast steel frogs were used, and several forms of construction have been made of steel plates alternating with layers of wood and rubber to secure elasticity. Frogs were also made of iron rails such as are used in the tracks, fitted together in various ways, but iron rails wore out so rapidly under service, that they were not found satisfactory. When, however, steel rails came into the market, it became entirely practicable to make use of them for frogs, and the result has been that frogs of this kind have superceded everything else. Steel rail frogs possess many advantages over the other varieties. Using the same standard rail as in the track, they become an integral part of it, can be secured with the same splice joints, use the same ties, spikes, etc. and for a perfect realization of the problem there should be no necessity for cutting away of any parts of the ties, or adjustment of them, different from what is required in standard track, and the rail which make the frog should be kept to their full section and have their full resistance to service that they possess in their ordinary location. What is wanted, then, is a simple construction that will bind the rails together in the form required, in a solid permanent manner. The nearer these conditions can be fulfilled, the better.

There are two principle kinds of frogs in use, the "Spring Rail" and the "Stiff Frog." Spring rail frogs are sometimes made by rivetting the paint rail and one side rail to a wrought iron bed plate, the two pieces forming the point of the frog, being dovetailed together and secured by heavy mortise rivets. The other side rail is loose, being kept in place by a cross-bar passing through a slot in the point and the fast rail, the loose rail being kept close against the point by rubber springs and a rod connecting it with the fast rail some distance beyond the point. There is an objection, however, to the rivet-work and, also, to the plate underneath from its accumulating ice, dirt, etc.. and interfering with tamping of ties. The bese construction is that with keys, the type being illustrated by Fig. 6, Page 325 showing that pattern made by the Pennsylvania Steel Company. The fixed parts are tied together by two heavy clamps, secured by split keys, and the "throat" or space between the point and wing rail is maintained by closely fitting iron blocks, which are prevented from moving by rivets and pins through the ra ls. Spring rail frogs give easy riding, smooth tracks but some of the best roads do not use them now to any extent, preferring the "stiff" frog. These also are made in several ways ; with rivetted plate, with dividing blocks and bolts, and with keys. The keyed pattern is deeidedly the best. Fig. 7, Page 324 shows this type as made by th e Pennsylvania Steel Co., and Fig. 8, Page 329 that made by the Wharton Switch Company. These frogs are best with three clamps, but the split keys for fastening are consieered preferable to bolts. This form of frog possesses all the elasticity of the rails, just the same as in the regular track, making it very easy riding; the strength of the rails remains as originally, the peculiar modes of fastening have great advantages over belts or other arrangements, as there is nothing that can interfere with wheel flanges, and the frog rests on the ties in their usual positions, giving ample room for tamping up, etc. First quality steel rails should be used, drilled for the stendard splice of the road; the pieces of rail foiming the point should be dove-tailed by planing cold, and thoroughly secured by heavy rivets; the clamps should be of heavy wrought iron, and the parts within should be secured by beveled split keys. Solid iron throat pieces fit the rails perfectly and maintain the throat space. The whole forms about as perfect a frog as can be designed. There is nothing movable about the frog but the keys. These should be examined by the trackmen in their course of duties, and if found loose, driven tight, the split end being spread open to hold them to place.

Where two railroads cross each other on a level, not at all an uncommon thing in this country, expensive crossing frogs are required. Much the same style of work is used in making these frogs as for the ordinary frogs, although the work is more complicated, Where the angle is very acute, they can be made like the keyed stiff frogs, but in other cases it appears difficult to design them without the wrought plates underneath.

The subject matter of this paper might be extended almost indennitely, including interlocking switches, signals, the Westinghouse Automatic air syitem, where compressed air is used as the moving power applied by electricity, etc., etc., but the author fears that he has extended his limits already, and he must come to a conclusion. He would like to say, that on a visit to Europe iu 1869, he examined very closely into the interlocking and blocking systems, returning full of ideas on these subjects, but could get no one to bestow a thought upon them. It was agreed that such things would not suit this country at all, that they were not needed, and that the operating of switches and signals through long distances would not succeed in our freezing winter climate. But there has been a revolution since then. The accumulation of business and exigencies of travel have demanded these improvements, and they are now in active use.

In conclusion, the author would dwell upon the importance of keeping a road in a thoroughly clean and neat condition, with every part to proper line and shape. The great value of this cannot be overestimated. Not only does it produce a good effeet on the public, but it inculcates care and attention on the part of the employés, and lessens their liability to neglect of the main essentials. A road superstructure well and coninuously kept up, is in the end at far less expense for maintenance, than one which is allowed to get out of order and to run down, until it is absolutely necessary by a strong effort to bring it back into good shape. It is true that there are many lines of road throughout the country in sparsely settled sections, and having a small traffic, which could not afford the expenditure on tne permanent way that a main trunk line could do. Such a line may live in hopes of raising its standard at some future time and improving its superstructure, but even now in its present state, it can keep everything in neat order and make its work thorough so far as it goes.

The author desires to express his acknowledgements to the various railroad and manufacturing companies who have so kindly furnished him with information and data.

N.B.—Read before Section G of the British Association at Montreal, 1884.

## JOY'S REVERSING AND EXPANSION VALVE GEAR.*

Four years ago, in August 1880, a Paper was read on this subject before the Annual Summer Meeting of the Mechanical Engineers' Society of Great Britain, then held in Barrow-in-Furness, describing this valve motion and its functions, which were then comparatively new. It was, however, illustrated by its application to a large express goods (freight) engine, built by the London and North Western Railway Company (England) specially to test the advantages and the endurance of the gear. This engine had cylinders of 18 in. diameter and 24 in. stroke, and six wheels coupled 5 ft. 1 in. diameter, and was designed by Mr. Webb, the Company's chief engineer, for their heavy fast goods traffic on the main line. The engine had been running this class of traffic ever since. In January 1884, it was passed through the repair shops for a general overhauling, when it was found that the valve motion was in such good condition as to be put back on the engine without any repairs.

*Paper read before the Mechanical Section of the British Association, at Montreal, August 1884.

The object of the present Paper is, however, to deal with the advantages of this valve gear and its application to various classes of engines both at land and at sea, and with the results of such applications, rather than treating it as a novelty, to give an exhaustive description of its construction and functions, which was done in the Paper above referred to. A very short description of its action and main features will, however, be necessary to the completeness of the Paper, and as a basis from which the improved results to be recorded should necessarily be shown to spring.

The essential feature of this valve gear is that movement for the valve is produced by a combination of two motions at right angles to each other, and by the various proportions in which these are combined, and by the positions in which the moving parts are set with regard to each other, it gives both the reversal of motion and the various degrees of expansion required. Eccentrics are entirely dispensed with and the time-honoured link gear abandoned, the motion is taken direct from the connecting rod, and by utilising independently the backward and forward action of the rod, due to the reciprocation of the piston, and combining this with the vibrating action of the rod, a movement results which is suitable to work the valves of engines allowing the use of any proportions of lap and lead desired, and giving an almost mathematically correct "cut-off" for both sides of the piston and for all points of expansion intermediately, as well as a much quicker action at the points of "cut-off" and "release" than is given by a link gear.

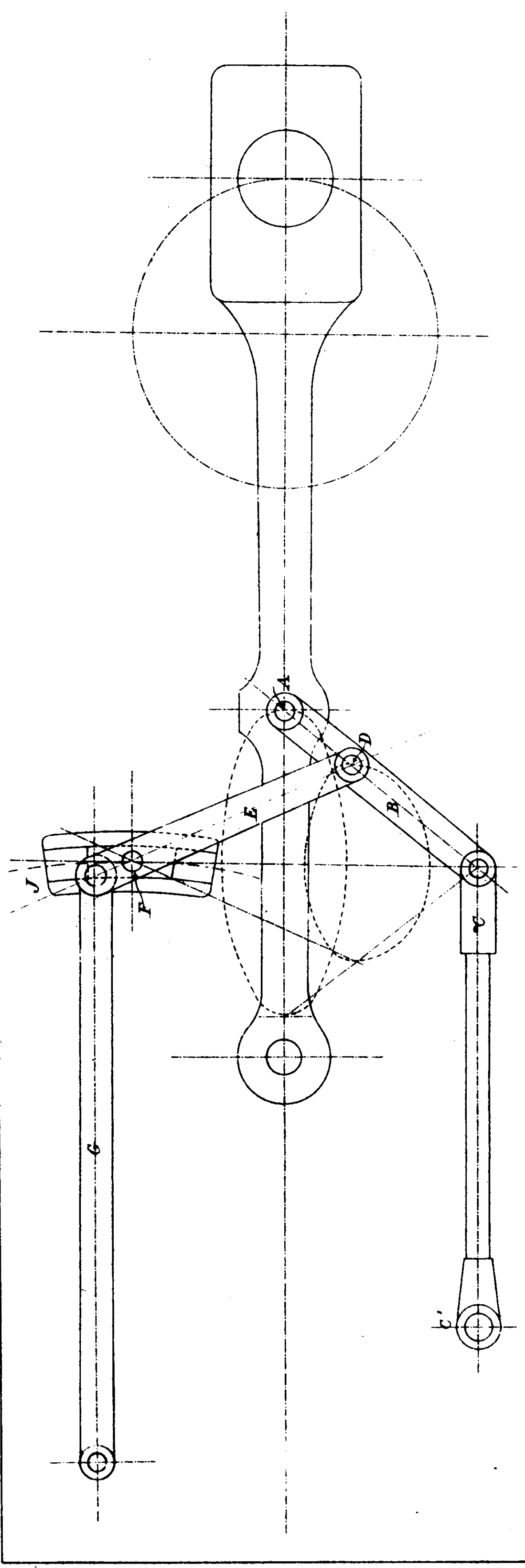
The machinery for accomplishing this is both less costly and less complicated than the ordinary link motion, and is shown in elevation on page 332, which is a full-size view of the complete motion as on the first London and North Western locomotive. Here E is the main valve lever, pinned at D to a link B, one end of which is fastened to the connecting rod at A, and the other end maintained in about the vertical by the radius rod C, which is fixed at the point C1 The centre or fulcrum F of the lever E, partaking of the vibrating movement of the connecting rod at the point A, is carried in a curved slide J, the radius of which is equal to the length of the link G, and the centre of which is fixed to be concentric with the fulcrum F of the lever when the piston is at either extreme end of its stroke. From the upper end of the lever E the motion is carried direct to the valve by the rod G. It will be evident thus that by one revolution of the crank the lower end of the lever E will have imparted to it two different movements, one along the longer axis of the ellipse, travelled by the point A, and one through its minor axis up and down, these movements differing as to time, and corresponding with the part of the movement of the valve required for lap and lead, and that part constituting the port opening for admission of steam.

The former of these is constant and unalterable, the latter is controllable by the angle at which the curved slide J may be set with the vertical.

It will further be evident that if the lever E were pinned direct to the connecting rod at the point A, which passes through a practical true ellipse, marked in red, it would vibrate its fulcrum F unequally on either side of the centre of the curved slide J by the amount of the versed line of the arc of lever E and F D: it is to correct this error that the lever E is pinned at the point D to a parallel motion formed by the parts B and C. The point D performing a figure which is equal to an ellipse, with the error to be eliminated added, so neutralising its effect on the motion of the fulcrum F.

Thus the "lap" and "lead" are opened by the action of the valve lever acting as a lever, and the port-opening is given by the incline of the curved slide in which the centre of that lever slides, and the amount of this opening depends upon the angle given to that incline. Consequently when these two actions are in unison, the motion of the valve is very rapid, and this occurs when the steam is being admitted. Then follows a period of opposition of these motions, during which time the valve pauses momentarily, this corresponding to the time when the port is fully open. Further periods of unison follow, at which time the sharp "cut-off" is obtained.

The "compression" resulting with this gear is also reduced to a minimum, owing to the peculiar movement given to the valves (*i e.*, the series of accelerations and retardations referred to), as while the "lead" is obtained later and quicker, the part is also shut for "compression" later and quicker, doing away with the necessity for a special expansion valve, with its complicated and expensive machinery, and allowing the main alve to be used for expansion, as the "compression" is not




of an injurious amount, even with a "cut-off" reduced to 15 per cent., or about 1-6th of the stroke.

Thus, so far as the distribution of the steam and its treatment in the cylinder is concerned, a marked advantage is shown in favor of this valve gear. But next in its favour, as before said, is that the above advantages is not gained at the cost of added complication of parts or increased cost of machinery, but the reverse, as this gear can be built at a less cost than link gear, varying according to the circumstances, but reaching as high as a saving of 25 per cent., or, if it be compared with a link gear supplemented by the usual special expansion valve and gear as employed on marine engines, then the total saving is fully 50 per cent., and an equally good result is obtained as to the distribution and subsequent treatment of the steam.

After accuracy of result and reduction in cost may rank saving room and the advantages arising therefrom (though for steam-ships perhaps this should have come first). Taking locomotives of the inside cylinder type, which is the general form in use in England and the continent of Europe, by clear-away the eccentrics and valves from the middle of the engine, much larger cylinders may be introduced and a higher rate of expansion employed and this is being done. Also room is left for increasing the length and wearing surfaces of all the main bearings with even less crowding than is now the case with the smaller cylinders.

But this advantage of saving room comes much more prominently forward in marine engines, especially in war ships, where every inch of room saved is valuable; and in the new type of triple-cylinder engines now coming so much into vogue in the mercantile marine, whether those engines be only the ordinary three-cylinder engines with double expansion, or the newer, triple expansion engines, expanding the steam consecutively through three cylinders—the form of marine engine which promises to come into use wherever high-class work and economy are required. On this system by placing all the valve chests in front of the cylinders instead of between them, or in a line with them, sufficient room is saved to get the new-type three-cylinder engine into the space occupied by the old form of two-cylinder engine.

Besides these prominent advantages there are others which, though of minor importance, are still necessary to the practical and permanent success of any new mechanical arrangement, such as the accessibility of all the working parts while in motion, for examination and oiling; the ease with which any part or the whole can be stripped and cleaned, or pinned up out of the way in case of break down or accident, or got at and dismantled for ordinary repair; the ease with which the whole may be handled, started, reversed, or set at any point of expansion—all these being recommendations to enlist the care and attention of the engineers in charge by lightening their duties and rendering the engines easy to work.

With these advantages it is perhaps not surprising that this valve gear has been very considerably adopted for many classes of steam engines, especially where a high result has been required, with economy of space, and a minimum of complication; and by an examination of the indicator diagrams following, it will be seen how far the objects aimed at have been accomplished.

Having crucially tested the original engine on the London and North-Western Railway, Mr. Webb proceeded to build others similar, from which class, indicator diagrams are given at Fig. 2, at cut-offs of ·50 and ·75 per cent. And on his bringing out his Compound Express Engine—notably the most advanced step in locomotive design of the present day—he adopted this valve gear throughout. There are now a number of these engines running some of the fastest trains on the London and North-Western Railway, with the most satisfactory results.

Following these, others of the leading Railways took up the system, and prominently among these Mr. Worsdell, of the Great Eastern Railway, built a number of large express engines for his fast and heavy traffic, and is now building a number of others similar as to the valve gear for his suburban traffic, which is especielly heavy. Also the Lancashire and Yorkshire and the Midland and others of the chief Railways are employing the system specially for large express engines; the Midland engines having cylinders of 19 in. diameter by 26 in. stroke, and four coupled wheels of 7 ft. diameter. A number of the above-named engines have run large mileages, in many cases exceeding 100,000 miles per engine. For other countries also a number of locomotive engines have been built or contracted for—both of inside and outside cylinder types—making a total of near 300 locomotives built and building, many of them being of special design and large size, up to 20 in. and 21 in. diameter of cylinder.

Passing now to the other great type of engines, those covered under the general designation of marine engines, this gear has been applied to nearly 40,000 h. p. indicated, built and building, and to all classes and sizes, from the launch engine with cylinders 8 in. by 9 in., running at 600 to 700 revolutions per minute, up to engines for the largest class of war ships, such as Her Britannic Majesty's steel cruiser, "Amphion," of 5,000 h.p., with cylinders in duplicate of 46 in. and 86 in. diameter, and 3 ft. 3 in. stroke, running 100 revolutions per minute.

## THE SPENCE AUTOMATIC DESULPHURIZING FURNACE.

BY W H. ADAMS, NEW YORK CITY.

Among the persistent experimenters of the present century no one man is more widely and favorably known in the metallurgical world than the late Peter Spence of Manchester, England, to whom we are indebted for many of the successful processes in the manufacture of acids and alkalies, and for much of that perfection in mechanical detail which goes so far towards securing success.

For the past twenty-five years—a period covering the greatest changes in soda-processes and a revolution in acid manufactures effected by the substitution of pyrites for brimstone—Mr. Spence was constantly engaged in perfecting the plan for the economical treatment of pyritous ores; and no text-book has been complete without reference to his many inventions, patented or otherwise.

The results of his labors for the past six years were not given to the public, by reason of the active competition existing among manufacturers on the continent of Europe and in Great Britain; but it was well known and conceded that the crowning triumph of his life had been achieved in the successful working of his automatic desulphurizing furnace, which mechanically calcined "smalls" or finely crushed pyrites—the bugbear of all chemical manufacturers.

That he was met by many delays and disappointments, and that many difficulties were overcome by him personally, goes without saying. when we remember the wrecks of so many attempts in this direction; but the systematic workings of these furnaces, at the several factories under his control, attest the correctness of his plans and the careful attention he paid to details, giving him as a reward unquestioned advantage over all competitors, an advantage held for several years already, against all opposition or new devices.

Although negotiations have been in progress for two years past, it was not until after the death of Mr. Spence that patents for this furnace could be secured outside of England, or that the study of its mechanism could be made; but now that Americans have the control of the invention in this country, and since, without doubt, this perfected mechanical furnace will play an important part in the future treatment of all classes of ores containing sulphur, I deem it worthy of early mention before the Institute.

Fig. 1 shows the double furnace in perspective; the space occupied by it being 34 feet x 18 feet. When two double furnaces are coupled together and run by one engine (as preferred in all cases), the space required is 34 feet x 32 feet. A building 40 feet x 40 feet is therefore necessary to accommodate this plant, with a shed-roof, if connection is made to towers and chambers, or an ordinary flat-roof building with supporting posts placed between the furnaces, when connected direct with the chimney, as in the process of desulphurizing gold ores.

Figs. 2 and 3 are longitudinal sections which explain themselves.

A striking feature to the observer, however skilled he may be in mechanics or furnace-working, is the simplicity of the

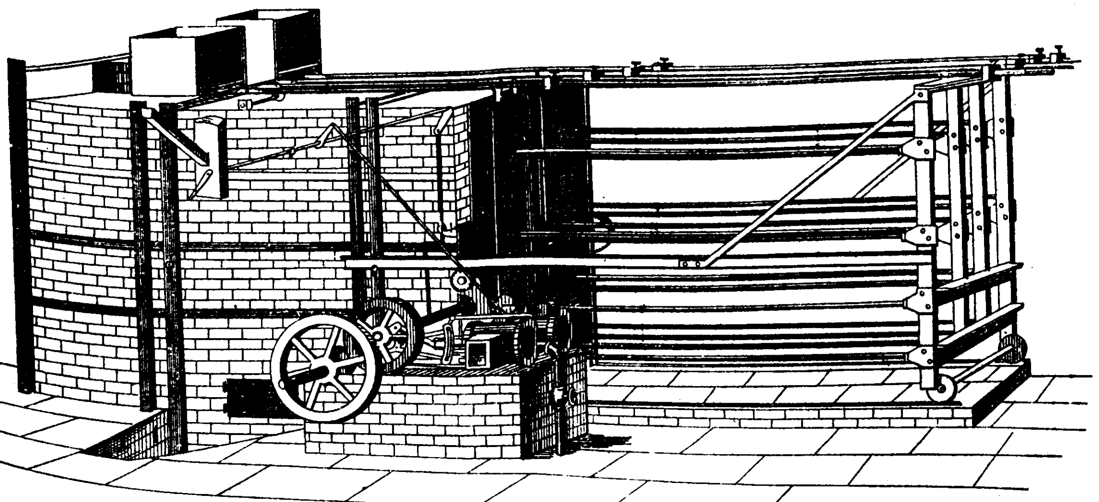


FIG. 1. SPENCE AUTOMATIC DESULPHURIZING FURNACE.
ELEVATION IN PERSPECTIVE SHOWING ENGINES, RAKES, FEED-HOPPERS & EXTRA FIRE-BOX.

parts, the certainty of the action, and the absence of all the complications attendant upon such operations generally. All the parts might be thrown together in a heap, yet so obvious are their forms and uses, that any man of intelligence could put them together from drawings here given. The same may be remarked as to the furnace, which is simply a multiple-shelf type of the hearth-furnace, used from time immemorial in every prominent mining centre of the world.

Mr. Spence exemplified his well-known good judgment and practical mechanical sense in working from tried and satisfactory models; and whether he ever was led into experiments with any of the types connected with so much sorrowful experience to most metallurgists, cannot be seen in any one part of this, his finished production, which is built from common forms of brick and tile, operated in a positive manner with little gearing, and adapted in all respects to every-day service.

There are several practical points of excellence about the furnace (which has been in operation near New York for past three months), which entitle it to careful examination by engineers. I do not think it necessary to enter into details connected with its working, further than to state generally the method of handling ores and the results obtained, leaving to those most interested the study of separate parts or special features.

The action of the furnace will be understood to be automatic, the ores being elevated from the furnace-floor, brought in from the floor above, or by other means supplied in quantities as required to keep the hoppers full. This matter of detail will readily be understood by those practiced in handling ores from different levels, and the drying of the ores (if wet) will also be understood to be a simple matter when small quantities are regularly fed.

The hoppers being filled, a small auxiliary engine is started, and by means of a changeable gear, properly connected, opens the valves to start the pair of engines shown in the foreground of Fig. 1.

These engines, having 7 in. x 12 in.-cylinders, and running at 40 revolutions per minute (giving a minimum of wear and tear for the service performed), quietly and positively operate by means of geared wheels the rods to which, in the furnace, are attached toothed rakes (Fig. 2).

The rods are very firmly held in place and position by the rack, which, supported at its rear end by wheels, travels along a railway.

The movement of the rack (with rakes inside the furnace) opens the port, for the admission of fresh ore from the hoppers to the first shelf, and the discharge of finished or calcined ore from the lower shelf into cars. When the rakes have finished the forward stroke, the engines reverse automatically, and the rack returns to and stops in position.

The auxiliary engine continues running, and at stated times (determined by the manager) again starts the large engines, another operation of stirring and raking with feed and discharge of ores taking place.

This automatic and regular method of feed and treatment of the ore on the bed of the furnace is the result of years of study and practice, directed to the object of replacing by a uniform mechanical procedure the discretionary operation of hand-labor.

By study of the plant now in question, the following conclusions are reached:

1. The constituent elements of the ores being first determined, the feed and discharge is regulated to exact amounts in pounds, and the number of charges fed into the furnace is duly registered.

2. The auxiliary engine being set to start the motive power, say, every five minutes, and the time required for the forward and backward being, say, one and one-half minutes, it follows that the interior parts of the rakes are exposed to action of heat and acid fumes but one-third of the time, thus approximating manual labor in wear and tear of plant.

3. The draft of air being regulated and controlled by the chemist at will, insuring the proper oxidation of the ores, and no more, less chamber space must be required than by any other process of burning pyrites, and, moreover, no special care need be given to location of plant, since strong winds or variable currents can have no effect in causing "blow-outs" of gas at the doors.

4. The movement of the ores from the hoppers to the discharge-opening is accomplished by a system of reversed teeth, which are positive in action.

The deterioration or destruction of cast-iron rakes and teeth has been reduced to a minimum by the simple but novel idea of *burying the parts in ore*, which accumulates at the front of the furnace beds when the rakes are at the position of rest (Fig. 3).

5. Pyrites "smalls," such as are found in Virginia, at the Milan or Capelton mines, carrying 47, 45, and 40 per cent. of sulphur, respectively, can be calcined with two double Spence furnaces, run by one engine at the rate of 15,000 to 20,000 pounds per day of 24 hours, the cinders containing from 1½ to 2½ per cent. of sulphur.

It is claimed that larger amounts of "smalls" containing copper, blende, etc., can be put through, and double the above quantity, where sulphur fumes are passed directly into the air as would be the ease in working auriferous concentrates.

6. Where necessity exists for bringing the sulphur contents of cinders from iron pyrites ($FeS_2$) down to ¼ to ½ per cent. to utilize the iron, or, for the like treatment of rich gold-bearing sulphurets, the result is accomplished by the addition of a fireplace to the lower hearth. This is shown in Fig. 1, although not ordinarily used.

By this means the proper heat is kept in the ores until they are discharged into iron cars, but in general working the ores are "dead" on the lower shelf.

7. The average cost of calcining ores by this automatic furnace is not greater than by any other method at present in use.

The cost of the furnace, complete, with power, is about the same as that of the equivalent grate-bar space in kilns, or equal burning space in the present type of shelf-furnaces.

## Notes.

TOUGHENING GOLD.—Dr. J. C. Booth, of the United States Mint, has discovered a general method of toughening gold and silver which he recently described to the American Chemical Society. Some time ago Mr. Booth found that a quantity of brittle gold accidentally melted with some tough gold in a crucible had rendered the whole mass very brittle, crystalline in fracture, and thereby useless for coining. The whole—5154 lb. av.,—was toughened by him in one and a half day at a trifling cost by the new process. The 75,000 oz. of gold were divided into 14 "melts" of 5,400 oz. each, and each melt separately toughened. The ingots, which could be broken into pieces by striking them on the edge of a wooden box, were put into the crucible with soda ash and anhydrous fused borax, in the ratio of one or two ounces to a melt, until the crucible was nearly full. It then appeared as a quiet mass of metal covered with a viscid slag, disposed to swell and puff. A few crystals of saltpetre, say one or two ounces, were then dropped into the centre of the metallic surface, and as they melted, their spreading out over the whole surface was aided by the concentric motion of the bottom of a small crucible. The moment the visible oxidising action began to slacken, the melter skimmed off, by a small blacklead dipping crucible, the fluxed matter as rapidly as was consistent with the care necessary to avoid taking up metal. The remainder in the melting pot was the toughened metal.

ESTIMATING MANGANESE IN CAST IRON,— Mr. Charles Bloxam, the well-known chemist, has recently given the following test for manganese in cast iron, which is much simpler and easier than those generally employed. The metal is dissolved in HCL in a small beaker, the solution evaporated to dryness in the beaker, the residue dissolved in water with a little HCL, filtered from graphite and silica, the filtrate peroxidised by adding a few drystals of $KClO_3$, and heating, diluted, with a convenient quantity of water, $NH_3$ added until the first formed precipitate dissolves reluctantly on stirring, $NH_3$ mixed with excess of acetic acid (added in sufficient quantity to convert all the iron into acetate), and an excess of sodium phosphate. The cream-coloured precipitate of ferric phosphate is filtered off, the precipitate re-dissolved (without washing) in HCL, the solution again nearly neutralised with $NH_3$, and precipitated with the mixture of $NH_3$ with excess of acetic acid. The two filtrates are mixed, an excess of $NH_3$ added, and boiled, when the manganese is precipitated as the crystalline, very insoluble, ammonia phosphate- which is filtered off and washed. As soon as the washings leave no residue or evaporation, the wet filter, with the precipitate, is placed in a platinum crucible, which is then covered and quickly heated ta redness by a Bunsen burner. After ignition the precipitate is $Mn_2P_2O_7$. It is well, if possible, to keep the ammoniacal solution near its boiling point for an hour, and to set it aside for the night, though the greater part of the manganese is precipitated at once on ebullition. The ignited precipitate should be re-dissolved in HCL, and the solution mixed with ammonium acetate to detect any ferric phosphate, which, if worthy of notice may be ignited, weighed, and deducted.

PROF. F. E. NIPHER finds from data taken from Dr. Engelmann's observations at St. Louis, Mo., lasting over a period of forty-seven years, that the duration of maximum rains is inversely proportional to the violence, or that the product of violence into duration is constant. This constant is the amount of water which may fall in a continuous rain, and is, for Dr. Engelmann's series of about half a century, about 5 inches. A rain of five inches per hour may last one hour. A rain of four inches an hour may last per hour may last an hour and a quarter; and such a rain Dr. Engelmann observed. A rain of two and a half inches per hour may last two hours, and several such rains were observed. A rain of an inch per hour may last five hours. Each of these cases would be a five-inch rain. For a longer period of time than fifty years it is likely that greater rains than five inches may be observed. The same is to be said if observations are to be taken over a wider area of country. In fact, a rain of six inches in three hours occurred near Cuba, Mo., some years since. This would increase the value of the constant from five to six, but otherwise the relation will probably remain unchanged.

The importance of this law is very great in engineering, where the capacities of sewers, culverts, and bridges must be such as to carry the water. A more general investigation which Professor Nipher is now making will determine the relation between the violence, duration, and frequency not only of maximum, but of all rains. This work, when completed, will enable an engineer to construct the water-ways of bridges of such a capacity that they will probably stand a definite number of years before they are washed away. This number of years will be so determined that the interest on the invested capital during the probable life of the bridge will equal the possible damage when the destructive flood comes which the engineer determines shall destroy his work. The running expense of maintaining the bridge is then the least possible.

SIGNAL-SERVICE note xvi., entitled "The effect of wind-currents on rainfall," by G. E. Curtis, is one of the most carefully prepared numbers of the series, both in the reference to previous work on the subject, in which English, French, and German authors are quoted, and in the discussion of the special series of records from five gauges on the summit of Mount Washington. The author concludes that the rainfall (without snow) in such exposed situations varies materially within distances of only one or two hundred feet; that the windward gauges receive least and the leeward gauges most rain, as had been stated for buildings by Bache in 1837; and that, in high winds, small gauges do not collect enough rain, the discrepancy between eight-inch and three-inch gauges varying as the square of the wind's velocity; and, for velocities of sixty miles an hour, the three-inch receiving only two-thirds of the rain collected by the eight-inch gauge.

THE elasticity in the carbon filaments of the incandescent lamps, at least in some of the patterns, is rather remarkable. Take an Edison lamp of about a hundred ohms resistance, and a moderately sharp blow with the hand at right angles to the plane of the loop will vibrate it so far that it strikes tbe side of the glass bulb; and it will continue for two minutes, swiftly vibrating through very slowly decreasing amplitudes, and with beautifully complicated nodal effects, according to the direction of the blow. So sensitively elastic are some of them, that it is difficult to hold them in the hand so steadily that the upper part of the loop is not blurred by rapid incessant vibrations of small amplitude.

THE first patent granted to an inventor in the United States is memtioned in a speech of ex-Senator Wadleigh, of New Hampshire, in the forty-fifth Congress. The senator said: "An intelligent gentleman of my own State has referred me to an Act of the general court of Massachusetts Bay, passed in 1646, granting to one of his ancestors, Joseph Jenks, the exclusive right of making and selling his improved scythe for the term of fourteen years. That, I think, was the first patent granted to an inventor in America. The improvement referred to changed the short, thick, straight English scythe into the longer, thinner, curved implement with stiffened back now in use.

AMERICAN *versus* RUSSIAN IRON.—American planish sheet iron is now made fully equal if not superior to the best Russian iron. A Pittsburg firm, W. D. Wood & Co., have laboured assiduously for 30 years to perfect this description of iron. They have now attained such a degree of success in its manufacture that some workers in that metal pronounce it quite superior to the Russian make. It is said to be more evenly rolled, equally soft and ductile, more highly polished, or "glanced," as it is technically called; equally as durable to weather, exposure, etc. It is also made of different widths, which gives it the advantage of being worked up more economically, while Russian iron is always made of a given length and width, and probably always will be. It is no longer necessary to go to Russia for this indispensable material. We can now obtain it from our own shops, and it is said that since the more recent improvements in it manufacture have become generally known the importation of the foreign article has fallen off fully one-half. Indeed it is stated that the consumption of American planished iron is now more than double that of the imported article. We have in this manufacture another evidence of the mechanical progress which out people are making.

THE *Chronicle*, says that the little feeder of the Leadville division of the Rio Grande exceeds all other roads in its steep grades and short curves. When the line first went into operation many accidents occurred by the trains breaking away at the top and running back down the steep grades, wrecking locomotives and cars and destroying limbs and sometimes lives. Later, however, extremely heavy locomotives have been built and the most skilful and the bravest train hands employed, who never flinch in the supremest moment of danger. The result has been that accidents now seldom occur. It is said that the flight of one of these trains descending is one of thrilling interest, the sparks from the car wheels cutting a pathway of light down the mountains, which can best be described as having the appearance of a molten stream of fire rushing down to the river-bed of the canyon.

## *NEW BOOKS.*

*Traité Pratique d'Electricité Industrielle*, by E. Cadiat and L. Dubost (Paris: Baudry & Co.)

This valuable work will be reviewed in the next number of the Magazine.

## A NEW PRESSURE-FILTER.*

BY R. P. ROTHWELL, NEW YORK.

A year ago I commenced experiments in precipitating and saving gold from chloride solution, in the course of which I found $H_2S$ (made from paraffine and sulphur) the most convenient and inexpensive precipitant. The gold is thrown down as gold sulphide; and a considerable time is required for this precipitate to settle. Even after it appears to have settled, we find by experience that there is a notable loss of gold, if the clear liquor be decanted off in the usual way.

To remedy this evil, I made a small and very cheap pressure-filter, which has now been used for nearly nine months, and has given the utmost satisfaction. This filter is constructed as follows:

Three frames, about 4 feet by 2 feet, are made of 2-inch by 3-inch pine. Two of these frames are filled in with ½ inch slats leaving about ⅛-inch spaces between the slats, as shown in Fig. 1,

These slats are covered with cloth or drugget, and Swedish paper is laid on the top of the cloth. The notches shown in the figure receive bolts of ⅜ or ½-inch iron, to hold the frames together.

The third frame shown in Fig. 2, is of the same size and thickness as the others, but has, instead of slats, only only one cross-bar. When the filter is put together, the third frame is placed between the other two, and the cross-bar serves to press on the joint of the filter-paper and keep the two sheets together. This cross-bar is perforated, to permit the passage of the liquid, which enters through a pipe at the end provided with a faucet, and fills the whole filter.

* Read before the Institution of Mining Engineers.

THE SPENCE AUTOMATIC DESULPHURIZING FURNACE.

FIG. 2.

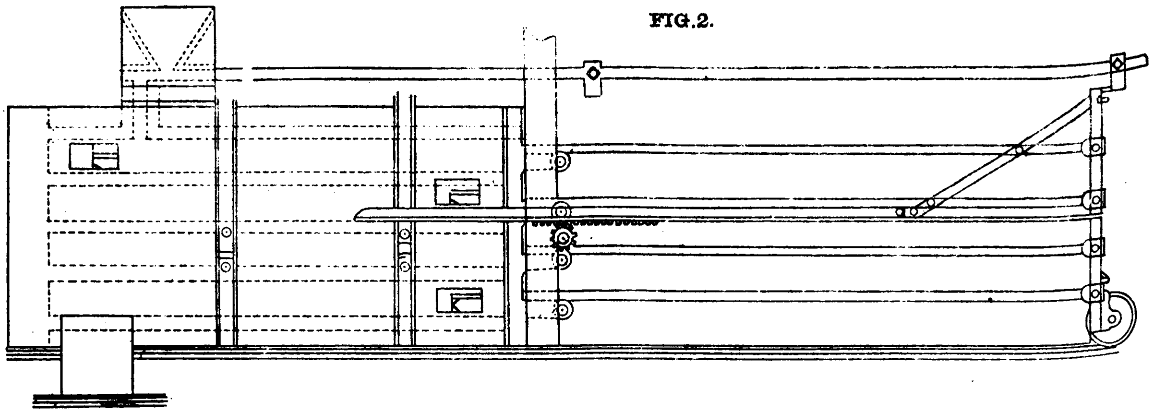


FIG. 3.

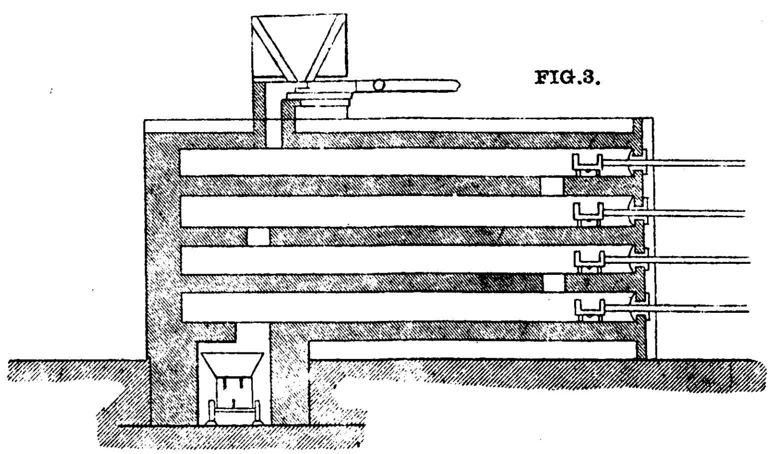


Fig. 3 shows in perspective the filter complete. It will be seen that the middle frame, keeping the other two apart, furnishes a space between them to be filled with liquor. This is brought through a rubber or iron pipe from the precipitating-tank. Since the filter is set on a lower level, any desired head or pressure can be obtained. About five or six feet is generally enough. The liquor passes out through the filter-paper, which collects the gold; through the cloth, which is merely a support for the filter-paper, and then between the slats forming the sides of the filter.

Fig. 4 is an enlarged view of one of the malleable iron castings screwed on the outside frames, to receive the bolts. There, when loosened a little, may easily be lifted out of the notches, and thus the filter is very quickly opened. Before opening, it is laid on a sheet-iron tray. After the filter has been opened, the gold precipitate is rolled up in the filter-paper, fresh sheets are put in, the frames are again bolted together, and the apparatus is ready for further use.

We strengthen the filter still further by a couple of cross-bars of hard wood, as shown in Fig. 5. This is required by the swelling of the frames, held around their edges by bolts, which tends to loosen the joints of the frames.

The total cost of the filter will not exceed five dollars. It requires no attendance; the cloth lasts indefinitely (since the liquor is necessarily neutral before the gold will precipitate); and we have still the original cloth of one of our filters. Such a filter, 4 feet by 2 feet in size (giving an area of two sheets of filter-paper and hence containing, on the two sides, four sheets), will filter from fifty to one hundred and fifty gallons per hour, according to the amount of precipitate on the paper. The liquor passes very rapidly through it at first, and more slowly as the precipitate accumulates; but the filtrate is always perfectly clear. When the filtering becomes slow, the faucet is closed, the hose is disconnected, and the chemists and his assistant carry the whole apparatus into the assay-office, where it is laid in a sheet-iron tray, and opened as already described.

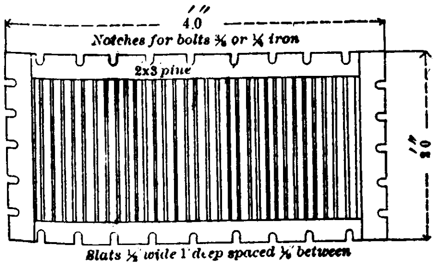
No one but the chemist has anything to do with it; and, standing in a closed box, it attracts no attention.

DISCUSSION.

C. A. Stetefeldt, New York City: "In European works, where solutions with precipitates have to be filtered, the filter-press is now in general use, and there are quite a number of good constructions. I have myself seen those of Dehne and of Johnson. Johnson's are of English construction and can be bought in New York. No doubt Mr. Rothwell's press is quite an ingenious one and has been got up for this special purpose at slight expense; but perhaps it would be preferable where large quantities of solutions have to be filtered, to buy a filter-press of more perfect construction. They are exceedingly convenient and filter almost anything, leaving the precipitate in the form of a dry cake. In Oker, Germany, they are used, for instance, in Claudet's process. The filter-press has largely taken the place of the centrifugal machine.

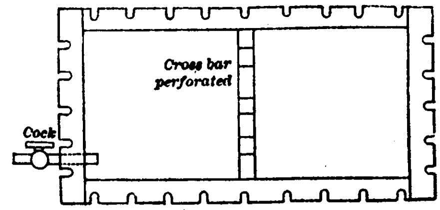
## A NEW PRESSURE-FILTER.

FIG. 1



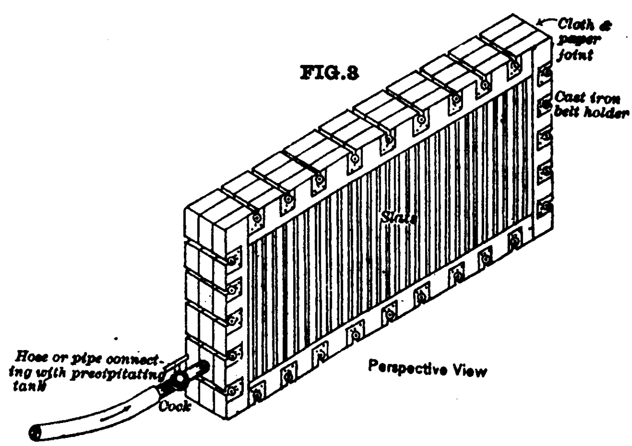

Plan of outer frames

FIG. 2



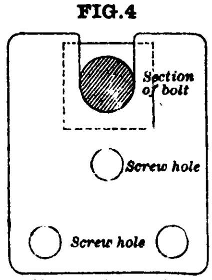

Plan of inner frame

FIG. 3



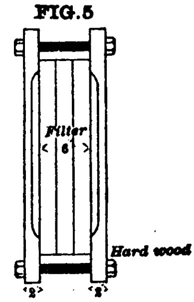

Perspective View

FIG. 4




Malleable iron casting screwed on frames to hold bolts which clamp sides together

FIG. 5




Clamp for strengthening filter

## CANADIAN PACIFIC RAILWAY.

BY VERNON SMITH, C.E.

The Canadian Pacific Railway, the early completion of which is now a question of a short time only, is the latest and probably the most important of a series of steps for the development of the new Dominion of Canada that have raised this country from a comparatively obscure colonial position to be the most important of the dependencies of the Empire and destined probably in the near future to be the home of a larger number of British subjects than now live in the islands from which most of us draw our origin, the Greater Britain it may be of the next generation. In a country where distance is frequently most conveniently expressed in geographical degrees, whose longitude covers over 80 degrees, or nearly one-fourth of the entire circle, and where communication by water is impossible for five months in the year, the development of the railway system is of vital necessity to the comfort and convenience of the people, or even to the settlement and cultivation of her broad domain; and in recognition of this fact, every encouragement has always been given to the construction of railways; the aid extended to the earlier lines being probably far more of a tax upon the resources of the country than all that has been done for this last and most important of them all.

In 1867 an important step for the advancement of the country, for the removal of the obstacles that impeded its progress and for the development of its industrial pursuits, was inaugurated by the Confederation Act, which linked under one Government the four older Provinces, and made provision for all the other British dependencies in North America to join them in forming one United Canada. The immediate outcome of this was the construction of the Intercolonial Railway and the commencement of a number of new lines which raised the mileage of the Canadian system from 1,968 miles at which it had remained for some years previous to 1867, to 7,038, the number of miles of completed road at the end of 1882.

Other steps in the progress of the country have followed, and for the last fifteen years the country has enjoyed its full share of prosperity.

In the year 1870, the original confederation of the four older Provinces was increased by the admission of the North-Western Territories and Manitoba, and in 1871 by the entrance of British Columbia, and it was upon this last accession of territory that the construction of the Canadian Pacific Railway became a legal, political and commercial necessity. It was under the distinct pledge that a railway should be immediately commenced from the Pacific Ocean to join the Canadian system, and should be completed within ten years, that British Columbia was induced on the 20th of July, 1871, to join the Dominion of Canada, and on that same day the surveys for the present line were actually commenced in the Pacific Province, and the work was never discontinued. This portion of the agreement with British Columbia became, however, the subject of a vast deal of debate and animadversion, the result of which was a considerable delay in the prosecution of the works, and the extension of the time for the completion of the road for a further ten years, or until 1891.

When the Canadian Pacific Company signed the agreement with the Government on the 21st of October, 1880, none of the 2,000 miles that had to be constructed was commenced, or even surveyed, whilst of the 700 miles that were to be completed by the Government and handed over as part of the subsidy, only 65 miles of the old Pembina Branch were constructed so as to be of any service to the contracting company. This agreement became law on the 1st of February, 1881, and on the 2nd of May following the Government handed over as part of their bonus 176 miles of completed railway in the neighborhood of Winnipeg, and it is a significant fact that this transfer was made about the same date that by the agreement with British Columbia in 1871 the whole railway was to have been completed from ocean to ocean.

As soon as the present Company assumed possession they decided upon an entire change of route from the line originally surveyed and adopted by the Government for the Western division of the work. The original proposition was for the main line to cross the Red River some 20 miles north of Winnipeg, and taking a north-west direction, pass north of Lake Manitoba to the valley of the North Saskatchewan, and thence by the Yellow-head Pass to the valley of the Frazer River. The new location placed Winnipeg on the main line, made this rising city the point of conveyance of a number of branches, serving amongst them the whole district south of Lake Manitoba, and thence taking a westerly course to the South Saskatchewan followed the valley of one of its tributaries through the mountains to the Frazer River on a course a 100 miles shorter, and altogether to the south of the original location.

By the end of the year 1881, the Company had completed 165 miles to the West, from Winnipeg to Flat Creek, and they had built branches and acquired from the Government 176 more of the Winnipeg Division, whilst at the Eastern end of the road they had acquired the lines of the Canada Central and its extension to Ottawa, giving them a length of 257 miles, being a total of 599 miles of railway in operation, and making the eastern terminus of the line the city of Ottawa, instead of the legal but unimportant Callander which their charter had designed as the commencement of the Pacific Railway.

For the season of 1882 great preparations were made for a busy year's work, and on the 11th of March a contract was made with Messrs. Langdon, Shepard & Co. for the construction of the whole prairie section from Flat Creek to Calgary, of which 500 miles were to be completed during the season, and the whole length, 677 miles, by the 15th of August the following year. As this is probably in many respects the most remarkable and difficult work that has ever been undertaken under the same circumstances, it may not be uninteresting to go somewhat fully into the details of this contract, the means by which it was accomplished in the short time given by the agreement, and the general results obtained by the system employed for its rapid installation. The country was at that time comparatively unexplored and entirely uninhabited. Every workman to be employed had to be brought from a distance, and a large body of men had to be suddenly collected, organized and set to work in a district without any appliances in existence for their maintenance or comfort, where there were none of the materials on the ground for the construction of the line, no food to be locally obtained for the men and but little for the horses. In addition to the other difficulties of the situation, the season was very wet and backwaid, and a most unusual spring freshet flooded all the streams and low lands, saturated the tenacious clay of the prairies, and made it almost impossible for the passage of either men or horses. It was well into the month of May before these floods were sufficiently abated to admit of working to advantage, and the 1st of June before earthwork operations could be satisfactorily commenced. Under these adverse circumstances Messrs. Langdon & Shepard commenced their race against time, but by the 8th of November the early winter had fairly set in, and the necessity was forced upon them of dismissing most of their men and retaining only such small crews as could complete work already commenced, or by making preparations for the work of the ensuing season. But during the brief season of a little over five months, 6,102,210 cubic yards of earth had been moved, 411 miles of main line had been built, 388 miles of track had been laid and opened for traffic, besides thirty miles of side tracks, and the engineers had surveyed and definitely located 620 miles of new continuous railway.

In addition to this the Company had commenced and finished in the Winnipeg district 114 miles of branch lines, they had extended the main line 45 miles on the eastern division, the Government had turned over to them 41 miles of completed road from Telford to Rat Portage, and they had acquired by purchase from the Government of Quebec that portion of the Provincial railway extending from Montreal to Ottawa 120 miles with 42 miles of associated branches. At the end of the season the Company had under operation on the eastern division from Montreal to Lake Nipissing and branches 464 miles and on the Central Division from Rat Portage to Swift Current 718 miles of main line and 200 lines of branches, a total of 1382 miles against 599 miles the previous year.

In 1883 Messrs. Langdon and Shepard were enabled to commence their grading operations by the end of March, and track-laying on the 18th April. The daily record of progress this season exceeded in every point the operations of the year before and enabled them to complete the contract to Calgary by the 15th of August, the very day named in their original agreement. In fifteen months, with the delays of starting, the loss of time by the floods of the Assiniboine and Red River Valleys and the interruption of a winter, they had completed 677 miles of main line and 48 miles of sidings. They had moved ten million yards of earth and completed satisfactorily and well a feat in railway construction that will not unlikely remain for a number of years the best record of work that has yet been accomplished, a wonderful proof of executive ability, and a monument to their untiring energy, and skilful application of the resources at their command.

Nor must it be supposed that because the road was rapidly completed, the work was insignificant, badly finished or temporarily disposed of. On the contrary, the amount of earthwork per mile is heavier than is usual on prairie roads. The average amount of earthwork from Winnipeg to Calgary was 16,300 cubic yards to the mile. With the exception of one short length near the Saskatchewan crossing, the maximum gradient is only 40 feet to the mile and the curves are nowhere more severe than a 4° or a radius of 1433 feet. Each night saw a certain definite length of the road absolutely completed, the ties all in position, the rails thoroughly spiked, and the whole left in complete running order, and ready not only for the construction trains to run over without injury to the rails, but for the ordinary traffic to be conveyed the moment the necessity occurred for its inauguration.

In anticipation of the completion of Messrs. Langdon and Shepards' contract the Company made preparations early in 1883, to complete that portion of the line which commenced at Calgary where the railway begins the eastern ascent of the Rocky Mountains and passing through the great backbone of the Continent and the rough district of British Columbia to a junction with the section being constructed by the Government from the Pacific Ocean, and early in April the engineering staff of the Company consisting of nine locating and fourteen construction parties left Winnipeg for their destination, some of them having to travel more than 500 miles over the prairie in carts and by pack horses over the mountains to reach the commencement of their labours. A constant communication was maintained with each of these parties by a courier mail service and the head office was in daily and direct advice of every particular of the movement of each separate camp whilst this survey was in progress.

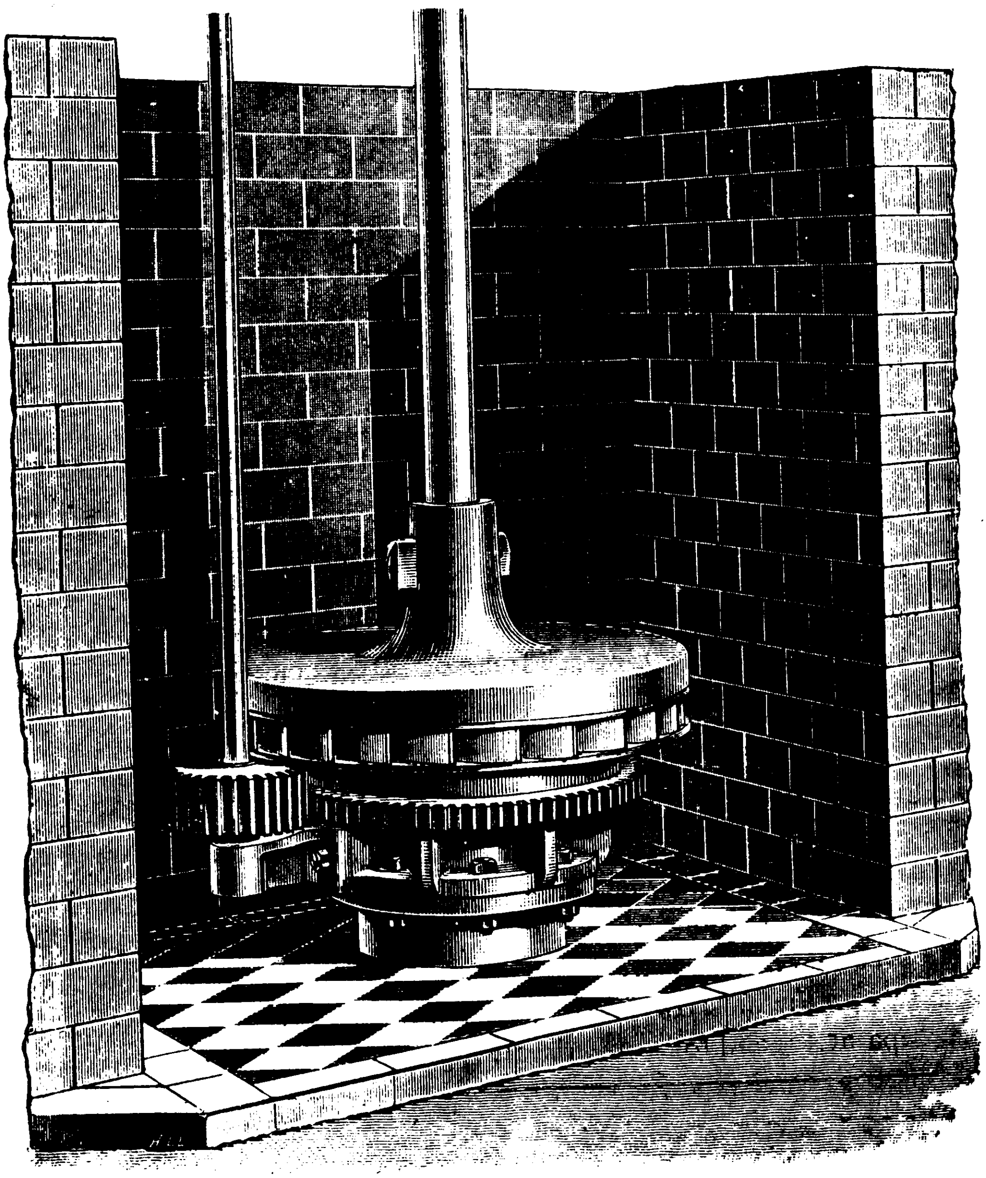
During the season of 1883, the Company completed 123 miles of road carrying the end of the track to the summit of the Rocky Mountains, 962 miles west of Winnipeg. This was reached on the 27th of November, the 123 miles having been completed in 80 working days.

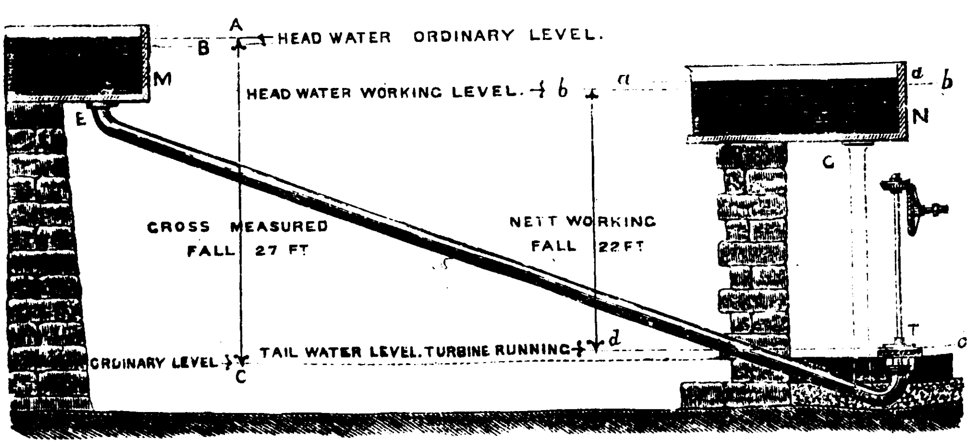
The total mileage under operation at the end of the year the third of the Company's existence was on the Western Division from a point 100 miles east of Port Arthur to the summit of the Rockies—1495 miles of main line and 244 of branches and on the Eastern Division from Montreal to Lake Huron 445 miles of main line and 199 of branches.

Besides this the Company had constructed on their Ontario Division 200 miles from Perth to Toronto and they had acquired by lease and purchase the Credit Valley Railway with its branches—184 miles—and the Toronto, Grey and Bruce of 196 miles so that at the end of 1883 they had under operation 2963 miles of finished road against 1382 in 1882 and 599 in 1881, the annual mileage brought into operation being 599 miles, 783 and 1581 a record that so far has not been approached by any existing corporation.

Turning to the other sections of the railway upon which the construction has not been under the direct control of the Company, the most important section was the length from Lake Superior at Port Arthur to Winnipeg. For a long distance the works upon this division of 429 miles were extremely heavy, the country was uninhabited and for some distance the line passes over a succession of rocky ridges, wastes and muskegs; but for the last three years large parties of men have been at work wherever they could be advantageously employed, and early the last year the whole section was turned over to the Pacific Company as a continuous running line, although unfinished in many

TURBINES.




A
B
HEAD WATER ORDINARY LEVEL.
M
HEAD WATER WORKING LEVEL. b
a
a b
N
E
G
GROSS MEASURED
FALL 27 FT
NETT WORKING
FALL 22 FT
T
c
d
ORDINARY LEVEL
TAIL WATER LEVEL. TURBINE RUNNING
C

of its details, and it has since been in process of improvement and completion without however interfering with the regular running of the trains.

The Pacific end of the road 215 miles in length has been under construction for some years and though now almost completed has not yet been handed over to the Company. A large force of labour principally Chinese has been constantly employed for the last four years and this difficult section has now been finished. The prominent feature of this portion of the road is the passage of the railway up the gorge or canyon of the Frazer River, and the great iron cantilever bridge which carries it at an elevation of 125 feet over the ordinary height of the water across its boiling tumultuous current. The water here often rises as much as 60 feet within a few hours and any ordinary construction involving temporary staging or scaffolding would have been impossible in this locality. The bridge as completed is 525 feet long between the rocky anchorages in each side, the projecting levers being each of them 210 feet in length and carrying between them a girder 105 feet long. The centres of the levers are carried by stone piers 72 feet in height, grounded upon the solid rock on each side of the river and the strains of the superstructure are calculated to carry a train weighing 1¼ tons to the lineal foot and extending over the whole bridge, headed by two of the heaviest locomotives each with a concentrated weight on its driving wheels of 26 tons.

At the end of 1883 only two gaps remained to be filled up to complete the Pacific Railway—2900 miles long from Montreal to the Pacific coast. These were from Sudbury Junction 444 miles west of Montreal to the completed portion on the north shore of Lake Superior 449 miles, and from the summit of the Rocky Mountains to the end of the Government Section in British Columbia about 290 miles. On the first of these gaps not only is the work being rapidly pushed from either end but the ground is accessible at almost every part and the whole length is under rapid construction. About 70 miles of rails have already been laid from Sudbury west and track-laying has been commenced at several points around the Lake. 9000 men are employed upon this division and each day's work is rapidly filling up the gaps that intervene between the completed portions of the line. At the western gap the work is heavy, especially the descent from the summit of the Rockies to the Valley of the Columbia, but it is all under construction. A considerable length of rails has already been laid west of the summit, and the Kicking Horse Paas is being rapidly smoothed down for the passage of the "iron horse."

*(To be continued.)*

---

EFFORTS to cultivate the tea-plant are now being made in several parts of Europe. In France, on the lower Loire, the plants have been extensively set ; but it is still a question whether the leaves will retain their characteristic aroma on a foreign soil. In Sicily the plants set three years ago at Messina are strong and healthy, and have flourished in leaf and seed. Russia has also made the attempt, the first planting being at ten versts from Aleschbri on the Dnieper, and proving satisfactory ; and plants have also been sent from Odessa to Suchum. In Germany the Silesian committee of agriculture have received seed and directions from Professor Göppert of Breslau, with a recommendation to attempt their cultivation.

## TURBINES.

BY ARTHUR RIGG,

### HIGH PRESSURE TURBINE, 92 FEET HEAD, 80 H.P.

The illustration Fig. 1, page 340, is taken from the photograph of one of the best descriptions of these patent turbines. It is working from a clear head of 92 feet, or 40 pounds per square inch, and producing 80 horse-power, while maknig 450 revolutions per minute. The guides, buckets and sluice are made of the best gunmetal ; and the turbine runs with perfect freedom from vibration.

### GENERAL CONSIDERATIONS.

In every description of turbine it is an object of the designer to reduce the velocity of a stream of water and its pressure by converting both into the rotation of a shaft. This is done by conducting the current through fixed guides, by which it is directed into a spiral or screw-like form, and the buckets of a revolving wheel are opposed to these streams in such a manner as to yield under their impact or pressure, so giving a rotary motion to any shaft with which the buckets may be connected. So long as the proportions of passages and the curves of guides and buckets are properly proportioned, turbines constructed in any of the four types hereafter noticed will give results which are practically identical as far as the economical use of water is concerned.

For any particular locality, therefore, that form of turbine may be chosen which lends itself most conveniently to the conditions of prime cost and available space under which it is required to work, and it will be useful briefly to refer to the actual horse power obtainable from water-falls, and to pass under review some of the more usual considerations for which one or other class of turbine is preferred.

### VARIOUS DESCRIPTIONS OF TURBINES.

Turbines are usually considered as belonging to one of three different classes, which receive their designation from the direction in which the entering streams of water flow in relation to their axis. There exists also a fourth, or compound class, in which the direction of motion of entering streams may be considered as belonging to some two of the first three types. It will be convenient to describe each separately, and to summarize their respective advantages.

### CLASS I.—INWARD FLOW TURBINES.

In the oldest class of impact wheels, the prototypes of modern turbines, streams of water were directed from the circumference inwardly, and this direction of the current finds renewed favour with some manufacturers in England and America.

These are useful where a steady, unchanging head or pressure of water is available, and they possess an advantage in maintaining a fairly regular speed under varying loads without a governor Although these turbines require an intricate arrangement for adjusting the "Gate" or area of openings by which water is admitted, yet they give certain facilities in construction, and are easily regulated by hand.

### CLASS II.— OUTWARD FLOW TURBINES.

M. Fourneyron's improvements led to a reversal of the direction in which streams flowed, and he guided them from the centre of the wheel to its circumference, a plan which has been most extensively followed in England and America, and of which illustrations are given in pages 341 and 344.

This class of turbine is easily accessible, and free from all complicated shutters for regulating its supply. It also can vary in speed without losing its high rate of efficiency, but is not so steady under an irregular load as the inward flow turbine. This defect can, however, easily be remedied by hand regulation or a governor, and it leads to a peculiar advantage which this class of turbine possesses over others when the fall of water varies and the load is tolerably regular. Such falls are far more common than those of extreme regularity, and it is therefore important to have a turbine that can run at a uniform speed without loss of efficiency with variable falls ; and the outward flow turbine possesses this necessary qualification in a higher degree than any other kind that is made.

One of the patent governors applied to regulate its sluice will produce a greater regularity than is possible with any ungoverned inward flow turbine ; and thus, by acquiring a regularity greater than any of its competitors, and retaining special advantages, the outward flow turbine becomes better suited than any other kind for the usual circumstances and considerations of practical work.

CLASS III.—PARALLEL FLOW TURBINES.

When it is required to insert a turbine in a pipe or narrow channel it is most generally convenient to direct the current downwards, in the form of a screw, giving rotation to a wheel enclosed in a cylindrical case. For considerable volumes of water at a low fall, and for replacing a water-wheel by a turbine, this form offers peculiar advantages. It is also extremely cheap so far as ironwork is concerned, and can be fairly well regulated by hand.

CLASS IV.—COMPOUND FLOW TURBINES.

Various combinations of Classes I., II. and III. are used, principally by American patentees, many of them being apparently more for the purpose of establishing a claim to novelty than for any advantage secured thereby, for it is not a matter of any consequence whatever in what particular direction a current is guided, so long as its initial velocity is gradually diminished until there is only enough left to carry the water out of the turbine buckets.

VERTICAL OR HORIZONTAL SHAFTS.

These different classes of turbines are understood to run in a horizontal plane, with their shafts vertical, but it is easy to construct any of them to run in a vertical plane, with their shafts horizontal.

This latter arrangement involves some modifications in design and increased cost in their construction, but it is sometimes found extremely convenient. It makes the motor self-contained, and lends itself readily to placing any turbine that always works full bore at any elevation above the tail water up to 20 feet, or less in hill districts, where the atmospheric pressure is not so great as at the sea level.

HORSE-POWER OBTAINABLE FROM WATER-FALLS.

In reckoning up the power of turbines it is sometimes assumed that the entire vertical fall or head of water may be taken as available for driving them. But this never can be the case, for various losses have to be taken into consideration before the net working fall can be ascertained with correctness.

The diagram Fig. 2, page 340 is intended to explain generally these sources of loss, which vary greatly in amount under different circumstances; it must theresore be noted that the example given for the sake of illustration is intended for the purpose only of making the subject understood, and not as embodying any general law.

A wooden lander or trough M, leads a stream of water to A, where, when all is still, its level stands at an elevation of A C, above the tail race at C, taken as 27 feet in this example. In order to convey the supply to a turbine at T, cast-iron piping is needed of a length here assumed as 75 feet.

On opening the sluice the stream begins to flow, and a lowering the head-water ensues to an amount dependent in part upon friction against the sides and bottom of the channel. A corresponding rise occurs in the tail-race, and both these represent losses of head, which may be taken together as 9 inches. It is well also to allow (say 6 inches) for occasional floods, making the diminution of head from these causes 15 inches altogether.

But power is needed also for overcoming friction in the supply pipe, and its proportionate amount depends upon their capacity for conveying the quantity flowing through them. This power may most conveniently be considered as a percentage of the entire fall lost upon whatever length of pipe is employed, and may vary from 2 to 10 per cent. If the supply is scanty, then large pipes should be used, but if cheapness of first cost outweighs a permanent loss of power then the loss may vary from 5 to 10 per cent. In the present example the proportion of 5 per cent. upon 75 feet is assumed, and this is equivalent to a loss of 3 feet 9 vertical head.

Thus, although the measured vertical fall is 27 feet when all is still, yet when the turbine is running it is necessary to deduct 1 foot 3 and 3 feet 9, or 5 feet altogether, before arriving at the working fall. All calculations as to power and efficiency must be based upon this working fall, so as not to be misleading; and the proportion of loss that must be allowed in any special case depends entirely upon local circumstances.

Had the tail-race been cut further into the inside, or the head water been brought vertically over the turbine, only 25 feet of supply-pipe would have been needed; this saving the original cost of 50 feet, and, what is more important, adding the equivalent of 2 feet 6 inches extra head for driving the machinery.

Every 550 pounds of water falling 1 foot per second, or every 33,000 pounds falling 1 foot per minute, is taken to represent one horse power, but it is impossible for more than a proportion of this to be realized through a turbine or any other contrivance on account of these losses which vary considerably in amount, and no method of construction can avoid them altogether, and all that can be done is to minimise their influence. The results obtainable in practice generally vary from 60 to 80 per cent., of the amount of work due to the working fall and quantity of water; the higher values being obtained from larger turbines, by increased care in construction, together with certain differences in design, which are applicable to any form of turbine, and well understood by those who are experienced in the general principles upon which all these motors must be arranged to work satisfactorily.

Somewhat higher efficiencies can be readily obtained from turbines of any description, but at enhanced cost in construction and at greater risk of their becoming choked in use. So that dynamometer tests, not to be misleading, should be taken not only when a turbine is new, but also after it has worked awhile; then it will be found that frequently only a lower efficiency remains permanent, while the higner one has proved itself temporary and evanescent. Consequently, it seems wiser to be content with a more durable result in the first instance rather than attempt to secure more than can be permanently maintained in the rough usage of practical work.

CHEAP TURBINES FOR LOW FALLS—PARALLEL FLOW TYPE.

The illustration, page 341, represents a simple inexpensive form of turbine of the parallel type. It is one of several made by the writer in 1870 to be driven by sewage water at Croydon; since that date these turbines have only required new footsteps once, giving no trouble whatever in any other respect.

For replacing water-wheels—or for situations where regularity of speed is not important—for being driven by any foul supply, such as sewage water—for cheapness of original construction and durability under unfavorable conditions—this arrangement of parallel flow turbine can be applied with the best results.

Water flowing over its guides is admitted through any desired number of them by opening leather-faced valves according to the quantity and power required. Directed by curved channels into a spiral descending course, the currents impinge upon the opposed concave surfaces of numerous buckets below, and while imparting to them the tangential elements of their velocity, thereby causing the vertical shaft to rotate, the currents themselves are re directed into a downward course of a diminished velocity, and then flow away along the tail-race.

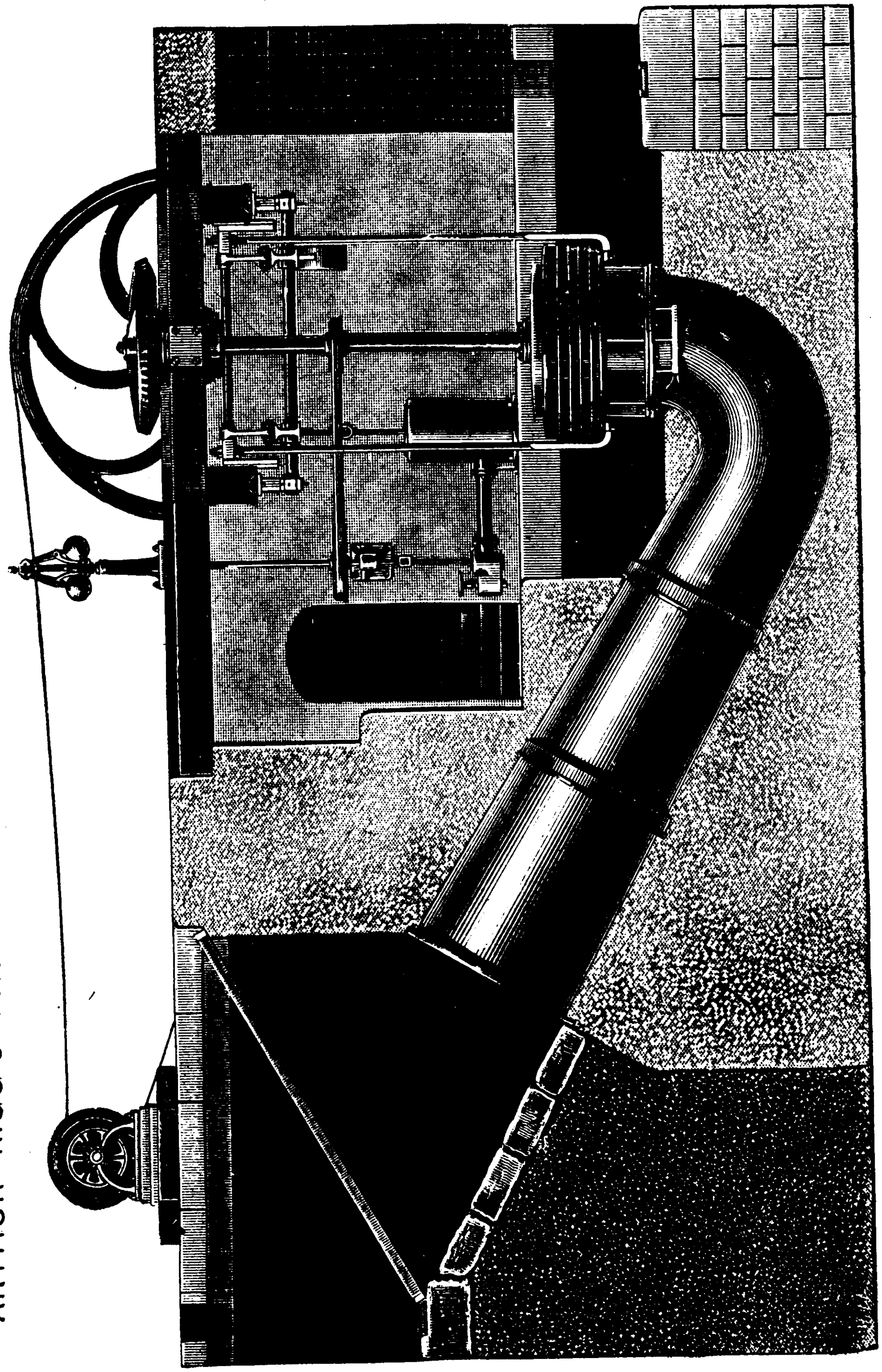
PARALLEL TURBINES FOR HIGHER FALLS.

When desired to enclose a turbine within the narrow area occupied by its supply pipe, or where no space is available for the convergent inlet of Class I., or the divergent outlet of Class II., then the parallel form of turbine can be used with great advantage, and for any desired fall—provided the full supply is always used. Under these conditions it can be conveniently fixed at a height less than 20 feet above tail-water level, and thus driven to that extent by suction.

FIRST CLASS PATENT TURBINR FOR LOW FALLS OUTWARD FLOW TYPE.

Wherever original cheapness is not the first consideration, and the economical use of a stinted water supply, or a uniformly governed speed is essential, then the Outward Low Turbine, as illustrated on page 344, is found the most suitable form that can be applied.

It is constructed to work by the combined forces of Impact and Reaction, so securing the highest efficiency; and, being closely regulated by the Patent Hydraulic Governor, a uniform speed can be relied upon, however the load varies. A usual form of this type of Turbine, as made in France, Germany, and America, receives its supply from above, but this construction is open to a serious objection, inasmuch as it causes the Wheel and its working parts to be complicated and difficult of access,

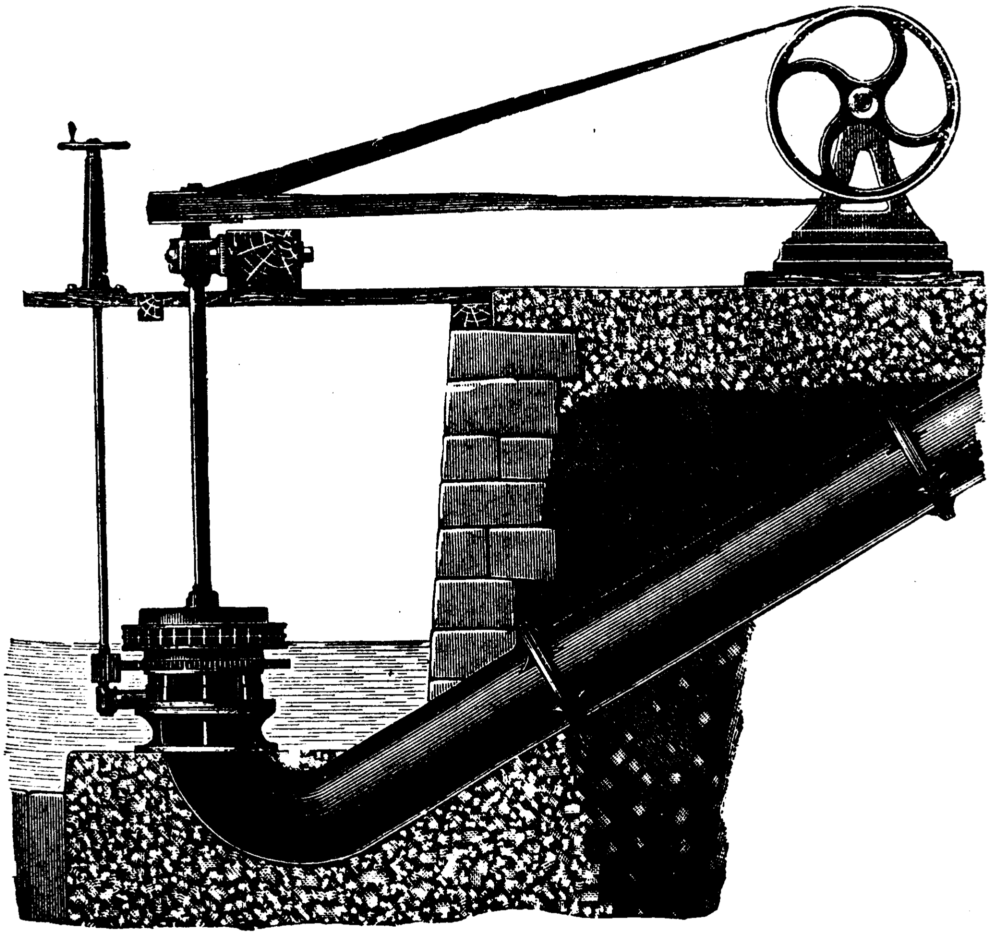


ARTHUR RIGG'S PATENT OUTWARD TYPE TURBINE FOR LOW FALLS.

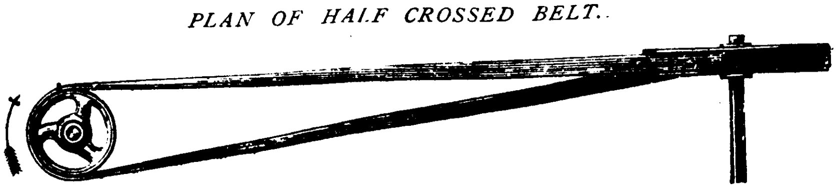
# HIGH FALL TURBINE,

## WITH PATENT REGULATION BY HAND.

*Side Elevation.*



*PLAN OF HALF CROSSED BELT.*



through being covered by the Inlet Pipe and Guiding Channels.

By bringing the supply from below, through an Inverted Syphon, all such inaccessibility is removed, and there is no loss of head through this arrangement more than by the friction through pipes, which is a loss common to all systems. As the streams of water pass horizontally out of the Guides they impinge against opposed Concave Buckets, and a revolution of the Main Shaft is produced from which any required machinery may be driven.

Surrounding and outside the Guides there is a Cylindrical Sluice, raised or lowered by hand, or by the action of a Governor, hereafter to be explained, admitting more or less water into the Buckets, and so regulating speed or power. It is well-known that when Turbine Buckets are running more than half empty there is a falling off in relative efficiency, and to avoid this loss it has been arranged that separate tiers of Buckets shall be employed where there is a prospect of great variation, and while the filled tiers are working up to their best results any deficient duty of a single unfilled tier bears so small a proportion to the whole that it is found of no practical disadvantage whatever in the working of this class of Turbine.

### PATENT-HIGH FALL TURBINE.

The illustration on page 345 represents a small High Fall Turbine, with vertical shaft, provided with a pulley at the upper end, from which a half crossed belt transmits motion to a larger pulley on a horizontal shaft.

The Patent method of regulating the speed of this Turbine consists of a spiral or screw, cut on the outside of the supply pipe upon which the Regulating Sluice rotates. A Segment Spur-Wheel attached to the Sluice and moved by a deep pinion, or by one mounted on a screw, causes a rotation of the sluice, which thus is screwed up or down, and so determines how much opening there shall be in the Supply Guides of the Turbine.

When there is great variation in power required, or in the water supply, the Turbine is constructed in several tiers, so that the lessened efficiency of half-filled buckets shall not greatly affect the total duty performed by whatever quantity of water is being used at any given period.

This seemingly simple arrangement of Pulleys requires some care in erection, in order that the belt shall run without any tendency to fall off.

Half-crossed belts can only be driven in one direction, and are particularly well suited for transmitting power and reducing speed for running Turbines with vertical shafts, and they may often be found to save the necessity for erecting the more expensive Turbines with horizontal shafts, referred to on page 000.

In the plan, page 000, an arrow indicates the direction that a belt must travel, and it shows that the only condition to be observed is for a belt to lead away from one pulley into the plane of the other. For those unaccustomed to this method of driving, it would be best to make a rough model of any proposed arrangement, so as to ensure the machinery working correctly.

### GENERAL REMARKS.

All Turbines described in this pamphlet are constructed specially for individual requirements, and not stock sizes, made up to suit incongruous conditions. The cost of Turbines varies in proportion to the economical use of water required for them ; but in order to guide intending purchasers the following list has been compiled. All Turbines included in it are of such proportion as will give a regular duty of from 60 to 80 per cent., the larger sizes giving the best results, but it must be understood that cheaper or more expensive Turbines can be made, giving lower or higher returns.

In every case a sluice is included, with hand regulations, but not the Syphon Pipe upon which the Turbine stands, or any other pipe. Each shaft is assumed 10 feet high above the level of the Tail-Water, and an upper pedestal is included, but not the guide or beam to which it may be fixed. The footsteps are made self-lubricating and practically show no wear for many years.

### TURBINES FOR EXCEPTIONALLY HIGH PRESSURES.

*From* 100 *lbs. to* 1,000 *lbs. per Square Inch.*

By a modification in the construction of one class of these Turbines it has been found possible to run them at moderate speeds when driven by pressures varying from 100 lbs. to 1,000 lbs. per square inch, or the usual Hydraulic Peressure of 1,600 feet.

Thus a cheap simple machine, and one running with perfect regularity is made to supersede Hydraulic Engines, and, by knowing the pressure, power and revolutions per minute required, any desired condition can be fulfilled.

These Turbines will be found particularly useful where towns have a constant high pressure service, or where an artificial pressure is distributed through special mains.

Particular and prices will be given on application for Turbines to run at any desired speed, driven by pressures, however high and up to any power.

*General Memoranda on communicating Particulars of Turbines required.*

In communicating particulars of any situation where it may be contemplated to erect a Turbine it is very desirable to supply a general plan and elevation or sketch of the intended site, and also to furnish particulars of

I.—Quantity of water flowing per minute.

II.—Vertical elevation of fall measured from head of water to Tail-Race when both are at rest.

III.—Actual horse-power required to do the intended work, remembering that the misleading term "nominal" horse-power applied to engines is happily unknown in relation to Turbines.

IV.— When it is intended to replace an ordinary Water-Wheel by a Turbine, particulars of situation, speed and diameter of the main shaft should be given.

V.—Turbines may be made to run "right-hand" (that is, in the same direction, looking from above, as the hand of a watch laid on its back) or else "left-hand," as desired.

VI.—*Variable Power.*—State whether the fall is constant; also whether the quantity alters through different seasons, and give the variation.

VII.—*Regularity of Speed*, —Where this is important, and cannot be sufficient secured by hand regulation, a Governor is generally required.

Horizontal Turbines described on page 000 are entirely self-contained, requiring no separate outer bearing, and their costs are twenty-five per cent. greater than Vertical Turbines of corresponding power.

When it is desired to know the horse-power that can be obtained from any given fall and quantity of water, it is necessary first to arrive at the real working fall by deducting from 5 to 10 per cent. from the statical fall, so as to compensate for the losses described on pages 000. Then knowing the cubic feet of water flowing per minute.—

$$\text{The Available Horse Power} \Big\} \; \frac{\text{Net Working Fall in feet x quantity in cubic feet.}}{700}$$

EXAMPLE.—600 cubic feet of water flowing per minute, gross fall 45 feet, loss (say) 3 feet, gives net fall 42 feet—

$$\text{H.P.} = \frac{\text{42 feet net fall x 600 cubic feet}}{700} = \text{36 H.P.}$$

Using the same data it is as easy to find out the quantity of water required for any given horse-power and fall thus—

$$\left.\begin{array}{c}\text{Quantity of Water}\\ \text{Cubic feet per minute}\end{array}\right\} = \frac{\text{Horse Power x 700}}{\text{Net Working Fall.}}$$

---

A CURE FOR STEAMED AND FROSTY GLASS.—A correspondent writes that a very thin coat of glycerine is a perfect cure for the trouble caused by water condensing on glass ; he first noticed it used on a steam-gauge glass where the gauge leaked inside. Surveyors can use it on their instruments, and it does not injure the usefulness of field-glasses. It is very useful when applied to the windows of locomotive cabs in bad weather. The only disadvantage is that it collects the dust, and for this reason it should be applied very thin, and rubbed off and renewed when the dust collects to an injurious extent.

## GRASS OF PARNASSUS.

BY GRANT ALLEN.

As we have been going in lately for a course of coincidences in KNOWLEDGE, I will begin this paper with a sufficiently curious one which happened to me during my summer holiday the other day in Norfolk. I had walked over by the breezy cliff path from Cromer to Beeston Common, and had been diligently investigating for a whole sunny afternoon the exceptionally rich boggy flora of that pretty bit of the deep, waterlogged moorland scenery. The ground, for acres together, was covered with pale yellowish-green rosettes of tufted butterwort, and tall lush trefoils of beautiful buckbean, and golden clusters of belated marsh marigolds, blossoming still out of due season. But the prettiest flower in all the wide stretch of swampy vegetation was the white grass of Parnassus, whose exquisite veined blossoms starred the soil on every watery patch in the most astonishing profusion. I stood for a long time watching the flies buzzing idly around them, and then picked a number out of pure wantonness, to take home with me as an appropriate tribute to a great poet who was staying in the neighbourhood. As soon as I got back, I put the drooping flowers in water, and proceeded to open the letters which were waiting for me on the parlour table. The first one at which I looked had been forwarded to me by the Editor of KNOWLEDGE, and it ran as follows :—

SIR,—Would Mr. Grant Allen or any of your botanical contributors kindly state what useful object (if any) is attained in *Parnassia palustris* by the very curious development of its imperfect stamens, and oblige. A STUDENT OF BOTANY ?

Clearly this was the finger of fate. *Parnassia palustris*, with its abortive stamens, was staring me in the face from the glass in front of me ; and I had been spending all the afternoon in watching the flies in the very act of being taken in by the deceptive staminal organs in question.

First of all, then, let me begin by briefly describing this grass of Parnassus. It is a marsh-land plant, of the saxifrage family having some affinities with the sundew, but even more (as has been recently shown) with the true saxifrages and chrysosplenium. From a small tuft of heart-shaped, glossy-green, radical leaves, a rather tall scape rises abruptly, enclosed half-way up by a curiously clasping leaf, and bearing at its summit a single, large, snow-white flower. The blossom has five petals and five perfect stamens ; but the place of the five inner stamens (which occur normally in the saxifrages) is taken by some very strange abortive organs, at the base of the petals, split up into eight or ten short, spreading filaments, and terminated at the end, where the anther ought to be, by a little, yellow, shining, globular gland. So very bright and glassy are these tiny balls that they look for all the world exactly like a drop of liquid ; and the imitation goes so far that even when one has touched them with one's finger it is difficult to believe they are not really glistening drops of limpid honey. These are the organs whose use and function "A Lover of Botany" wishes to learn about.

It was Hermann Müller who first pointed out the true meaning of these odd staminodes. They are really deceptive organs, which attract flies and other insects by the fallacious appearance of a store of honey. "The yellow knobs placed at the ends of the hairs," says Müller, "look so extremely like drops of fluid that it needs close examination to convince one they are thoroughly dry. An observation of my son's proves that even flies are taken in by the appearance of liquidity. He saw from a short distance a specimen of *Eristalis nemorum* trying to lick these bodies for a long time, until at last it flew away on his coming closer." I myself observed exactly the same thing several times over at Beeston Common ; the flies alighted on the disk of the pistil, and tried hard to lick honey, over and over again, from the small, dry glassy bulbs.

We have thus, as Müller remarks, in grass of Parnassus an excellent example of a deceptive flower, which deludes the foolish flies by offering them a number of conspicuous but sham drops of honey. At the same time, the deception is not quite absolute, for the staminodes have a broad base, which secretes two small lots of nectar in two shallow depressions on its inner side. This honey is sufficient to prevent the flies from altogether discovering the imposition, and giving up the hunt in future as useless. After long and vain attempts to find nectar in the deceptive glands, they are at last rewarded for their pains by a much smaller store laid by in the depressions at the base of the staminodes.

The perfect stamens lie at first with their anthers coiled up over the immature pistil, and they ripen slowly, one at a time, each anther as it begins to shed its pollen bending over outward, so as to come into contact with the head and shoulders of the fly who is busily hunting for nectar among the false staminodes. As soon as all the stamens have shed their store, the stigmas of the pistil become fully mature, so that the flies in visiting the younger flowers, collect pollen on their heads and legs, which they finally rub off upon other blossoms in the second or female stage. This, of course, is a common and familiar device for ensuring the benefits of cross-fertilisation.

It is worth notice that such deceptive flowers occur most especially among the species which lay themselves out to attract the true flies (Diptera). Flies appear to be far more stupid and unintelligent than bees, sand-wasps, moths, and beetles, and therefor more liable to be taken in by simple forms of floral deception. Thus the carrion-flies are imposed upon by many reddish flowers (of which the great oriental *Rafflesia Arnoldi* may be taken as a type)—flowers that imitate putrefying meat in colour and odour, and so induce the flies to lay their eggs upon the surface, and incidentally to cross-fertilise the alluring plants. In the common English arum, again, a very small fly is tempted by the odour to imprison itself behind a *chevaux-de-frise* of hairs ; which also happens somewhat differently to another species in the long tube of the south-European birthwort. Müller notes other instances of pure deception in *Ophrys*, *Paris*, *Stapelia* and a few more flowers, every one of them designed to take in various species of Diptera. There can be very little doubt that this consensus of condemnatory evidence points to an exceptional degree of stupidity on the part of the two-winged order.

On the other hand, the æsthetic taste of the flies is distinctly high. The colours of the flowers which we owe to the selective action of Diptera are generally pretty ; and the grass of Parnassus in particular, which is a creation of the drone-fly group (*Syrphidæ*), is one of the most beautiful and gracefully marked of English flowers. A still more curiously variegated and dappled ally, which also owes its colouration to the selective action of the same family, is the pretty little London Pride of our rockeries and flower gardens. Hardly less delicate is the sky-blue germander speedwell of our hedgerows, yet another production of the lively flies. As in so many other cases, the taste for colour, produced by the search for food among bright blossoms, has re-acted through sexual selection upon the general aspect of the insects themselves ; and several of the Syrphidæ are noticeable among all Diptera for the unusual brilliancy and variety of their dainty hues. In fact, wherever in nature we find bright plumage or metallic lustre, we may be almost certain that the creatures which display it feed among crimson and purple flowers, or else among red and yellow tropical fruits.—*Knowledge*.

---

SELF-REGISTERING RAIN-GAUGE.—The self-registering rain-gauge is made on the principle of weighing the rain-water, and consists of two parts, the weighing apparatus and the registering apparatus.

From the receiving-vessel the rain-water flows to the collecting vessel, which, to prevent evaporation, has the smallest possible opening at the top, and is provided with a tap at the bottom to run the water off. A later improvement is to run the water off by means of a syphon, and thus let the receiver be self-acting. The collecting vessel hangs on two wires, which pass over two pairs of pulleys, and are attached to the last of them. To these is fastened a lever, at the end of which, by a hinge, hangs a weight. As the weight of water in the collecting vessel increases, the length of the horizontal arm of the weight increases, so as to maintain equilibrium, the increase in the length of the arm being proportional to the increase in the weight of the water. The length of the horizontal arm, which is thus a measure of the amount of rain, is brought to paper as follows. The weight is so hung that it is always vertical, and keeps in a vertical position a light rod which slips through it, and at the end of which is a pencil which records on a strip of paper, passed under it by clockwork at a fixed rate of speed, the length of the horizontal arm. In this way a diagram is made on the paper, its abscissas being proportional to the time and its ordinates to the rainfall.

The weights of the collecting-vessel and of the lever are counterbalanced by weights, and, to diminish friction, all the axles work between steel points.

The defect of the machine at present is, that it does not register snow.

**A NEW APPLICATION OF INDIA-RUBBER.**—*La Nature.*

If iron takes the lead among articles of modern industry in the extent and number of its applications, it yet falls short of india-rubber in their variety. This latter article, indeed, promises soon to attain a universal diffusion. Its industrial career, though little more than just begun, already outstrips that of most substances that were first in the field.

The mere enumeration of its qualities would suffice to account for the diversity of its applications. It possesses so great an elasticity that by this quality alone it adapts itself to a thousand different uses—brace-bands, garters, sides of boots, &c.

Observe how, if not the lightest, india-rubber is at least the most powerful reservoir of mechanical energy known. It lends itself most readily to the restitution, under the form of mechanical labour, of the energy imparted to it by tension, and this restitution may be effected with remarkable quickness. It is owing to the relative lightness of india-rubber considered as an accumulator of energy, and above all, to its power, that the exactness of the principal of "heavier than air" may be demonstrated on a small scale.

From an electrical point of view, india-rubber acts as a better insulator than gutta percha, and is, indeed, one of the best insulating bodies known. At the same time that its specific inductive capacity is weaker than that of gutta-percha, it does not become plastic at a moderate temperature. These properties render it an excellent insulator in electrical applications; submarine and subterranean telegraphy, electric light, transmission of force, etc. While it insulates better than gutta-percha, the conductor, where india-rubber is used, does not run the risk of being put out of centre, as is the case sometimes with gutta-percha.

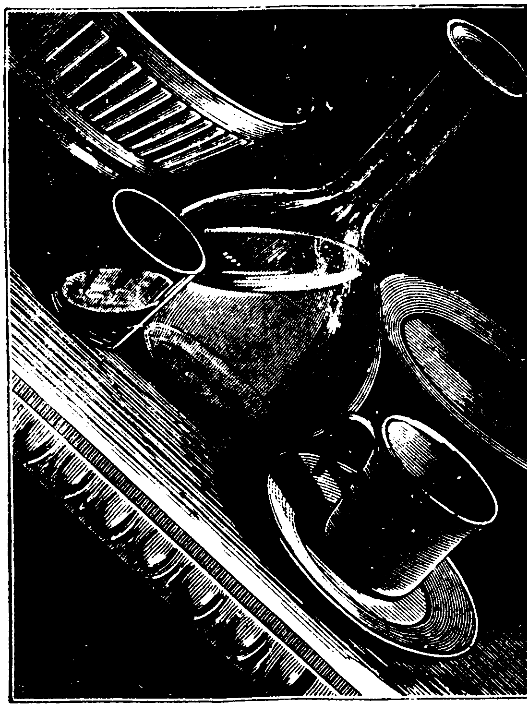


FIG. 1.—Position in which household utensils furnished with india-rubber may be placed without falling.

India-rubber is known to oxidize under exposure to air and light; above all, under alternations of dryness and damp. By subjecting it, however, to a special operation, called vulcanisation, a product is obtained which maintains its flexibility at low temperatures, resists heat much better, does not oxidize in air, and absorbs less water. It is especially under the form of vulcanized india-rubber that its applications are numerous.

There is, finally, a third form of india-rubber, no less useful, that of ebonite, or hardened india-rubber, a form which combines with its lightness and great electrical resistance, the further advantage of resisting acids, and which is therefore exclusively employed when vessels for the electric pile or other reservoirs of a light and not readily brittle character are wanted. Like a new Proteus, india-rubber is thus seen to adjust itself to the ever more numerous and pressing demands of modern industry.

To turn now to the new, curious, and original application an idea of which it is the object of this notice to convey. The aim of the inventor, whose name unfortunately has not reached us, has been to take advantage of the great mutual adherence of a soft and a hard body. It is by the utilisation of this relation that the inventor has originated quite a series of household objects in earthenware, porcelain, glass, etc., which manifest a remarkable adherence to the body supporting them, and this result he has obtained by the very simple expedient of securing to the lower part of all kinds of goblets (Fig. 2) a groove, A A, in the form of a swallow-tail, into which is lodged a band of red india-rubber, a variety of vulcanized india-rubber, forming, when deposited, a kind of circular cushion. Objects furnished in this manner are almost incapable of falling from their places. They may be placed on a wooden table, and the table be inclined (Fig. 1) from 45 to 50 or even 60 degrees without upsetting any of them. The most direct and immediate use offered by the properties which a vessel so provided with india-rubber thus acquires is evidently in the shipping service. At the Fisheries Exhibition of last year in London, and at the Health Exhibition of this year, the inventor has displayed a little barque, the bridge of which is entirely covered with dishes, plates, etc., all furnished in the manner described, and the barque, floating in a basin, may be tossed to and fro, in every direction without displacing a single piece.

All who have been on long voyages at sea know the disagreeable and painful impression produced by the screen of cord laid along the table to prevent the glasses and bottles from falling.

As an accessory advantage possessed by the undisplaceable india-rubber dishes may be reckoned the less noise they occasion, and the less risk of breaking they run on being clapped down carelessly or hastily on the table. Washhand basins and water-pots may likewise be advantageously constructed with the india-rubber band.

Invalids in bed and compelled to eat from a board placed more or less horizontally across the bed, and children so apt to upset glasses and bottles, will both find their advantage in the undisplaceable contrivance. We have thus a simple, ingenious, and useful application of india-rubber, which we thought incumbent on us to place before out readers.

## THE ENTOMOLOGY OF A POND.—*Knowledge.*

BY E. A. BUTLER.

(*Continued from page* 313.)

Scattered about here and there over the bottom of a clear pond may often be seen a number of dark and more or less cylindrical objects lying horizontally. A little watching will reveal the fact that they are living, for they will be seen slowly moving about over the bottom, and, perhaps, presently climbing the stem of some aquatic plant. Fishing some out with a net, we find that each consists of a cylindrical tube made of various materials, and inhabited by a sort of caterpillar furnished with six legs on the anterior part of its body. They are caddis-worms, or case-worms, but, notwithstanding the name, they have only a very remote connection with the true worms, being the larval forms of the order *Trichoptera, i.e.*, the caddis-flies or water-moths.

It is not an easy matter to extract the living occupant from its abode by mere pulling, though it is not in any way attached thereto. In such an animal as a snail, whelk, or winkle the difficulty of extracting the mollusc arises from the fact that it is fastened by strong muscular adhesion to the shell it constructs, but the caddis larva, like the marine tube-worms, merely builds up a case round itself for protection, and is not in any way organically united with it. But by means of certain hooks at the end of its body, it can, like a hermit crab with the molluscan shell it has appropriated, resist very successfully any attempts to drag it forth, and will even suffer itself to be pulled in twain rather than relax its hold. An application of boiling water, however, at once kills the little tenant, and we can then easily draw out its corpse and examine the case at leisure. Should it be desired to extract the animal alive, it must be attacked from the rear. The case is open at both ends, the hinder aperture being the smaller of the two. The head of a pin inserted at this opening and pushed gently forward will so startle the grub as to cause it to relax its hold and advance a little in the tube; a few more gentle "prods" from behind and it completely evacuates its fortress, without damage to itself or injury to its case, into which it will be ready to return at the first opportunity. On slitting open the case we find that the inside is beautifully lined with a tough, thin, papery substance, which is smooth enough, whatever may be the irregularities outside. This material, like the silk of the silkworm, is produced by the insect as a gummy secretion which hardens immediately on exposure.

The nature of the external adornment will depend upon the species we have secured, and upon the materials that may happen to have been obtainable by the larva. Small bits of stick, rushes, roots, or fibres, blackened by long soaking in the water, and completely water-logged, grains of sand or small stones, the leaves of trees or fragments of aquatic vegetation, the seeds of rushes or other plants growing by the water side, and the shells of fresh water mollusca, both dead and living—these are some of the principal materials employed, their exact nature and arrangement being different in different species, and sometimes in the same species at different ages. Some will cut little shreds of vegetable matter, all of the same length, and arrange them side by side in a spiral manner with wonderful regularity; others will take whole leaves of poplar, willow, and other trees, and attach them flatly to the case. Some will select small stones, and stick them on with great dexterity, forming a tube which reminds one forcibly of the exquisite structure made by the marine worm *Arenaria belgica*, which occurs not unfrequently on our sandy sea-shores. Others will strengthen their tube with very fine grains of sand, making a case in shape like an elephant's tusk. Some will select straight bits of stick or rush, and place them longitudinally, when they will sometimes project far beyond the ends of the caselike handles; others, using the same materials, but in shorter pieces, will place them transversely, putting each piece tangentially to the surface, so that the ends form a perfect *chevaux de frese* round the case, which, if looked at down its length, reminds one of a stocking carrying set after set of the needles with which it has been knitted. But unquestionably the most interesting are those that are adorned with shells. Caddis-worms are excellent conchologists, and by obtaining a number of their cases you may get together a very respectable collection of fresh-water shells. Sometimes you get the same shell throughout, when the case is often extremely elegant and symmetrical; but frequently you may find five or six species on one case, and then, if the shells are very dissimilar, of course the symmetry of the structure is destroyed. The most elegant are those formed of the smaller species of *Planorbis*, flat, spirally-coiled shells, something like tiny snakes rolled up. Of these elegant little objects sometimes as many as fifty specimens go to adorn a single caddis case. Then there are the smaller kinds of *Limnœa*, conical, spirally-twisted shells of delicate texture, one or two of which may sometimes be found filling up odd corners, while, projecting here and there, like so many excrescences, may perhaps be seen the stouter and broader shells of *Bythinus*, the mouth of which is closed by a sort of trap-door. Again, we may find the much smaller and more depressed spiral spiral shells of *Valvata*, which, with the spires all turned inwards, sometimes compose almost the whole case, and, lastly, stuck in here and there wherever there is room, the simply conical abodes of the tiny fresh-water limpets belonging to the genus *Ancylus*. But, besides all these, there are the shells made up of two similar parts hinged together—bivalves, as they are called—belonging to the genera *Sphœrium* and *Pisidium*; sometimes a single valve is used, but more frequently the pair, especially of the very common species called *Sphœrium corneum*. This is a tolerably bulky shell, and often exceeds in diameter the case which it adorns, so that if three or four of them are used on one case, it acquires a very irregular form. It is not always dead shells that are chosen; very frequently living molluscs are made use of just as they are,

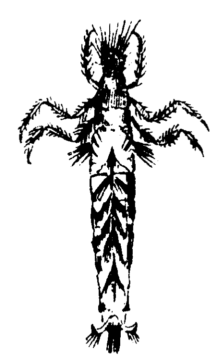


Fig. 1.

though consent to the arrangement does not appear to be sought and the plans of their life must be greatly interfered with by this unceremonious attachment. Mr. McLachlan, the historian of the European Trichoptera, says that he has seen the wing-cases of water beetles sometimes mixed with other things as ornaments to the cases, and even the cases of other and smaller caddis-worms, and that, too, while they still contained their inhabitants. The means of attachment of all these objects is the same silky secretion that lines the tube.

The operations of the insect in the construction of its domicile are very interesting, and may be watched by any one who will take the trouble to eject one from its dwelling and provide it with materials for the formation of another. The two following instances are from the records of the continental observers, Meyer and Pictet. The first refers to the formation of a vegetable case. A larva, deprived of its case, seized a piece of reed, and bit from it a portion of the requisite length; then, cutting a slit in one side, it crawled in and closed up the rent with silk and vegetable débris, and there was the case, fully made. When pieces of reed too short for the case were intentionally given to it, it pieced them out to the required length by cutting off fragments of leaves and attaching them to one end. The other refers to the formation of a mineral case. The larva collected two or three smooth stones of moderate size, and made a low arch by fastening them together with silken threads; then placing itself under this arch, it took up one stone after another, and, with its feet, fitted them in as carefully as a bricklayer would lay his bricks, attaching them to the neighboring stones when satisfied as to their position. The stones were always placed smooth side inwards. In this way it took between five and six hours to complete the case.

If the case should be made too long, pieces are cut off till the right length is obtained. As not only the length, but also the width of the case, is always suited to the size of the animal, it becomes interesting to inquire how the provision is made for growth in diameter; as the creature grows, each new circle added at the anterior extremity is made of rather large diameter, thus giving the whole tube a somewhat conical shape; then the smaller end is cut off, and so by repeated additions to one end and subtractions from the other, the case is always the right size, and thus one can understand how it is that a caddis which begins life with a leafy case may, perhaps, end it with a stony one or shelly one, and that too without ever quitting its tenement. Some species do not seem to be at all particular as to the materials they use, but others are so fastidious that they will rather go unclothed (which, of course, means speedy death) than adopt the wrong material.

The cases hitherto referred to are free, and the larva drags its abode about with it as it crawls slowly along with just so much of its body projecting from the case as carries the three pairs of legs. But many, especially of the smaller species, and those that live in very rapidly running water, make cases which are attracted to stones, and consist of oval, irregular masses of fragments of stones. Some, again, live in company under a common covering of vegetable débris fastened together with silken threads, while others form on the surface of large stones silken canals covered with slime and mud. These latter are supposed to be, to a great extent, carnivorous, feeding on other aquatic larvæ; but the larger kinds are, as a rule, vegetable feeders, eating the leaves of various water plants, which, when adult, they devour entirely, beginning at the edge, but when young they satisfy themselves with the tender green parts between the veins of the leaf, which are more suited to their juvenile capacities than the tougher veins themselves. They will, however, take to animal food when necessary, and will even, on occasion, turn cannibals.

We have now to consider the life-history of caddis worms. The parent insect, a moth-like creature living amongst the vegetation at the edge of the pond, deposits her eggs in the water, sometimes actually descending below the surface, and attaching them to the leaves of water-plants. But it is very seldom that they have been detected doing this. Mr. McLachlan speaks of having seen females of *Phryganea grandis*, one of our largest species, "on a calm summer evening *on* the surface of the water, with wings expanded and trembling, causing a commotion on the surface like that occasioned by a drowning insect; and as they took up the position voluntarily, and were evidently in no danger of drowning," he naturally came to the conclusion that they were depositing their eggs. But, again, on the other hand, females are sometimes found with their wings soiled, as though they had had a muddy bath, and had been contaminated thereby; so that in all probability there are different methods of conveying the eggs to suitable situations. The eggs, when first extruded, are enveloped in a gelatinous mass, and before being deposited in their final resting-place are often, for some time after actual extrusion, carried by the mother attached to the end of her abdomen. When in the water the gelatinous substance swells by absorption of the liquid, and attains twice its former diameter. The eggs soon hatch, but the young larvæ remain two or three days enveloped in the jelly; then leaving their cradle, which by this time is almost in ruins, they begin life on their own account, each constructing a tube for itself, proportionate to its infantile dimensions, and each species, even at this early age, manifesting the power of selecting appropriate materials for its domicile.

The larva (Fig. 1) has a pale, soft body, which is, no doubt, a tempting morsel to fish; and hence the necessity for the protective case. The head and front segments, however, are hard and horny, as they are the only parts exposed when the creature is crawling. The head carries a pair of stout jaws, often notched at the tips. To the three segments immediately succeeding are articulated three stout pair of legs, which have a wonderfully tenacious grip. To different parts of the body are attached in some species isolated threads, and in others bundles of the same, which are respiratory in function, *i.e.*, they contain branches of the tracheæ, and the interchange of gasses is effected in the same way as previously described in the case of the dragon-fly larvæ. At the end of the abdomen of those that construct movable dwellings, there are two short, recurved hooks, by means of which the case is kept in position and dragged along. The larval stage is the great feeding-time; the insect takes no nourishment during pupahood, and probably very little in its adult stage, its only business then being the reproduction of its kind. But the larvæ seem to be able to endure prolonged fasting, and it would appear that they must pass the winter almost with food. After some months spent in the larval condition, the time for pupation arrives. The two ends of the case must now be closed sufficiently to guard the helpless being within from foes, but, at the same time, not so closely as to prevent the access of water for breathing purposes. Some species construct at each end a sort of grating of silken threads, others fix a quantity of vegetable *debris* in the same position. Some take a further precaution still. There is one called *Micropterna sequax*, which inhabits clear running water. This insect, before pupating, elongates its case by adding stones to one end, and then sinks it vertically in the mud, until it is almost entirely imbedded. To do this the larva turns rounds in its case, a gymnastic feat no doubt difficult of performance, but still rendered possible by the flexibility of its body and the dimensions of the case—and, thrusting its head and legs out at the wrong end, digs a hole and so lets itself down; this done, it resumes its ordinary position and patiently awaits its coming change. In three or four days the pupal stage is entered, and the creature is thereby much altered in appearance. It is no longer a caterpillar-like being; but all the organs of the adult insect insect appears—wings, legs, and antennæ being neatly folded down by the side of the body, each wrapped in a separate portion of the pellicle which enshrouds the whole creature. The peculiar arrangement of its limbs gives it a most amusingly sanctimonious expression. It is generally free in its case, though its only movements consist of oscillations of the body. When the time arrives, some two or three weeks after, for making its final transformation, it ruptures the grating at the larger end of its case, darts out of its prison with great speed, swims rapidly through the water by aid of its still encased legs, and on its back, like a water boatman, and thus makes its way to some dry place, where its thin pupal skin splits and allows the soft imago to creep out; some, however, do not take the trouble to leave the water, but, like gnats, merely float on the surfaee, and effect their transformation there, using the old pupa case as a raft on which to dry their wings.

Caddis worms are particularly careful not to expose more than the well-armed part of their body while walking, and even then, if an intruder appears, they will instantly and sharply retreat into their cases, when the only part exposed to attack is the hard head, and even this is not to be reached without entering the case. But, notwithstanding all their precautions, they not succeed in escaping the attacks of those inveterate foes of insect life, ichneumon flies, and from one species also has been bred a two-winged fly belonging to a group well known for their habits of parasitism.

Though caddises are, as a group, aquatic in the larval state, there is one species the larva of which lives in moss at the roots of trees far removed from water. Nor are the insects absolutely confined to *fresh* water. One marine species has been reported from North America, and another from New Zealand, the latter of which formed a straight tubular case of fragments of coralline seaweed.

We may here notice some allied insects, the larvæ of the *Ephemeridæ* or Mayflies. These crawling things, which may easily be recognized by the three bristle-like appendages at the tail, and a number of leafy projections at the sides do not make cases, but burrow in the muddy banks of ponds and streams, and constitute what is known to anglers as "bank-bait." The burrows are tubular and after running straight for a little distance, bend back upon themselves in the form of a U, and open into the water at both ends, so that the insect has no need to turn in its burrow, but can enter at one end and makes its exit at the other. Small though they are, they are said to line two or three years in the larval condition, a remarkable contrast to the extreme brevity of their adult life, which is measured by hours, or at most by days. The pupa is similar to the larva, except that it exhibits traces of wings; When about to change into the winged form, it quits the water and "shuffles off its mortal coil," after the manner of several other insects already referred to; having so done, it looks like a perfect insect, and might faily be expected to be such, but, marvellous to relate, it has yet another change to undergo—another skin to cast—before it reaches maturity. This is remarkable as being the only instance in the whole class of insects in which a change of skin is effected after the assumption of the winged form. So perfect is this last rejected vestment, when left sticking to the stalk or leaf which formed the disrobing place, that, like the cast armature of a cray-fish or lobster, it might easily be mistaken for the complete animal itself.

## Miscellaneous Notes.

GERMAN technical papers recommend the following mixture for the staining of wood in imitation of cedar : 200 parts catechu, 100 parts of caustic potash and 10,000 parts of water, all by weight. The longer the wood remains in this solution the better the stain penetrates its fibres, and thick veneers can in this way be stained right through the whole thickness, which permits a re-finishing without injury to the color.

A NEW CAOUTCHOUC.—It is reported that the attention of the Indian Government has been drawn to a tree in Southern India, from which large supplies of caoutchouc can be drawn. This is the "Tuchmig" of the Chinese, or *Prameria glandulifera* of botanists. Unlike the South American tree, from which the caoutchouc is tapped by piercing the bark, the gum is obtained from the new source by breaking the boughs and drawing it out in filaments. If the new caoutchouc is at all equal to the old in insulating properties it will form a timely discovery, for the introduction of electric lighting has created an increased demand for india-rubber coated wires. Indeed several have lately been engaged in trying to manufacture a substitute for gutta-percha and india-rubber out of oxidised oils, that is to say, oils treated with chloride of sulphur, mixed with asphalte, ozokerit, and other insulating substances.

LIGHT AND THE ELECTRIC RESISTANCE OF METALS.—Mr. Arthur E. Bostwick has made an elaborrte series of experiments on the supposed influence of light in altering the resistance of metals. Since the dimution of resistance of selenium, when a ray of light falls upon it, was discovered by Messrs. May and Willoughby Smith, Dr. Richard Bornstein has attempted to show that not only selenium and tellurium possess the property in question, but other metals such as gold, silver platinum, also possess is. This effect was not verified by Siemens and Hausemann, of Berlin, and now Mr. Bostwick's researches have not established the fast asserted. His conclusion is that "if light causes any diminution in the electrical resistance of metals, it probably does not exceed a few thousandths sf one per cent."

A TELL-TALE ELECTRICAL BELL.—In order that the person ringing an electric bell may be able to tell whether, on making contact, the bell actually rings. Mr. Douglass MacKenzie has devised the following arrangement. Besides the press-button, and let into to wall, is a simple telephone receiver of the Elisha Gray or Bell model, and consisting of an electro-magnet with a soft iron plate armature free to vibrate over one of its poles. The sounding or "clinking" core of Page may also be employed instead of the diaphragm armature. This electro-magnet is formed up in circuit with the bell and battery, so that when the bell is in action with tis contact interrupting the current, the telephone or electro-magnet will emit a musical note or hum, which, when heard by the person ringing the bell, informs him that the bell is ringing, always supposing that the current is strong enough.

WARPING OF WOOD.—It is said that the wood on the north side of a tree will not warp as much as that from the south side, and that if trees are sawed in planes that run east and west, as the tree stood, it will warp less than if cut in the opposite direction. However this may be it is certain that the tendency to warp when sawed into boards is much greater in green than in dry wood, and that the convex side of the curve is always toward the heart. This warping, due to unequal shrinkage, and to the more open texture of the external portion of the tree is not found to occur in the middle plank or board of the log, excepting as it may in slight degree reduce the breadth. This quality of not warping which is in many cases absolutely indispensable for certain uses, as, for example, in the sounding-boards of pianos, is secured in the case of spruce timber by first quartering the logs, and then sawing them with the angle downward. It is then sawed into boards very nearly at right angles with the line of annual growth, and a small triangular strip must be taken off to make the board square edged, but qualities of stability and strength are secured that could not otherwise be had.

### NOTES ON ELECTRICITY AND MAGNETISM.

BY PROF. W. GARNETT.

The electromotive force between the extremities of a conductor is measured by the number of units of work done on a unit of electricity in passing from one end ot the conductor to the other. It is, in fact, identical with the difference of potential between the ends. If we say that a current C is flowing in the conductor, we mean that sea units of electricity pass across any section of the conductor in a second. Hence, if an electromotive force E send a current C along the conductor the work done in each second will be EC units.

Similarly, if E denote the electromotive force around a circuit, and C the current in the circuit, then E repres nts the number of units of work done in a second.

The work done in driving the current round the circuit is derived from the battery engine (and dynamo), or other source employed for the production of the current. Of this work some may be expended by the current in decomposing chemical compounds which may form a portion of the circuit (electrolysis), some may be employed in producing motion in magnets, or in other conductors, or in the conductor itself, as in the various forms of electric motors ; some may be expended in producing currents in other conductors, as in the induction coil. But if no energy is expended in any such ways the EC units of work done by the electric forces during each second must be converted into heat within the conductor, and must be the mechanical equivalent of the heat so produced. This is the case in a metallic wire which is conveying a current, but is itself stationary, and not in the neighbourhood of any moving wires, or magnets. Now, by Ohm's law, if R denote the resistance of the conductor, $E = CR$ Hence the amount of work converted into heat by the passage of a current C through a conductor (or conducting circuit) of resistance R is $C_2R$ and increases as the square of the current.

This theoretical conclusion was verified experimentally by Dr. Joule, and is known as Joule's law. If H denote the amount of heat developed in the wire per second, expressed in mechanical units, then Joule's law is expressed by the equation,

$$H = C^2R.$$

The heat generated per second may also be expressed in terms of the electromotive force between the extremities of the conductor, or, if the conductor form a closed circuit, the electro-motive force round the circuit, and the resistance, thus :

$$H = \frac{E^2.}{R}$$

Hence we have :

$$H = EC = C^2R = \frac{E^2.}{R}$$

The practical units of current (the Ampère), and electromotive force (the Volt) are such that the work done per second when a current of one Ampère is sustained by an electromotive force of one Volt is 10,000,-

000 ergs. Now, one horse-power is equivalent to 550 foot-pounds, or, about 7,458,000,000 ergs per second. Hence, if an electromotive force of one Volt be employed to send a current of one Ampère round a circuit, work will be done at the rate of $\frac{1}{745\cdot8}$, or nearly $\frac{1}{746}$ horse-power.

If an electromotive force, E, be employed to send a current C, the horse-power exerted will be $\frac{1}{746}$ EC.

Similarly, if a current of C Ampères is made to pass through a conductor, whose resistance is R ohms, the horse-power required to sustain it will be $\frac{1}{746}$ $C_2R$.

For example, if a 20-candle lamp requires an electromotive force of 110 Volts between its terminals, and allows a current of ·6 Ampère to pass, the horse-power actually required to light the lamp will be

$$\frac{110 \times \cdot 6}{746} = \cdot 0885, \text{ nearly.}$$

Again, suppose the current for 20,000 lamps, each requiring ·6 Ampère, is transmitted along a cable having a resistance of ·1 ohm, the horse-power wasted in sending the current through the cable will be

$$\frac{12000_2 \times \cdot 1}{746} = 19303, \text{ nearly.}$$

Hence conductors of very much less resistance must be employed in conveying the current for so large a number of lamps, and hence the lamps should be very near to the dynamos, or else conductors of very great sectional area must be employed.

When a current is made to flow through certain chemical compounds, such as dilute acids, saline solutions, &c., these compounds are decomposed into their elements, or into more simple substances. The operation is called *electrolysis*, the compound which is decomposed is the *electrolyte*, and the substances formed by the decomposition are *ions*. The conductor by which the current enters the electrolyte is called the *anode*, that by which it leaves it is the *cathode*. The *ion*, which appears at the anode, is sometimes called the *anion*, and that which appears at the *kathion*. This nomenclature was established by Faraday.

When the electrolyte is a simple binary compound, as, for example, silver chloride, the passage of a current separates it into its elementary constituents. It was by the electrolysis of the caustic alkalies that Sir Humphrey Davy prepared the metals of the alkalies (potassium and sodium). When the electrolyte is of more complex constitution, the passage of the current is frequently accompanied by uhe separation of the electrolyte into two compounds.

When the electrolyte consists of more than one compound it often happens that the ions into which one of the compounds (the true electrolyte) is separated, react upon and decompose the other, so that it seems as if two sets of ions had been produced by the same current. This is called secondary action, and it frequently accompanies the electrolysis of a metallic salt in aqueous solution. For example, suppose we are electrolysing a solution of sodic sulphate, $Na_2 SO_4$. We may suppose that the true electrolysis consists in the separation of this compound into metallic sodium, which appears at the negative pole, or kathode, and sulphiod ($SO_4$), which appears at the positive pole, or anode. Now, the metallic sodium will decompose the water forming caustic soda and liberating hydrogen, thus,

$$Na_2 + 2H_2O = 2HaHO + H_2.$$

while the sulphion will also combine with water forming sulphuric acid and liberating oxygen, thus,

$$SO_4 + H_2O = H_2SO_4 + O.$$

Hence as the result of the passage of the current, we find caustic soda and hydrogen liberated at the kathode, and sulphuric acid and oxygen at the anode, but the current is not to be held responsible for both these actions. The true electrolysis is the separation of the sodic sulphate into sodium ann sulphion, and the decomposition of the water is a secondary and purely chemical action.

The great law of electrolysis, that of electro-chemical equivalents, was discovered by Faraday. This law may be briefly stated thus :—

If the same current be made to pass though several different electrolytes the amount of chemical action produced in each will be the same, and if the current be made to vary the amount of chemical action per second will be proportional to the current.

In more definite language, the law may be expressed as follows :—

If the same current be made to pass through several different electrolytes, the quantity of each ion produced will be proportional to its *combining weight* divided by its *valency*, and if the current vary the quantity of each ion liberated per second will be proportional to the current.

Thus, if the electrolyte consist of fused potassic chloride, fused silver chloride. copper sulphate, and dilute sulphuric acid, the electrodes in each case being platinum plates, for each gramme of hydrogen liberated in the sulphurie acid cell there will be 8 grammes of oxygen liberated from the sulphuric acid, 39 grammes of potassium and 35.5 of chlorine from the potassic chloride, 108 grammes of silver and 35.5 of chlorine from the silver chloride, and ½·83·5 or 31·75 grammes of copper and 49 of sulphuric acid from the copper sulphate. while 8 grammes of oxygen will escape from the copper sulphate solution, as the result of secondary action.

An *apparent* exception to Faraday's law occurs when secondary actions takes place, when it seems as if the same current decomposed two electrolytes and did double duty in the same cell, but this has already been explained.

The amount of hydrogen liberated in one second by a current of one ampére is about ·000105 grammes, which may be taken as the electro-chemical equivalent of hydrogen. From this the amount of any other ion liberated by any given current in any time can be determined by Faraday's law.

All electrolytes must be in the liquid condition. Metallic salts must either be fused or in solution.

If a battery is employed to decompose dilute sulphuric acid with the evolution of oxygen and hydrogen, or to separate any other compound into its constituents, a definite amount of work must be done in decomposing the compound for every unit of electricity which passes through the electrolyte ; for the passage of each unit of electricity corresponds to the decomposition of a definite quantity (one electro-chemical equivalent) of the compound.