SCIENTIFIC CANADIAN

MECHANICS' MAGAZINE AND PATENT OFFICE RECORD

Vol. 13. | MARCH, 1884. | No. 3.

Communications relating to the Editorial Department should be addressed to the Editor, HENRY T. BOVEY, 31 *McTavish Street, Montreal.*

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

No notice will be taken of anonymous communications.

Recent Wonders in Electricity, Electric Lighting, Magnetism, Telegraphy, Telephony, &c., by Henry Greer, (New York : N. Y. Agent College of Electrical Engineering.)

This is an interesting work, though, "hastily compiled and written," and contains among other valuable information, descriptions of the Brush Storage System, of various kinds of electrical apparatus, e. g., recent telephones, Ayrton's electric motor, the Ferranti dynamo, the Ball unipolar dynamo, Hopkinson's current meter. &c. Important papers on electrical transmission and storage by Siemens, on electro-magnets by Count du Moncel, on electric lighting by water-power by Grierson, are reproduced in full, and the work concludes with several articles on recent advances in telegraphy.

LONDON is now without a rival as regards size and population, not only in the present, but as far as is known in the past history of the world, London, or the Metropolis, as defined by the Metropolis Management Act of 1855, contains at present nearly 4,000.000 people, covering an area of 117 miles, upon which are built 500,000 houses. Its population is equal to that of the whole State of Holland, is greater than that of Scotland, and double that of Denmark. At the same rate of increase, by the end of the century, it would equal that of Ireland, as indeed Outer London now does. Its population has quadrupled since 1801, when it numbered 959,000 ; and it is now increased at the rate of 70,000 per annum, equivalent to the addition to London every year of a city as large as Geneva or of Plymouth. The rateable value of property in London has grown from £6,000,000 in 1841 to £28,000,000 at present, or nearly five-fold in forty-three years. But the traffic through London has risen even more rapidly. The arterial lines of thoroughfare, wide enough half a century ago, are now altogether insufficient. Thus, although the Strand and Cheapside has been relieved by the formation of a new route between Charing Cross and the Bank, along the Victoria Embankment and Queen Victoria street, and Holborn has been relieved by a new route from Oxford street to Shoreditch, and new and widened streets continue to be made through the city and other crowded localities, the old lines of thoroughfare still remain congested by the traffic. There now pass over the Metropolitan bridges daily 384,000 pedestrians and 75,000 vehicles, the annual increase being at the rate of 4½ per cent. and 13 per cent. respectively. The traffic on three Metropolitan railways has risen from 79,000,000 passengers in 1871 to 136,000,000 in 1881, or to 373,000 daily.—*Inst. C. E. Eng.*

ARCHITECTURE AS A STUDY.

(Being a glance at the origin and development of some of the modern styles.)

BY A. T. TAYLOR, M.R.I.B.A.

(Continued from page 42.)

How shall we know Early English when we see it? may be the natural question of some of you.

I have shown in the diagrams a few leading characteristics. Examine the mouldings, the capitals of the columns, the arches and the general ornament.

I have already stated that the Norman style is distinguished by round arches, except in the transition period when it was merging into Early English. At that time we find pointed arches alongside of round ones as in Kelso Abbey and elsewhere, but these are exceptional.

You will remember that the mouldings are bold and generally round and not much undercut, that the earlier capitals are cushion shaped although more or less enriched, and that the whole features have a rough though healthy vitality.

In the Early English we find much more refinement, the arches are now quite pointed—sometimes very acutely so—the columns instead of being massive round ones, are clustered, the mouldings are undercut, that is, deep hollows filled with shadow. The capitals are sometimes gracefully plain and bell-shaped ; at other times carved in what is generally called the "stiff leaf foliage," and as an enrichment in the mouldings the "dog-tooth" ornament is very largely used—a very simple, yet extremely effective enrichment. You are familiar with the term "lancet" windows which were in use at the beginning of the Early English period, but their builders speedily grew bolder and wanted larger and richer openings, and the development of tracery in the windows soon succeeded.

To enrich their gables, they put on crockets and finials and they became bolder than their Norman predecessors and covered large interiors with groined vaulting which they beautified by moulded ribs and richly sculptured bosses.

This style alone deserves a lecture to itself but I must let this suffice for the present and introduce you to the next period which is popularly called the Decorated Style, for the dates of which you may take from about 1270 to about 1378, but there is no exact date at which you can say here E. E. ends and here the Decorated begins, it gradually developed and until the one style becomes entirely absorbed in the other.

The distinguishing features of this style are larger windows, more freedom in tracery and acuter cusping, while the mouldings again become flatter and are not so deeply hollowed out. Instead of the dog-tooth enrichment we have the ball flower and the four-leaved flower. The carving takes what might be called the "crumpled leaf" form, and is more natural in its treatment. The features generally become richer, and a few timber roofs begin to appear.

This brings us to the watershed of the Gothic. We have reached the top even if we have not begun to descend, and our progress now will be downwards.

The Perpendicular Style dating from say 1378 to 1545, has many splendid features in it, notably its magnificent timber roofs, screens and general woodwork, but the architects became possessed with an insane desire to cover every space with panelling. The windows became enormous, of which a good example are those in the west front of York. The mullions and tracery became more rigid and were taken up into the arch. The arches became depressed in the centre and are what are known as 4-centred arches. The mouldings are shallower and made up largely of half and quarter rounds, and ogee patterns take the place of the ball flower and four-leaved flower, and the Tudor flower forming a kind of corona along the top of screens, arcades, &c., was largely introduced. The carving is rich and often very beautiful, not seldom grotesque, and inclined to square and angular forms.

I must not omit to mention the fairy-like, fan-tracery roofs, which are marvels of construction in stone, of which we have many examples as in Henry VII. Chapel at Westminster, St. George's Chapel at Windsor, King's College Chapel Cambridge, the Cloisters of Gloucester Cathedral and elsewhere.

There is much that is fascinating about the Perpendicular, but there were the elements of decay in it, which speedily showed itself. Throughout Europe there was a retrogade movement in favor of classic architecture again, which we may call by the convenient name of the Renaissance.

England clung longer to the Gothic, but in the time of Henry VIII. classic details began to be introduced amongst the Gothic ones, through the employment of Italian architects, and fluctuated more or less under the name of Elizabethan which though very impure, had yet much picturesqueness about it. In this period church building came almost to a standstill, but a large number of mansions and houses were built.

Under James I. there was an effort made to regain the purity of the Gothic, which has received the name of Jacobean, but the tide of fashion had set dead against Gothic, and indeed there was no vitality in it—it had run its course. Like some great monarch of the forest which had grown and spread out its branches and displayed new beauties it had by successive stages reached maturity, and had at last begun to decay; successive storms had robbed it of many of its spreading branches, but even in its ruin—quaint, rugged, searred, lightning-riven, it was sublime.

Inigo Jones, in the time of Charles I., designed many fine buildings, but entirely on classic lines, and with classic feeling. He had a worthy successor in Sir Christopher Wren, who had a splendid opportunity after the great fire of London, in 1666, of showing his capability, and right well did he take advantage of it. His work was no slavish copy of Greek or Roman antiquities, but inspired by these, he adapted them to the requirements of his day, and infused them with Gothic feeling; and although not free from many faults, he yet gave to London and England the rich legacy of St. Paul's Cathedral and some sixty churches, not to speak of various other buildings. He may be said to have originated the classic spire or steeple at least in England, which have been the forerunners of so many since.

A host of inferior men followed in his wake, working more or less on the same lines, displaying here and there some originality, but none calling for special metinon.

About the end of last century a cloud no larger than a man's hand began to rise in the architectural horizon. Gothic forms began to creep in again, and although at first bad in principle and in art, yet as it increased, men began to look with more respect on the Gothic Cathedrals and other buildings of the middle ages. A few enthusiastic men such as Britton, Rickman, and especially the elder Pugin, studied and wrote and published books on Gothic architecture. Largely strengthened by the Oxford movement, it speedily came into fashion again. Not only churches, but houses and public buildings were built of the most pronounced Gothic; some of them—if possible more Gothic than the original. The building of the new Houses of Parliament in London gave a great impetus to the new Gothic, and speedily there began a restoration of large numbers of the Cathedrals and churches; at first much that was injudicious was done, but latterly in the hands of such men as Sir Gilbert Scott, Geo. Edmund Street and others, who had imbibed the true spirit of the Gothic, the restorations have been well done.

The new Law Courts in London, the Manchester Town Hall, and other buildings testify to a genuine Gothic revival, out of which might have been evolved a nobler architecture, but Gothic vagaries in the hands of inferior men have brought about a revulsion again within the last few years. There has been a revival of a socalled Queen Anne Style, which has received any vitality it ever possessed by being led by one or two men of undoubted ability and genius; now we have soared far beyond the ken of Queen Anne, and have gone far and wide freely gathering material from all countries and all architectures, and not ashamed to borrow from the Arab, the Japanese, and the Indian; there is a regular carnival of the styles. There is confusion as at the building of the Tower of Babel—but of styles instead of tongues. Clients order their architecture, as they do their wines and cigars, of a particular brand, and architects are willing to supply them from a "large and assorted stock always on hand" although I say this yet, I am not without hope of improvement. We are only sharing in the eclecticism of the age. There is much monstrosity, but there is also great vitality in modern architecture, and "better a live dog than a dead lion." Out of confusion will come I trust order. Many earnest men are conscientiously working out on true artistic lines architectural forms, and I do not despair of the result. Whether this result will be in the formation of a new style or whether such is possible I will not take time to consider now, but hope to refer to it in another lecture.

I have been briefly sketching the progress of architecture in England as being nearer to us and in closer relation than any other country, but I must glance at the architecture of France, which is well worthy of a more extended notice than I can give it to-night. France possesses many splendid cathedrals, some early, as the Abbeys at Caen and other parts of Normandy, and others later, as Notre Dame at Paris, Chartres, Rouen, and notably Amiens, but the French—always an artistic people—have never had much sympathy with Gothic, and accordingly have had no Gothic revival as we have have just seen took place in England, but instead of that they have developed what might almost be called a style of their own, which is known as French Renaissance. The early Renaissance had a charm of picturesqueness and marvellous variety of feature and detail which inclined to the classic at one time, as in the Chateau Blois and Chambord, and several others, and in the old Hotel de Ville, at Paris; andaga in to the Gothic, as in the Palace de Justice at Rouen, Hotel de Cluny at Paris, and others.

Latterly they have, and I think wisely, swept away all copying from the antique and have developed a free classic, which if now and then voluptious is yet at all times fresh and refined.

The new Hotel de Ville at Paris modelled somewhat on the lines of the one burnt down, promises to be one ofthe most thoughtful and clever buildings of the century, and is worthy of the most careful study.

In America, until within the last few years, there has not been much in the way of architecture which could earn even a modest modicum of praise, but on a recent visit I was surprised to see what immense strides had been made. Where they have tried to be original in my opinion they have been least successful, but many of the rising architects, having been trained in Paris and London, are introducing great vitality and freshness, and at the same time maintaining the true principles of art.

They are privileged in that they are less tramelled with conservatism than in the old country, and have larger opportunities in the way of lavish expenditure. The new City Hall and buildings at Philadelphia, many of the new houses and buildings in New York and Boston are advances—by leaps and bounds on the old.

Of Canada I cannot say so much. We are not so favoured as our neighbours across the border in means, and our climatic requirements are such as to hamper freedom of design. I think, however, we have a few buildings and notably the centre block of the Parliament Buildings at Ottawa of which there is no need to be ashamed. In position this building I have named is almost second to none that I know of, and for grouping and planning and picturesque outline, it is very creditable to the Dominion.

I think, however, that Canada is not to be behindhand in architecture, and that in that department she is by no means at a standstill. She may not be in the van, but I am sure she will not be in the rear.

In my next lecture I hope to examine some of the principles which underlie all true design whether in architecture or engineering and to glance at some modern requirements in their bearings on our work.

THE ARMAMENT OF TORPEDO BOATS.

(*For illustrations see page 68.*)

The necessity of arming torpedo boats with light and efficient machine guns has been long fully recognised, for in consequence of the large and rapidly increasing numbers of this class of vessels in possession of the different navies, there is no doubt that in any future naval campaign they will be called upon to perform other duties besides that of attack on ironclads, and that there will be engagements of torpedo boats with each other, and with the armed guard boats, used to protect the larger fighting vessels against torpedo boat assaults.* Such guns will also prove very valuable for firing at electric search lights, for driving the gunners from the machine guns placed in exposed positions, and for covering a retreat. For all these reasons those governments which possess navies have under consider the development of torpedo boats into more perfect fighting machines than was contemplated when this means of attack was adopted. The principal difficulties in arming torpedo boats, particularly those of the light second-class, is the extra weight which a gun and an adequate quantity of ammunition entails, and the consequent loss of speed thereby occasioned, but it would appear that the value of a gun armament outweighs to a great extent this disadvantage. The requirements of such armament may be summed up as follows:

1. A minimum weight of armament and ammunition supply.
2. The smallest possible number of men to work the guns.
3. Sufficient power of projectile to perforate and put *hors de combat* any existing torpedo, or other similar boat.
4. Rapid fire and great facility of pointing during the swiftest motions of the boat.
5. The use of the same ammunition carried by the machine gun armament of the larger vessels, so that the supply of the torpedo boats may be replenished from their magazines if necessary.
6. A fore-and-aft fire, and if possible a an all-round fire, so as to provide equally for an attack or a retreat.
7. The smallest possible reactions and vibrations from firing so that no special strengthening of the existing torpedo boats may be required to stand the shock of the discharge.

One type of gun† which is now being largely adopted in Continental and other foreign navies for arming the so-called first-class and larger-sized torpedo boats, is the 37 mm. (1.46 in.) Hotchkiss revolving cannon; the total weight of this gun with its pivot and socket is 550 lb. It can be worked by two men and fired at the rate of about sixty shots per minute, the explosive shell employed having an energy sufficient to penetrate any existing torpedo boats, while canister can also be used against open boats at short ranges. As the recoil is very slight, no strengthening is necessary from this cause for the torpedo boats.

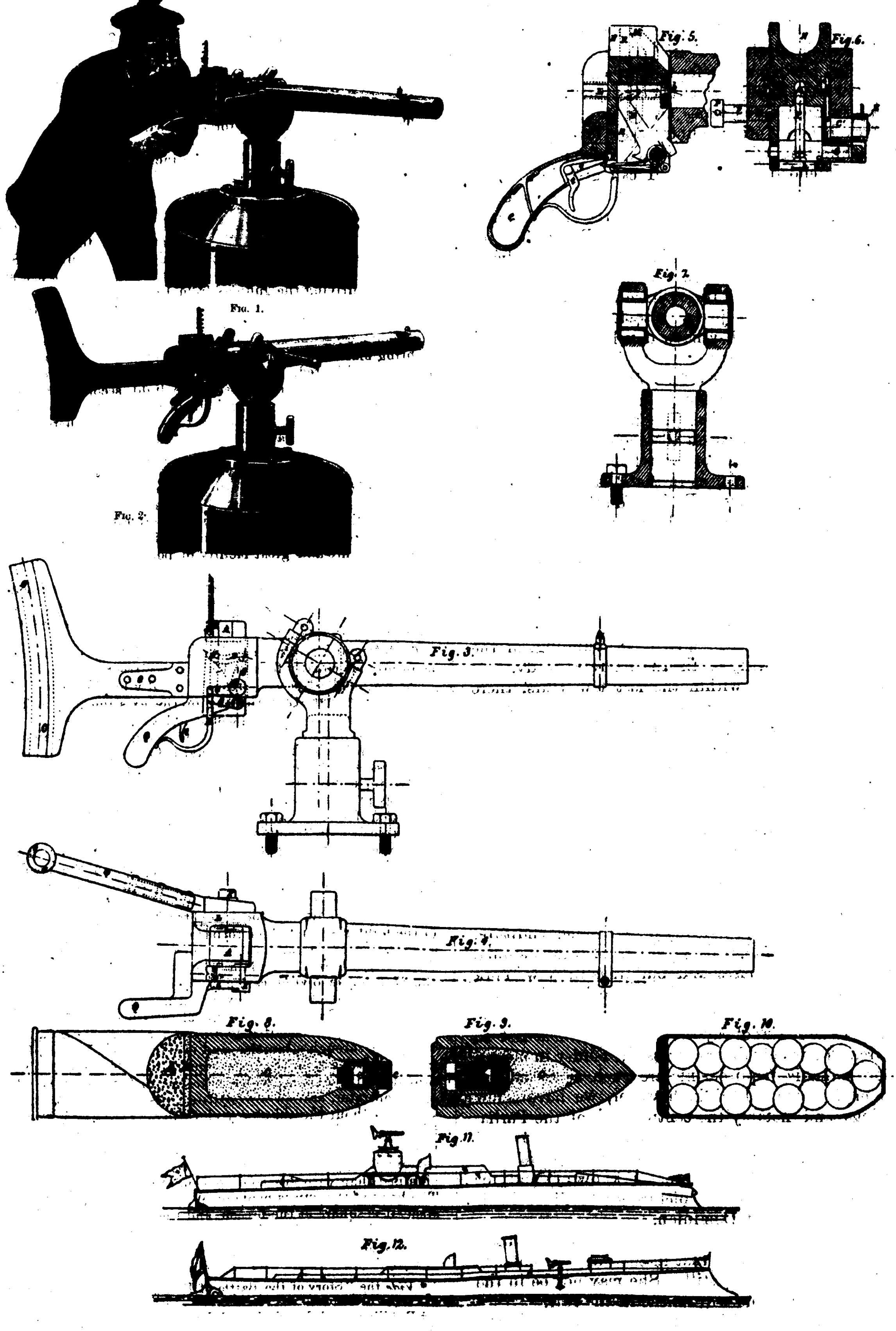
The gun is, however, considered too heavy for the armament of the lighter second-class torpedo boats. for which purposes Messrs. Hotchkiss and Co. are now manufacturing a rapid-firing single-barrel gun adapted for the same ammunition as the 37 mm. revolving cannon. This class of gun has been adopted to a greater or less extent in fifteen different navies.

Figs. 1 and 2 are general views of this gun, which resemble a large wall-piece mounted on a pivot; the breech-block slides vertically through a mortice, and is actuated by a lever, forming at the same time the trigger-guard. As will be seen it is provided with a stock, which bears against the left shoulder of the operator, and on the right is a pistol-grip for pointing, so that without the aid of any elevating or directing mechanism the work of sighting and firing (as is the case with the revolving cannon) is placed in a single hand, which, the makers claim, gives more accurate work, and better results are obtained than with any combination of men to sight and fire. The body of the gun is made of Whitworth's fluid compressed steel, it is square at the breech, and the trunnion ring (of steel) is screwed on in such a place that the gun is exactly balanced in the trunnions. The breech action consists of the square

* *Vide* the "Story of the Battle of Port Said," ENGINEERING, vol. xxxv. pp. 1, 27, 51, 80, 111, 133.

† For illustrated description of the Nordenfelt machine guns, see ENGINEERING, vol. xxxv. p.p. 51, 77, 123, 147.

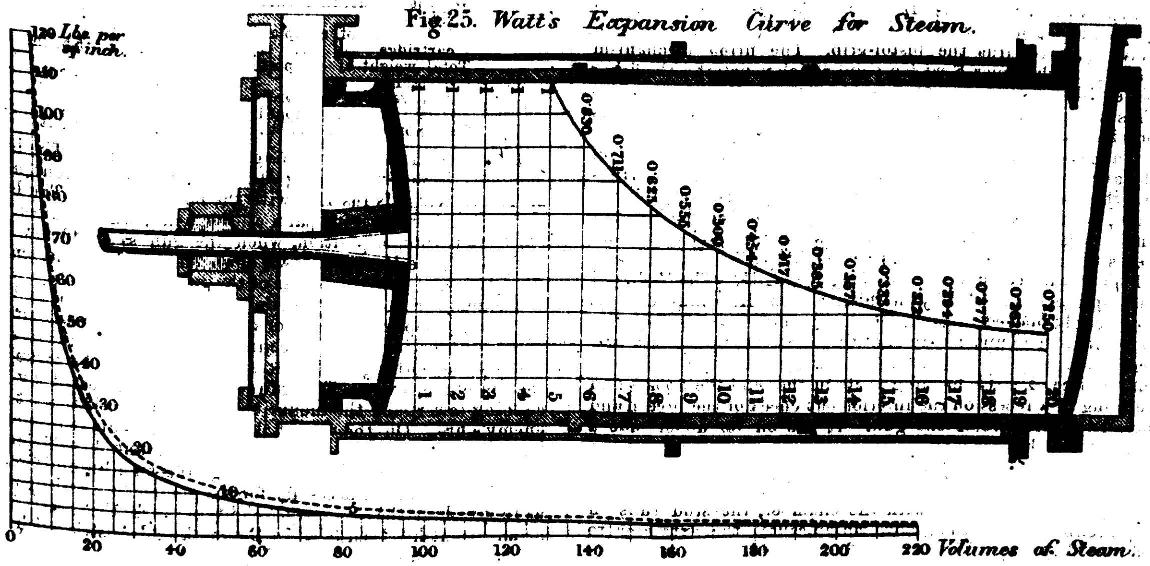
THE ARMAMENT OF TORPEDO BOATS.



INVENTIONS OF WATT.

Fig. 26. *Expansion Curves for Steam.*

Fig. 25. *Watt's Expansion Curve for Steam.*



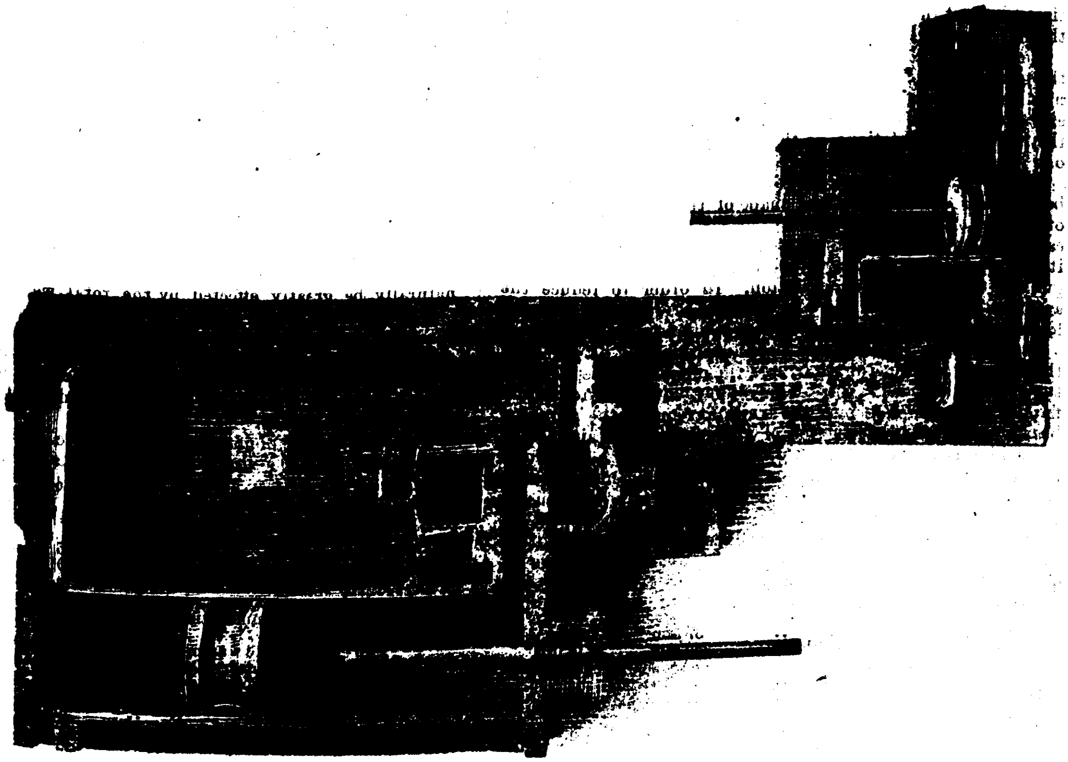


Fig. 28. Sectional Model Bull Engine.

wedge A with rounded corners, as shown in the details. It runs in guides B B on each side, and its run is limited by the set-screw *p* Fig. 6. It is moved up and down by means of the crank C, bearing in the right side of the breech, the pin *c* of which works in a curved groove D in the wedge. This crank C carries the lever handle E, which serves to open the breech by pushing it downwards and away, and to close the same by drawing it towards the pistol-grip. The firing mechanism consists of a hammer F with a point which penetrates the firing plate and strikes the cap in the cartridge on pulling the trigger. This hammer F is mounted on a rocking shaft G, which is provided with an arm *g* on the outside of the wedge.

The lever handle E carries a cocking cam *e*, which bears on the arm *g* of the rocking-shaft, and in this manner by swinging the lever handle downward the hammer E is drawn backward, or cocked. There is a small projection *f* on the hammer and a trigger sear H which catches on this projection and holds the hammer back until released by pulling the trigger, which in turn catches on the trigger sear H. The V shaped mainspring I is carried by the hinged piece K, arranged so as to be easily opened in case the spring should break and require replacing. The upper branch of the spring bears against a projection on the hammer F. The cartridge extractor I is a prismatic piece of steel, forming at its further end the hook *l* and running in a recess on the interior left cheek of the breech and parallel to the bore of the gun. It has on its under side a stud l_1 which works in a groove M on the left side of the wedge. This stud l_1 for a time runs in the straight portion of the groove, but as soon as the wedge is so far withdrawn that the opening N coincides with the chamber, the stud runs in the inclined part of the groove which causes the extractor to be moved back quickly, and the fired cartridge case is in this manner extracted and thrown out of the gun.

The stock O is of wood, fitted into a gun-metal holder ; it is attached to the breech of the gun by the screw P. The stock can be dismounted by turning the screw a quarter of a turn. To prevent the slight shock of discharge being felt by the gunner there is an india-rubber tube *o* attached to the back of the stock this forms a very elastic buffer. The pistol-grip Q is of gun-metal, it is hollow and is attached to the breech by two screws. This carries the trigger *q*, and serves at the same time to direct the gun by means of the right hand, thus leaving the left hand free to feed in the cartridges.

The front sight is a plain steel point attached by a collar to the gun. The rear sight is a folding leaf, which has a certain number of fixed sights with the usual notch, corresponding to elevations from 200 to 200 metres, and giving at the same time the permanent deviations, so that the gunner may pass from one range to the other without interrupting the fire.

The pivot and socket are of gun-metal, the case of the latter being made according to the shape of the conning tower, or other part of the boat to which it is to be fixed. The pivot carries the gun by its trunnions, and fits in the socket so that it can rotate, thus forming a universal joint, and allowing the gun to be trained in any direction. In order to reduce the action of the recoil on the boat as much as possible, the following description of recoil buffers is applied to the pivot.

The trunnion bearings are bored considerably larger than the diameter of the trunnions, and the circular space between the two is filled with soft india-rubber, entirely inclosed in flanged rings which fit over the trunnions and in the trunnion bearings, so that on the action of the recoil, a certain flow of the rubber takes place, and allows in this manner a recoil of a few millimetres in the trunnions bearings, sufficient to reduce the sharp shock on the fastenings without in any way causing inconvenience to the gunner.

One man can, with a little practice, fire this gun with a rapidity of about twenty shots per minute, but the time required, if the shots are carefully aimed, is far greater. The follew are the principal dimensions :

Calibre		37 mm.	1.46 in.
Length of bore (20 calibres)		740 mm.	29.14 in.
Helicoidal rifling left-hand twist.	Number of grooves	22	12
	Depth of grooves.. (uniform) ..	0.4 mm.	.016 in.
	Width of lands (uniform) ..	2 mm.	.08 in.
	Pitch Of rifling (in calibres) ..	29.9	29.9
	Angle of rifling ..	6 deg.	6 deg.
Weight of gun		33 kilos.	72.6 lb.
Length of gun (without the stock		840 mm.	33.08 in.
Total length of gun with the stock		1140 mm.	3 ft. 8.88 in
Weight of pivot and socket		25 kilos.	55 lb.

Ammunition.

Total weight of shell charged and fused ..	450 gr.	15.84 oz.
Bursting charge	22 gr.	.77 oz.
Length of projectile ..	33 mm.	1.30 in.
Charge of powder .	80 gr.	2.8 oz.
Weight of metallic cartridge case	95 gr.	3.34 oz.
Total length of complete cartridge	167 mm.	5.57 in.
Total weight of complete cartridge	630 gr.	1.2 lb.
Initial velocity with ordinary French Ripault cannon powder	402 m.	1318 ft.

The manipulations for loading and firing are : 1. The level handle is thrown by pressing with the thumb of the right hand. 2. The cartridge is inserted with the left hand. 3. The lever is returned to place with palm of the hand, which raises the block to its proper position, when the gun ss ready for fire. After firing the lever is thrown down sharply, and the empty cartridge shell is thrown clear of the gun.

The manner in which the gun is fitted on the torpedo boat will greatly depend on the construction of the vessel, but in most cases placing it on the conning tower appears the easiest and best, as nothing else is necessary but to bolt the socket on the top of the tower. The gunner is fairly protected by the conning tower, and the mounting of the gun itself against the enemy's fire. On the second-class torpedo boats, the single-barrel rapid-firing gun can usually be mounted sufficiently high so as to clear the funnel, thus giving an all-round fire. A light grating is then necessary for the gunner to stand upon so as to give him the necessary height to work the gun. This arrangement has been tried in Denmark and Austria with entire success, and is shown in Fig. 31.

In the first-class and larger boats where the funnel is placed abaft the conning tower, and too high to be cleared by the gun, it will often be found advisable, so as to obtain a fore-and-aft fire, to use a pair of single-barrel guns, one mounted on each side of the vessel, an arrangement adopted by the Russian and Victorian (Australia) navies, but this manner of placing the guns would only be practical on large torpedo boats, as it requires columns fitted like boats' davits, which can be dismounted if necessary, and small hinged gratings projecting over the sides or the boat for the men to kneel upon to work the guns. The total of fittings in this case would make about 150 lb. additional weight for each gun. (See Figs. 12 and 13).

By mounting one of the guns one each side of the conning tower, instead of on special columns, a fore-and-aft fire can be obtained with less weight than in the preceding case, as the socket for the gun pivots can be fitted direct to the sides of the conning tower, and its strength can be utilized for absorbing the action of recoil (Fig. 14).

In large torpedo boats, the revolving cannon will be best mounted on the conning tower as shown in Fig. 15.

The number of rounds of ammunition for each gun will naturally be greatly effected by the total weight considered possible for the boat to carry without too great a loss of speed. The time any torpedo boat would be able to use its gun will be extremely short, and therefore no doubt, 120 rounds per gun would be sufficient, particularly for the boats attached to the larger vessels, in which case the replenishment of ammunition is comparatively easy.

The total weight of gun, ammunition, etc., would be distributed as follows for a single-barrel Hotchkis gun :

	kilos.	lb.
Weight of 37-millimetre single barrel rapid-firing gun	34	74.8
Weight of universal pivot for same	15	33
Weight of socket and fastenings	10	22
" accessories and reserve parts	7	15.4
120 rounds of ammunition, each 630 gr.	75.5	166
Two steel plate ammunition chests, each to carry 60 rounds, each 10 kilos. 250 gr.	20.5	45.1
Total	162	

—*Engineering.*

Remedy for Bruises.—No carpenter or mechanic should ever be without a vial or bottle of Tincture of Arnica in his tool chest, or within easy reach. It is invaluable in cases of contusions from any cause. Let it be the first thing applied, and use it freely.

ON THE INVENTIONS OF JAMES WATT, AND HIS MODELS PRESERVED AT HANDSWORTH AND SOUTH KENSINGTON.

(*For illustrations see pages* 69, 72, 73, 76, 77, 92 *and* 93.)

(CONTINUED FROM PAGE 51.)

It should be noticed that what is now commonly known as the single-acting pumping engine has the stuffing-box and cover, and the equilibrium valve.

In the patent of 1782 Watt states that there are various arrangements that may be made of the several engines, but that he has given only those that appeared the best, and this no doubt is the case, and is what a patentee is bound to do. The author has found a model at South Kensington, which he takes to show a transition state, or form of engine that may probably represent an attempt to produce a double-acting engine by two single-acting cylinders, connected together by a chain over a pulley as follows.

Fig. 27, shows two single-acting vertical *air pumps* placed at some little distance apart, and with passages below leading to them; and there is an unique arrangement of two single-acting vertical *cylinders*, having their upper ends connected by passage without valves, but the pistons having self-acting valves in them, opening upwards, so that *any steam below either piston* could pass to the *upper sides* of *both* pistons. A chain connects the top ends of the piston-rods together, and and it passes over a pulley or drum to which it is attached, so that the drum will *reciprocate*, if the pistons work up and down in the cylinders.

To this drum is attached a long crank-pin, which could take hold of a pump-rod, or a connecting-rod.

There are conical valves to let steam into and out of the bottoms of the cylinders, and in each passage leading downwards from the eduction valves there is a small pipe, terminating in a jet of pointing upwards, no doubt for the *injection water*. Now, although when the models were first examined there was not the slightest indication that these pumps belonged to the cylinders, it appeared probable to the author that they had some relation to each other; and on further examination, two dowel-pins were found on one model, and two holes were found on the other model, into which the dowel-pins fitted, thus at once proving that the supposition that they belonged to each other was correct.

Thus we have a model of a double-acting arrangement for pumping or other reciprocating motion, such as a connecting-rod or crank, with the pressure of the steam *always* on the top of *both* pistons, and a vacuum formed alternately under one or other of the pistons, by injection of cold water into the eduction pipes; and with air-pumps to keep up the vacuum, and discharge the air, and the water of condensation, and the condensed steam. This is an arrangement that has not before been noticed, and of which, it appears, there is no description extant; and it is a good example of the ingenuity and inventive genius of James Watt.

Another *grand invention* in this 1782 patent is the use of steam *expansively;* and so thoroughly did Watt understand this action, that he has drawn a good indicator figure of what would take place in the cylinder of an engine, if the steam were cut off at one quarter of the stroke. See Fig. 25.

This figure, the author finds, is identical with Marriotte's Law, and not far from the true expansion curve that the author constructed from Pambour's table of the bulk of steam in proportion to the water that produced it; that is, so far as the figure goes, *i. e.*, to an expansion of steam at atmospheric pressure to four times its volume. (The author's diagram, Fig. 26, goes to 44 times the volume with 120 lbs. steam.)

At this point, it may be well to leave the consideration of the specification for a moment, to examine the drawing, Fig. 19, Page 48, of a model which it is believed is at the root of the invention of the "*Indicator*." This consists of a simple, small cylinder about 2 in. diam. and 3 in. stroke, open at top and closed at bottom, and with a cock and pipe to it; the piston-rod is connected by a light chain to a rocking-beam above, and a chain fastened to the other end of the beam is attached to the upper end of a good spiral spring, fastened at its lower end. There is a long light finger on the centre of the beam moving in front of a large segment. Now, if the pipe below was connected to an engine cylinder, and the cock opened, the degree of vacuum in the cylinder would at once be *indicated*. It only remains now to attach a pencil to the top of the piston-rod of this indicator, and move a sheet of paper on a board in front of it, to and fro, as the main piston of the engine moved, and we have "Watt's Indicator" as used by himself and all his people for very many years, in fact up to the author's time, when he saw the instrument in Mr. William Bennett's possession in Manchester. Mr. Bennett then showed the author's late father how to take indicator figures, of which some are shown in Figs. 23 and 24, Page 48, taken by Professer Cowper in 1840.

Mr. W. Bennett was originally at Soho, and on going to Manchester and joining Mr. Wren, he became Messrs. Bolton & Watt's agent there, for indicating their engines and taking orders for the same.

Our member, Mr. Henry Wren, has very kindly made the author a present of one of these indicators, shown in Page 49, Figs. 20 and 21, and it is now before you: you will see that it is just like engravings of Watt's indicator in the Encyclopædias.

Watt goes on in his specification to say that when the steam is cut off at one quarter of the stroke, there must be an equalising arrangement, to enable the piston to complete its stroke when pumping; and several plans are put forth. In one, Fig. 22, Page 49, there is a small fly-wheel with a pinion mounted up above the cylinder, the pinion taking into a toothed segment on the end of the beam (in place of the old "Horse-head"). The piston-rod has a rack attached to it, also taking into the toothed segment, so that at every stroke of the engine, either up or down, the fly-wheel must start from a state of rest and revolve rapidly and then stop, and in so doing would of necessity take a good deal of power to overcome its inertia, and would give it out again (less the double friction towards the end of the stroke. Another plan is, to mount a weight high up on the top of the beam of an engine, so that it should be somewhat lifted, in starting from either end of the stroke, and fall somewhat after passing the centre. Another plan is that of a loose weight, to roll along the top of the beam and do the same thing. Again, one plan is to have two large short-stroked, open-headed pumps, one attached to the beam on either side of its centre, so that one bucket rises while the other falls; and there being a trough between the heads of the pumps, the water is intended to flow from the one to the other, thus giving the engine more to do at the commencement of the stroke, and gaining a little towards the end of the stroke, by the weight of so much of the water as has flowed over in the time.

There are also several arrangements of levers, to give a variation in the leverage during the stroke, so that the piston should have more to do at the commencement of the stroke, and less to do at the end, when the steam was gradually losing its pressure from expansion.

Thus, in 1782 Watt had made a thoroughly good rotative, or mill engine, and an economical one also, though it does not appear that he actually use any considerable pressure of steam at any time. This engine is shown in Figs. 30 and 31, taken from a model in the South Kensington Museum.

One form of engine he describes, and which he calls a compound engine, consists of using two cylinders of the same size, and then, having used full steam in one cylinder, he lets that piston stand still whilst part of the steam expands into the second cylinder, and finally the steam from both is condensed.

In the patent of 1782 is described the plan of allowing the piston-rod of an engine to pass out through a stuffing box in the bottom, the beam being placed below, like what is now known as a "Bull Engine," (Figs. 28 and 29.) It is believed the name arose from an engineer of the name of Bull, who put some up in Cornwall, and whose son went into partnership with Trevithick, at the time that James Watt was complaining of their infringing his first patent for the condensation of steam.

It is a remarkable fact that the model from which this diagram was taken is almost exactly the same as the engraving at page 59 of the "Life of Trevithick," the injection jet being in the eduction pipe, as shown in some of Watt's drawings.

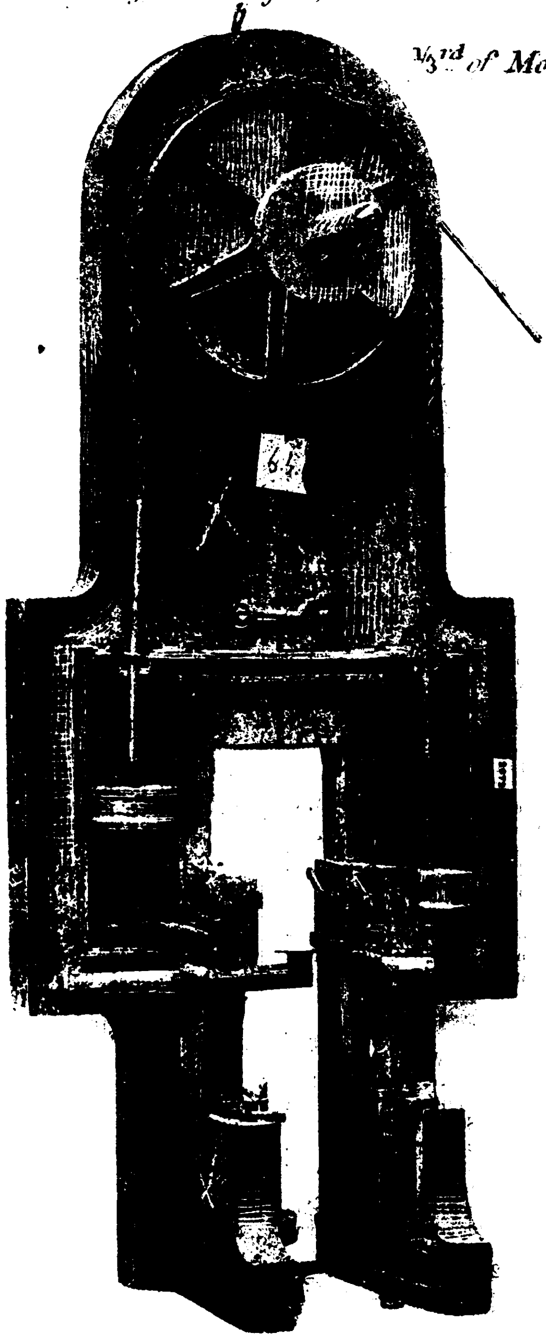
Watt, in a patent of 1784 describes an ingenius method of obtaining rotary motion in opposite directions, by two connecting rods from a crosshead at one end of the beam of an engine (Figs. 32 and 33.) Inasmuch as one shaft is placed somewhat lower than the other, that rod is jointed to a lower part of the beam, so that both may turn the centres at the same instant. The lower shaft drives the bottom roll of a rolling mill, and the higher one drives the top roll. This was probably intended for rolling metals for coining. The gearing by spur-wheels carries the power to another mill for slitting.

In the same patent the idea of a steam carriage for common

INVENTIONS OF WATT.

Fig 27 *Two-cylinder Engine, for double action.*

1/3rd of Model.



roads is put forth, to be worked by steam above the pressure of the atmosphere, which is to be allowed to escape into the atmosphere when it has done its work; a fore-carriage and steering apparatus is named, and a light and portable boiler with the fire inside the boiler in an iron tube, whilst the body of the boiler *might* be made of wood for lightness, and be strongly hooped to retain the steam.

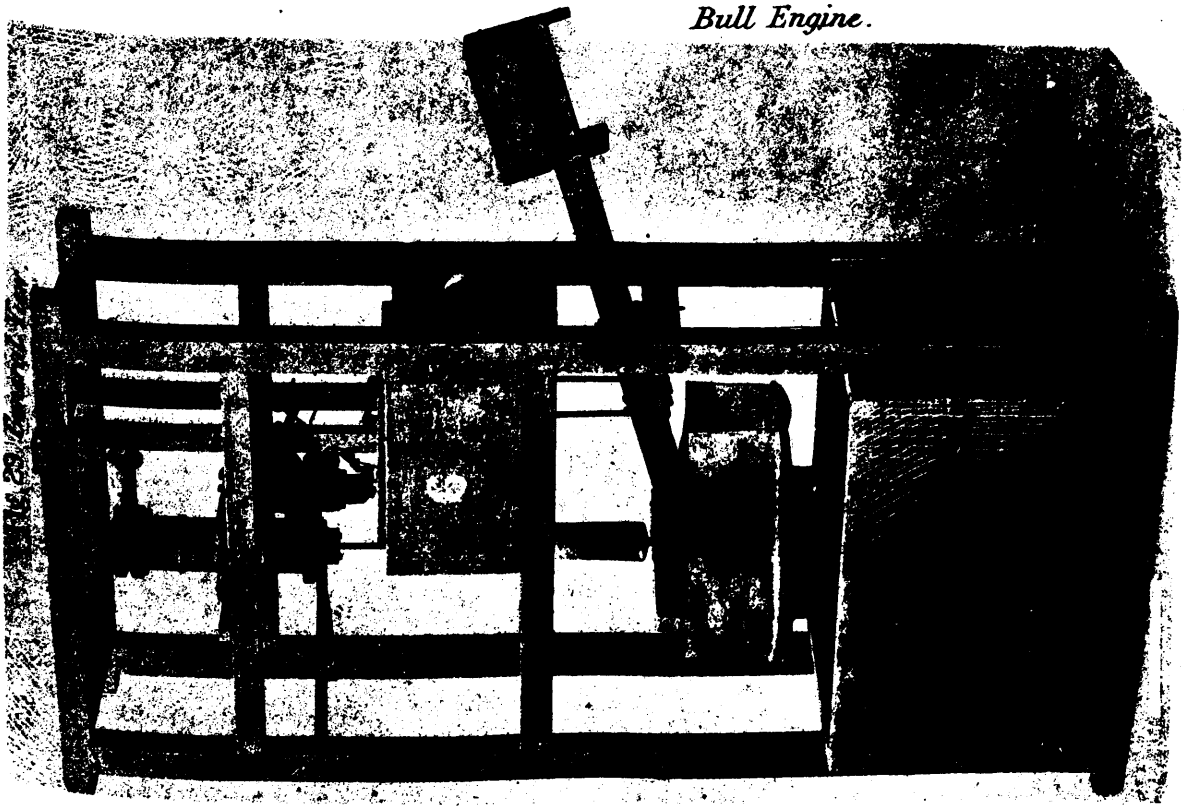
The author may mention the fact that some internally-fired boilers for practical work have had their shells made of wood; as his late uncle, about sixty years ago, assisted in the construction of one for a dredger in London, in which thick planks, well tongued together, and jointed with white lead, formed the sides and the top and bottom, there being a mass of clay placed on the top to help it to withstand the pressure of the steam. The pressure was very low, and the engine of the dredger was a condensing engine.

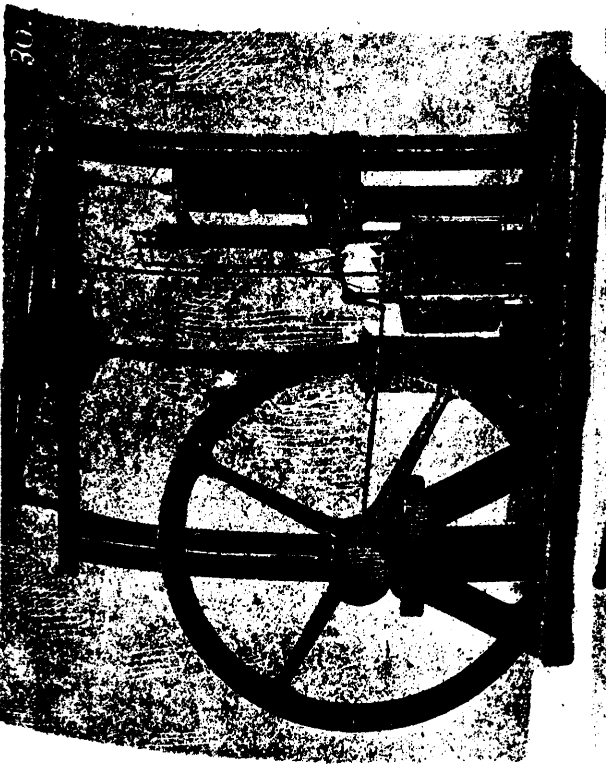
Watt went so far into detail as to give the diameter and stroke of the cylinders for a small steam carriage, to take two persons, viz. 7 in. cylinder, 12 in. stroke.

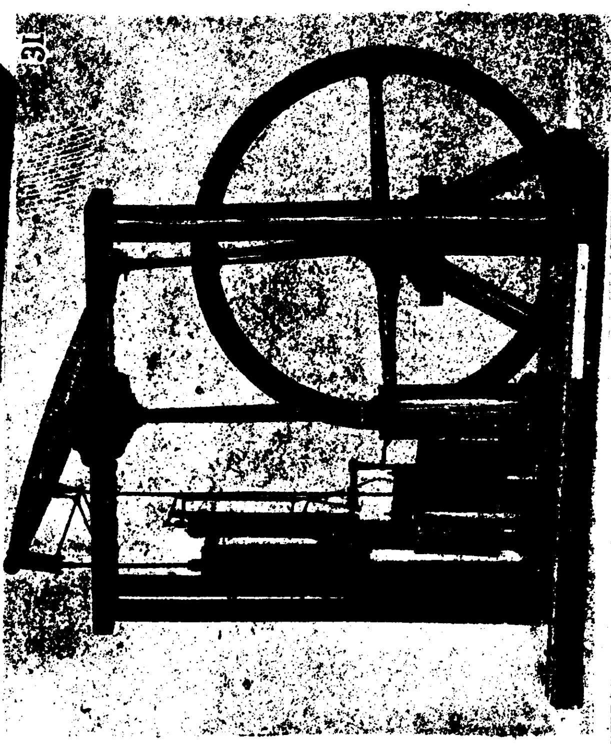
Watt says, "The elastic force of the steam in the boiler must occasionally be equal to the supporting a pillar of mercury 30 in. high."

INVENTIONS OF WATT.

Bull Engine.







Double-acting Beam Engine.

In spite of this, however, it is said that the firm of Boulton and Watt endeavoured, about 1804, to obtain an Act of Parliament to prevent more high-pressure engines on Trevithick's plan being made, on the ground that, "the lives of the public were endangered."

It may be only right here to mention that the present eminent firm of James Watt & Co. have discarded such limitation of pressure, and have for a long time made highly economical engines of all kinds, high pressure, expansive, and condensing.

It is worthy of note that one Cugnot, a native of Lorraine in France, made in 1769 a steam carriage for common roads; it had three wheels, and two steam cylinders single-acting, and a short beam between them, and they worked on to the axle with ratchet wheel. The carriage went at 2½ miles an hour for a short time. The author saw this old engine in an old church connected with the "Conservatoire des Arts et Métiers" in Paris.

One Francis Moore, a draper in London, invented a steam carriage in 1769, as mentioned in the letters of Dr. Small and Mr. Watt.

There is one Model, Fig. 33. which shows two hammers, worked by one engine, the one lifted by a cam from the "belly" like an ordinary forge hammer, except that the shaft is at right angles, whilst the other hammer is lifted by depressing the tail like a tilt-hammer by another cam.

This model was only just saved from destruction, as the shafts of both hammers were so worm-eaten that one had fallen to pieces and the other was nearly as bad; however, the authorities have kindly put a new wooden shaft, prepared by the author, precisely like the old, to the hammer-head that had fallen off, so now it can be understood what the model is really intended to show.

The patent for 1785 is for waggon boiler and the setting of same; this is an early form of such a boiler, and the sides are shown vertical. In 1833 the author (through the kindness of Mr. W. Bennett) was allowed, as a lad, to copy the working drawings of one very like it, except that the sides were curved to give extra strength, while stays were introduced inside, to tie the sides together. Of course it is evident that flat sides of boiler plate were exceedingly weak, but Watt generally worked with very low pressure, only a very few pounds above the atmosphere: when 7 lbs. steam pressure was carried, it was considered about as far as it was proper to go, and even then the "open feed head" had to be carried up some 18 or 20 feet, to prevent frequent "boiling over."

In fact, in practice Watt trusted to the vacuum to give him his power, and the iron plate of the boiler was rather to prevent the admixture of atmospheric air with the steam than to give him any high pressure.

So great in fact was the objection at that time to high pressure, that when offered an order for locomotives for an early railway, the firm would not look at it.

There are two very striking inventions of steam engines altogether different from the steam engines previously spoken of, and acting in a different manner; one is a rotary engine, Fig. 37, and the other a semi-rotary engine, Figs. 34, 35, and 36. In the rotary engine there is a piston, fixed as an arm, in a radial line to the shaft to be turned, and the cylinder of the engine fits the piston in its revolution; there being at one point a flap-valve, hinged to the inside of the cylinder, whilst its other end rests on the shaft, so as to form a cylinder bottom, or *point d'appui*, for the steam to act against when acting also on the piston. This flap-valve is at a slight angle to a radial line, so that when the piston comes round, it can heave it up so as to get past. This is about the simplest form of rotary engine that can be conceived, and has probably been re-invented fifty times since 1782.

The semi-rotary engine, Fig. 44, has likewise a piston fixed in a radial line to the shaft to be turned, and the cylinder fits the piston as it moves backwards and forwards through a considerable arc of the circle; fixed inside the cylinder at one part is a fixed stop or cylinder bottom, for the steam to act against *either way*, as it acts against the piston in either one direction or the other. It was intended to let the reciprocating shaft act with a spur wheel on two racks attached to the pump rods.

There is an unfinished model of this engine in the "Watt Room" at Heathfield Hall, which the author has examined; no doubt this was partly made by Watt's own hands. In a letter of Watt's, dated 27th September, 1782, he speaks of this model having been made, so far, in 1765 or 1766.

It remains now to give some description of the more important articles found in the "Watt Room" at Heathfield Hall, the residence of our Member, Mr. George Tangye, who, as before mentioned, has kindly photographed many articles for the Institution.

The room is about 20 ft. by 16 ft. 6 in. in size (for diagrams see next number), and really is a good attic, and nothing more, with one low long window only 5 ft. 4 in. from the top to the floor, so that it was a bad light for any machine a few feet from the window; and it is a wonder that Watt did not devote a better room to his purposes.

There are numerous shelves with drugs and parcels on them, and nests of small drawers with tools in them, some of them very excellent tools; and his small lathe and bench stand at the window, with his tools about, and his old leather apron on the vice, and his centre-punch tied with a piece of cat-gut to the vice, to save him the trouble of looking for it, or picking it up. There are now a number of busts on a bench in the room, and some marble and alabaster for working on. At the fire-place there is his old frying-pan and his Dutch oven or "hastener," and outside the door, on the landing, a little shelf, on which it is presumed his meals were placed.

Besides these things there are two large machines for sculpturing marble, alabaster, or wood, and a few smaller half-finished models, such as the semi-rotary engine just named, and a "counter," Fig. 41, for counting and recording the number of strokes that an engine makes. This is constructed on the intermittent principle; that is to say, the first wheel has 10 teeth, and when it has received 9 impulses from 9 strokes having been made, the 10th stroke not only turns the first wheel one tenth, but this wheel, owing to its having a raised tooth at that particular place, turns the next wheel one tenth also, thus scoring one tooth on the 2nd wheel, and so representing 10 strokes; and so on throughout the series, so that when 999 strokes have taken place, the next stroke in fact moves all three wheel, which then show 000, and the fourth wheel goes one tooth suddenly, and thus shows 1000.

There is a modification of this counter, Figs. 43 to 46, at the South Kensington Museum, in which there are seven wheels and pinions all geared together, the wheels having 100 teeth and the pinions 10 teeth, so that all the wheels are always moving when one moves. This is a very safe instrument, but is not quite so clear to read. It is believed that these are the first "counters" that were ever made, at all events to go to millions as these do.

An exceedingly simple, but handy plan, of blocking up anything to a given height is shown in Fig. 50, (see next number) being in fact only a pair of "folding wedges," but with a number of notches in the lower W edge, into which a pin, fixed in the upper W edge, can drop, and so keep them from sliding when at almost any exact height.

In this room the author found a large number of little slips of copying paper, with various receipts for making copying ink, and in one corner of the room a small "Letter-copying Screw-Press," that would take in such slips conveniently; the screw was only of wood, but powerful enough for the light work it had to do. This is shown in Watt's 1780 patent, together with his "Letter-copying Roller-Press," of which there is also an example at South Kensington, together with his old desk, in which he had a pair of small rollers fitted for the same purpose. These two last belong to Mrs. Bennett Woodcroft. The drugs on the shelves were many of them for the purpose of making the "Copying-ink powders" that Watt used to sell at ninepence a packet, and of which there are some dozens now at Heathfield Hall. It is believed that he sold these on his own account.

The next machine to be noticed is a very remarkable one, when we consider the date at which it was made, 1809. It is a machine for sculpturing or copying a bust or bas-relief of of thesame size as the original; it is shown in Fig. 52, (see next number) which is copied from a good photograph kindly taken by Mr. George Tangye at some considerable trouble. Watt called this machine an "Eidograph," and there are some drawings of parts of the machine in the room.

The machine consists, firstly, of an ordinary lathe, with treadle and fly-wheel, to supply the motive power, and secondly of two tall uprights about seven feet high, carrying at the top a slide on a strong horizontal bar; the slide being capable of motion horizontally, either at a slow or quick speed. Then, hinged to this slide, is a light square frame of metal, and at the outer edge of this, another light square frame of metal is hinged, so that the lower edged of such frame is capable of motion up and down, or in and out, like an elbow joint, and horizontally when the top slide is moved.

The weight of these frames is balanced by lever and balance-weights and chains above, and the lower edge of the second frame is furnished with a "feeler" or "guide" to traverse over the original model, and a "drill" driven at a high speed by a light cord to cut the work or copy; so that by handling the feeler carefully and tracing over the original in all directions, a piece of marble or alabaster or wood, placed in the machine alongside of the original, is cut to a perfect copy by the machine without fear of any mistake, and without any special skill on the part of the operator. The slow motion to the slide above, carrying the frames and "feeler" and "drill," is worked by a convenient handle and tangent-screw when cutting, and the quick motion can be thrown into gear with the lathe wheel to run back. The *quick* motion has a *coarse* traversing screw, having a nut in halves, that can be closed or opened; and the *slow* motion has a *fine threaded* screw with a similar nut, so that it also can be thrown into gear or released. A handkerchief is wrapped around a part of one frame, in such a position that one could put one's head against it, to push it up off the work at pleasure, besides moving it by hand.

There is a noticeable feature in the frames above mentioned, and that is, in order to prevent their springing or going "winding," they are practically formed into "solids" by the erection of the outlines of a pyramid on each. Fig. 42, shows a similar frame, apparently an experimental one, found hanging on the wall: this is even better, theoretically than the one in the machine itself. The plan gives extreme stiffness, at the expense of very little weight. The author considers it an extremely ingenious method of preventing a framing from going "winding," and one that he has not seen before.

After searching the room over, two specimens of work were found, one a finished original bas-relief, and the other the unfinished copy of it. Both the original and the copy can be mounted in their places in the machine, and be turned precisely together by a pinion gearing into the two wheels on the mandrils of the carriages on which the articles are placed, so that "undercutting" could be properly accomplished, as well as straight cutting into the work by the "drills."

The drills, circular-cutters, and other cutting tools are excellent, some being formed for roughing out apparently, and made to cut in steps, *i.e.*, to take several light cuts, and some in the form of globes with the whole surface formed into numerous cutting edges, so that it was a cutting globe, so to speak, and could go anywhere, as it would cut in any direction.

Fig. 53, (next number) shows the sculpturing machine for making a copy of a reduced size. After searching the room thoroughly, two "masks" or half faces, were found, the one eight times the size of the other, and the smaller one undoubtedly executed in this machine. Some drawings found of parts of this machine gives 1811 as the date. Watt called it a "Diminishing machine."

The machine consists, firstly of a lathe bed, with fly-wheel and treadle for obtaining the motive power for driving the drill. Secondly of a stout hollow tube forming a long lever, fulcrumed at one end on a "universal joint," so that the other end can be moved in any direction about the centre. This lever carries a "feeler" or blunt point near its outer end, and a "drill" near the fulcrum, so that whatever motion the "feeler" has, the "drill" has (say) one-eight part as much. Thus, if a bust or mask (in this case a plaster cast) is placed on the slide provided for it under the "feeler," and such "feeler," is carefully traced all over it, the "drill" will cut a piece of material placed under it, on the slide provided for it, to the same form, except that it will be one-eighth the size of the original. The lever is balanced.

The slides above named slide on the bed of the lathe, and are moved by a "pentagraph," or arrangement of levers, to give one-eighth as much motion to the work to be cut as to the original, that every dimension shall be in proportion. A further motion is provided for turning round the original and the copy, as is sometimes necessary when undercutting a "bas-relief," and of course when copying the round figure.

One example, and one only, was found of the round figure, viz. an unfinished head and bust in wood, so small that no doubt it was done in this machine from a larger original.*

* The Secretary has since been informed by Mr. Samuel Timmins that several beautifully finished miniature busts by James Watt exist elsewhere.

It would appear that the machines just described were used by James Watt, probably as a mere amusement for his leisure, during the latter days of his life; for they do not appear to have been patented by him, or in any way brought before the public. It is to be hoped that in the pursuit of this hobby he found agreeable relaxation and relief after the laborious life which he had long led.

In concluston the author would draw attention to the general effects produced by the inventions of James Watt.

Firstly, in 1769 there were many Newcomen engines at work pumping (in fact Watt's attention was first drawn to steam engines by having to repair a model of a Newcomen engine), and the effect of his invention was, to work *pumping engines* more economically and quickly.

Secondly, in 1681 he produced rotative power for driving factories, obtaining it, in a manner, by having a heavy balance-weight to act one way whilst the steam acted the other way; however the *obtaining rotative motion* by steam was an *enormous advantage*, far greater in its effect, in the author's opinion, than the improvement in the *pumping engine*.

Thirdly, the crowning invention of 1782 made the steam engine the one useful motive power, by making it *double-acting*, and fit to drive cotton mills, flour mills, and all other machinery requiring regular rotative motion.

The general effect of this invention on the manufactures of the world, and first, of course, on those of this country, is so widespread that it cannot be estimated; it has cheapened production to a marvellous extent, has in very many instances been the means of bringing new manufactures into existence, and has immensely increase the intercourse between nations, by developing from fire and water as many *tame giants* as we require to do our work.

Miscellaneous Notes.

Cosmical dust in snow.—Various analyses have recently been made of the dust found in snow in order to ascertain whether it is volcanic, and therefore in all likelihood connected with the volcanic outburst of Krakatoa. Quantities fell at Stockholm on the snow during the end of last December, and M. Nordenskiold made a communication to the French Society on the subject. Since then M. Yung has also examined the snow of the mountains about Geneva and on the summit of the Great St. Bernard (2490 metres high). At this altitude the snow was covered by a very fine blackish dust very sparse in some parts, and in the form of small isolated spherules. In no place did the snow seem regularly black. Analyses showed that it contained silica, irregular fragments attracted by the magnet and globules of iron. Some of the dust also contained particles of organic nature and their ashes contained iron. M. Carizzo, prior of the St. Bernard monastery, has assisted M. Yung in collecting snow from parts of the mountain during the last week of January, and analyses shows it to contain globules of iron. While upon the subject we may mention that the Council of the Royal Society have appointed a committee to collect evidence on the Krakatoa eruption; Mr. Norman Lockyer, Mr. S. Russell being members.

Piers and Jetties are usually constructed of screw piles or columns, connected by plate or lattice girders. In ordinary cases a span of from 20 to 40 ft. is most convenient. When strong cranes have to be fixed on the pier, or when railway waggons and locomotives are to be carried, large cylinders, columns, or groups of piles are used for the foundations. In the same way as for bridges. Estimates can only be given against receipt of accurate information of all the circumstances which have to be provided for. We illustrate two kinds of screw-pile used, viz., the hollow cast pile and the solid screw. The following are the chief points to be considered in designing and estimating for this class of work:—1st. The length and width of the jetty. 2nd. The height of the roadway from the bottom of the water, the slope of the shore, and depth of water at various times. 3rd. The nature of the sea or river-bed. 4th. The intended purpose of the jetty. If for loading and unloading ships, state how many at a time, and the heaviest weights to be lifted, also whether the vessels will be likely to roll against the pier.

INVENTIONS OF WATT.

Rolling and Slitting Mill.

Fig. 32. *End View.*

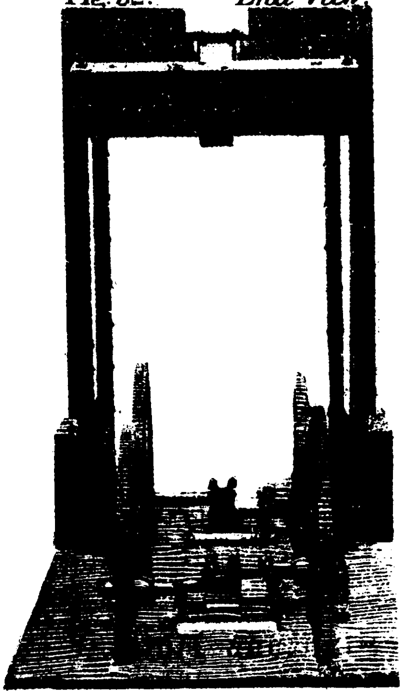


Fig. 33. *Elevation.*

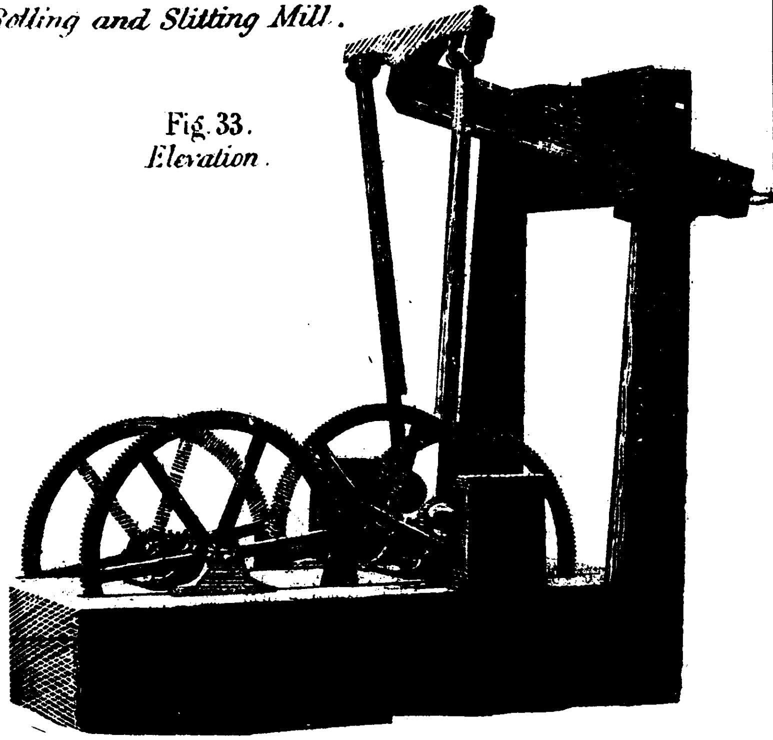
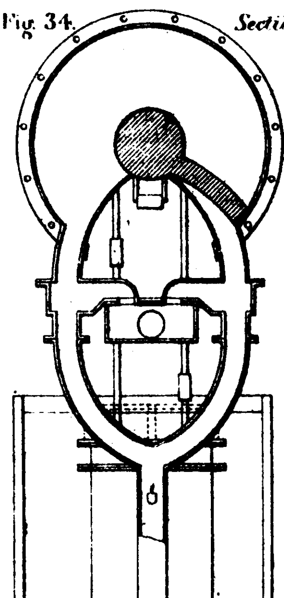


Fig. 34. *Section.*



Semi-rotary Engine.

Fig. 35. *Side View.*

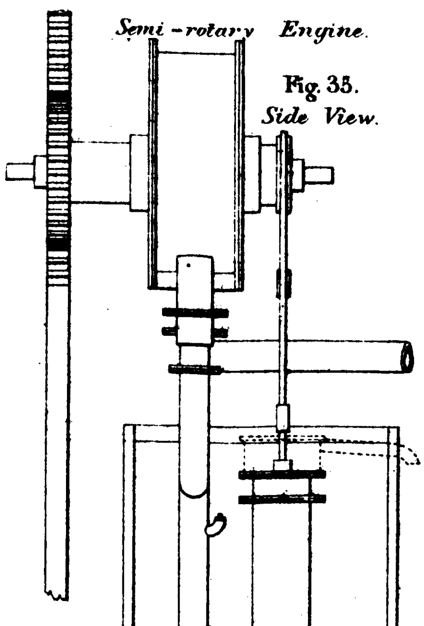


Fig. 36. *Pump-rods & Pinion.*

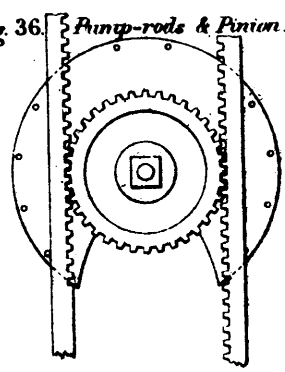
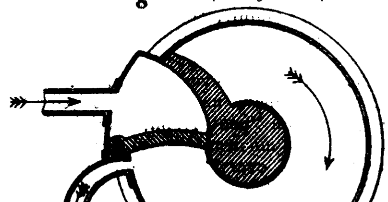
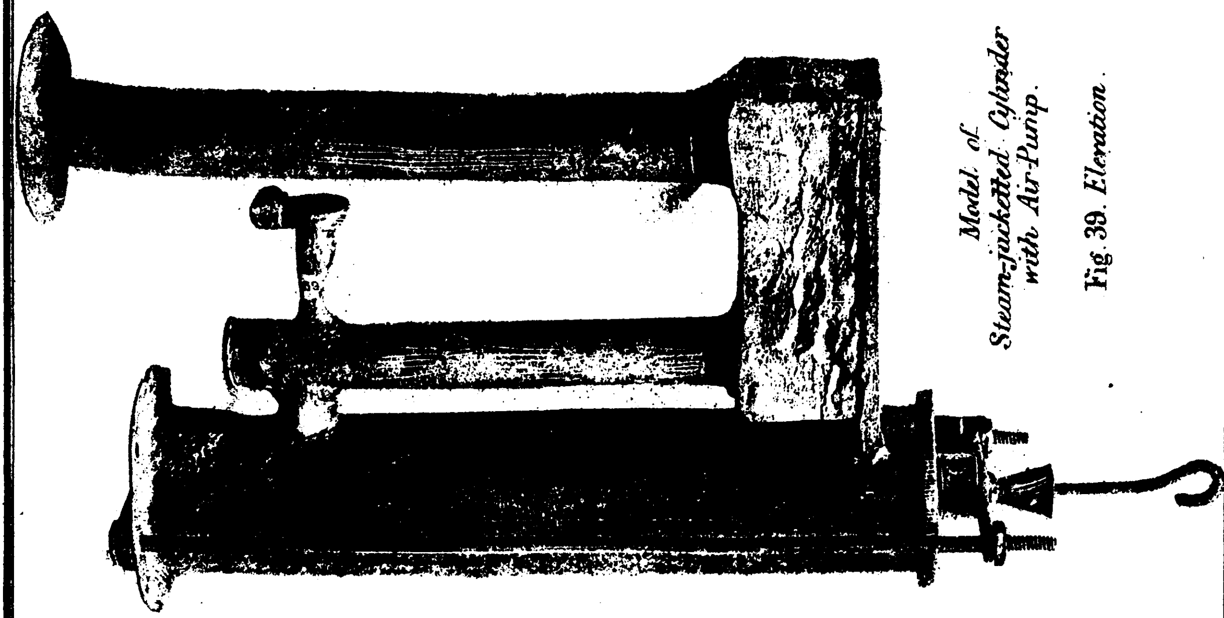


Fig. 37. *Rotary Engine.*



INVENTIONS OF WATT.



Model of Steam-jacketted Cylinder with Air-Pump.

Fig. 39. Elevation.

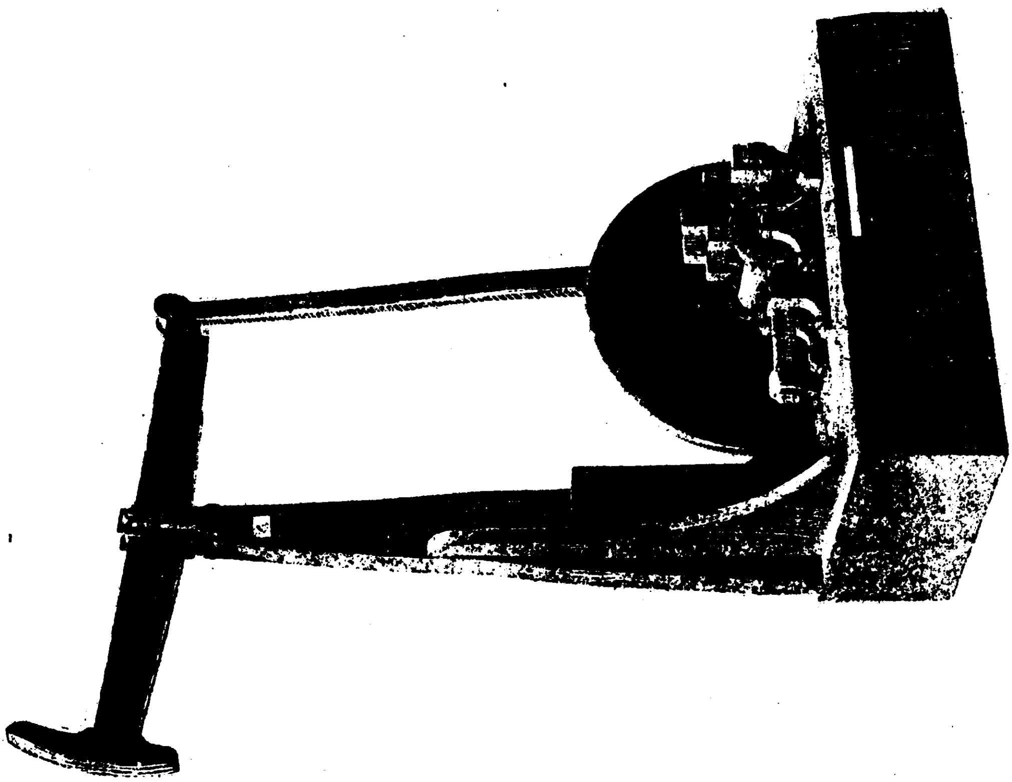


Fig. 38. Tilt Hammers.

ELECTRIC LIGHTING OF HOUSE, &c.

A paper was read on the evening of the 18th inst., at the ordinary meeting of the Royal Institute of British Architects, on the "Electric Lighting of Houses and the precautions to be adopted on its introduction," by Mr. Killingworth Hedges, C.E. The steady increase of electric lighting for house purposes was shown by the number of installations which have recently been made by the occupants of houses both in town and country. In large cities a temporary check has been ex-experienced with the general supply of electricity as contemplated by the Act of 1882. The electrical currents which would be employed for lighting a dwelling are very powerful, and without some precautions were taken to insure their being properly regulated, they might cause great risk from fire. Mr. Hedges pointed out how this risk might be occasioned, and suggested that the rules of the Fire Risk Committee should be strictly adhered to, especially those which advised that all work should be under the supervision of a competent electrician. Many fires hld been caused by the electric lights, which is used largely in America for mill lighting, the official report showing that all these were either due to neglect of precautions for safety or by not having the work properly supervised. As regards cost, the fixed charges with electric lighting, such as supervision, interest, etc., caused it to be much dearer than gas when used for a short period ; but if these charges were spread over a number of hours, electricity was relatively much cheaper. Mr. Hedges recommended the introduction of the electric light on account of the ultimate saving in the renewal of decorations and preservation of works of art. The property of not vitiating the air should, alone, make electricity rank, independent of its cost, as one of the greatest sanitarw improvements of the age. The paper was followed by a discussion.

LARGE CHAINS.—Two heavy chains, for use on the large floating bridge connecting Portsmouth and Gosport, have just been completed by Messrs. Jones & Lloyd at their Cradley Works, Staffordshire. Each chain is 640 yards long, and consists of nearly 5,000 links, its weight being about 21 tons. The chains are of 1-11-16 in. round iron of the well-known "Lion" brand made by the New British Iron Company, Limiten, Corngreaves, near Birmingham. The proof test was 40 tons or 20 per cent. more than the Admiralty test, and the breaking strength was proved to be 70½ tons. For chains, Staffordshire iron of this class has often been proved superior to even Yorkshire iron, its tensile strength being considerably above the average, and its excellent working qualities admitting of sound workmanship in the smith's shop.

CHISELS.—All carpenters know how soon the butt end of chisels split, when daily exposed to the blow of a mallet or hammer. A remedy suggested by a Brooklyn man consists simply in sawing or cutting off the round end of the handle so as to make it flat, and attached by a few small nails on the top of it two round disk of sole leather, so that the end becomes similar to the heel of a boot. The two thicknesses of leather will prevent all further splitting, and if, in the course of time, they expand and overlap the wood of the handle, they are simply trimmed off all around.

SPEED RECORDER FOR LOCOMOTIVE.—(*Engineering.*)

The speed recorder, of which we give illustrations (for illustrations see gage 81), was designed by Mr. A. Klose, and manufactured by the Werkzeug and Maschinenfabrik, Oerlikon, Zürich. It belongs to that class of speed-indicators in which the vertical movement produced on a spindle by solid rotating masses, acting against a spring, is indicated on a dial, showing at all times the speed with which the apparatus is revolving, while simultaneously the speeds are registered on an endless paper band, moved by clock-work, thus giving a graphical picture of the fluctuations of speed during a given time.

The construction will be easily understood on reference to Figs. 1 and 2, Page 81 of our illustrations, which represent vertical sections in two different directions of the tachymeter. The vertical spindle *a b* carries on its upper end the fork or frame-shaped enlargement *c c* ; pivotted in this at *d d* is the disc *e*, provided with a long slot, into which fits the connecting link *f* fork-shaped and pivotted to the disc by a bolt *g*. The link *f* is at its upper end, hinged at *i* to the socket of a little vertical spindle *h*, while its lower end has a little connecting rod *r*, governing the motion of the fork piece *f*. Acting against the influence of the rotative force is a conically coiled spring *k* fixed with its upper and smaller end to the socket of the rising spindle *h*, with its lower and larger end to the projections provided on the frame *e*. All the parts so far described rotate with the vertical axle *a b*, which receives its motion by means of the bevel wheels *l l*. While rotating, the pivoted disk *e*, and the levers hinged thereto, change their relative positions, and the point *i* rises and falls according to the speed of the rotating masses. The lower end of the little spindle *h* rests with a foot bearing in the socket carrying the point *i*, and does not revolve, but only receives a slight vertical movement which, by means of a toothed fork, see Figs. 3 and 4, embracing a pinion *q*, to the centre of which is attached a pointer, giving a partly rotary motion to this pointer, which indicates the number of miles per hour at any moment on a divided dial plate. The motion is transmitted from the driving wheel of the locomotive to the speed indicator, eitner by means of a friction wheel running against the tyres, or by means of a little crank from some convenient point on the connecting rod. All parts in this apparatus have to be carefully shaped, pivotted, and balanced, and the spring accurately set, so as to give correct results on the dial-plate, and the whole is inclosed in a dust-tight box to prevent any dirt interfering with the delicate worxing parts.

It now remains to describe the arrangement, by means of which a continuous record of the mileage is obtaihed. A clock A rotates once in an hour a drum B, over which, and a second similar but loose roller B1, runs an endless paper band. In thh vertical rod *h*, at a convenient place, is provided a little cross slot *m*, in which the free end *n* of a bent lever *n t*, pivotted at *t* to a plate *p*, ean slide to and fro ; the marking lever *r o* is attached by means of a light parallel motion to the lever *n t* ; it carries at its lower end *o* a marking point, and is at its upper end hinged by means of the short link *r s* to a fixed point *s* on the plate *p*. A roller guide *u* is provided for the vertical rod *h*. This marking apparatus also is enclosed in a strong box to protect it from dust and interference, and is in ordinary running locked up. The proportions of the paper are chosen in such a manner that ten miles are represented by about ⅝ in., thus allowing mile lengths to be read with accuracy, while a length of paper band of nearly 2½ in. represents an hour, minutes being represented by lines about 1-25th in. apart. A piece of the paper band is reproduced in Fig. 10 to half the actual scale ; in this the speeds are given in kilometres, and the distances for time in millimetres, while also a note is made on the slip, that 1750 revolutions per minute of the speed indicator, corresponding to 105 kilometres, or about 65 miles per hour, the maximum speed for which the apparatus from which the paper strip was taken, fitted to an engine on a Swiss line, can be run. It will, however, be understood that the indicator is capable of adjustment for any desired speed. Wherever it is convenient the indicator is driven by means of a friction roller pressed againstt he wheel tyre and fixed to the horizontal shaft of the gear wheels *l l*, which shaft is carried in a bracket D pivotted round the bearing of the vertical spindle *a b* ; to enable the friction pulley to follow any unevenness of the tyre, this bracket can slide laterally in a guide E, and is pressed against the tyre by a strong spring F. Where this arrangement is not practicable a small crank *w*, attached to the connecting rod, is employed working a second set of bevel wheels *z z*. This mode of driving is not so convenient since every different size driving wheel requires a different division of the scale.

Speed indicators of this type have given very satisfactory results on the lines where they have been used, and have been highly approved by the Society of German Railways. All parts of these indicators can be readily tested ; if the springs, which can be tested by direct loading, are found either too strong or too weak, they can be readily adjusted by turning them in their attachments, thus either lengthening or shortening them as required, and again fixing them. The clockwork requires occasional attention and should for this purpose be taken to the office and there tested for accurate timekeeping. The paper band records are easily readable, and if stations and other fixed positions are printed on them give an excellent and clear picture of the whole run.

HYDRAULIC CHAINS FOR STEEL WORKS.

(*For illustrations see page 80.*)

The following paper was read by Mr. R. M. Daelen before the Iron and Steel Institute. Mr. Ludwtg Huckenholz, of Wetter-on-the Ruhr, has recently sent us sketches of four types of hydraulic cranes executed by him for steel works, and of which we publish diagrams above. The principal feature of these crones is, that the crane-post is an independent structure, quite apart from the hydraulic cylinder and ram, and it can therefore be constructed of any desired section and form; its weight in no way influences the action of the crane; in addition, all side strain and bending movements are entirely removed from the cylinder and ram, a point of considerable importance, and one through which much trouble with the stuffing-boxes is avoided, since they have neither side strain nor does the plunger turn in them. In addition, the hydraulic cylinder and plunger are of considerably less dimensions, having the carrying bracket and the actual load only to lift, and not the crane-post and balance-weight.

The form for the crane-post generally chosen in the types illustrated is a wrought iron stanchion of rect-angular section, rivitted up of angle-iron and plate; it is not only a favourable section for strength, but also one to which the roller guides for the crane arm or bracket are conveniently attached. In Fig. 2, Page 80 the hydraulic cylinder is arranged inside the crane-post, in the other three types it is placed on one side, so that cylinder and plunger turn with the crane arm.

This arrangement, of course, necessitates introducing the water through a stuffing-box in the cantre of the crane-post, either top or bottom, from whert it passes to the cylinder, but although this may appear a little complicated, yet in actual practice no difficulty is experienced with it, the stuffiing boxes being easily kept in good order.

There is no reason why, when desirable, a second cylinder should not be attached for balancing the moving loads; but since these are not nearly as large as in the usual constructions, the saving in water will only in rare cases be worth this extra cost. Both turning and moving the cradle in and out can be arranged with equal facility to that in ordinary hydraulic cranes.

The diagrams require no further description, but a few words may be said as to their intended use. Fig. 1 represents a foundry crane with no side or top supports, the foundation being arranged on the plan of the Fairbairn cranes, where a ring rolling on a series or small rollers takes the side thrust, and this type of crane is specially suitable for Bessemer cranes up to the highest desirable loads and the greatest necessary radius. Fig. 2 represents a self-contained ingot crane, such as is wanted for Gjer's soaking pits. In this case the crane-post ir held by conical plate-iron pedestals above the floor level.

Fig. 3 represents an ingot crane of smaller dimensions, in which the crane-post, constructed as a rectangular box girder, turns round a solid vertical steel spindle, while in Fig. 4 is illustrated an ingot crane with top bearings. The two latter types have also been carried out as steam cranes, for ten tons load, two steam cylinders being placed one each side of the hydraulic cylinder, the former performing the lifting, while the latter only serves as brake, and to regulate the speed; as in Brown's cranes, steam will of course only be used in such places where there is no hydraulic plant, or where lifting work has to be performed too far away from the accumulators. For instance, for loading or unloading ingots, or in small Martini steel works, where the same crane serves as ladle and ingot crane.

It cannot be denied that hydraulic cranes of these types are more costly in the first instance than ths ordinary cranes; but not only are they cheaper to work since they require less water, but they are certainly much less liable to cause bursting of the hydraulic pipes, since the moving weights are so much less, speed and pressure of the water in the pipes are considerably reduced, and sudden shocks which frequently arise when lowering with heavy cranes, are nearly entirely avoided.—*Eng.*

NOTES ON ELECTRICITY AND MAGNETISM.

BY PROF. W. GARNETT.

(*Continued.*)

If a number of Leyden jars be supported on separate insulating stands, and the outer coating of the first be connected with the inner coating of the second, the outer coating of the second with the inner coating of the third, and so on, the outer coating of the last jar only being put to earth, while the inner coating of the first jar receives the charge from the machine, all the jars will simultaneously receive a charge which will be nearly the same for each. Such an arrangement is sometimes called "a cascade," and the operation of charging is called "charging by cascade." In accordance with the analogy of a battery it may be said that the jars are arranged in *series*, while the ordinary system of connecting all the inner coatings together and putting all the outer coatings to earth may be called an arrangement in *multiple arc*.

If the outer coatings of the jars completely surrounded the inner coatings, and there was no project-knobs, the charges of all the jars when arranged in series, or cascades, would be very nearly equal, and if Q units of electricity were supplied by the machine each jar would Q units of electricity. But the jars cannot be charged each to the full potential which the electric machine can produce, for potential of the inner coating of the first jar is the sum of the difference of potential of the several jars in the series, and this cannot be greater than the potential produced by the machine. Suppose there are six jars, each having the same capacity, C, and suppose that the potential which the machine can produce is V. Then each jar can be charged to potential 1-6V. The charge of each jar will be 1-6VC, and the energy 1-72CV^2, while the energy of the whole series of jars will be 1-12 CV^2. If one jar alone had been charged to the full potential of the machine its charge would have been C√ and its energy 1-2CV^2, so that the energy of a single jar charged to the full potential of the machine will be six times that of the whole battery when charged in "cascade." If the battery were charged "in multiple arc" to the full potential of the machine its charge would be 6CV and its energy 3CV$_2$, that is, thirty-six times that of the battery charged "in cascade."

The "cascade" arrangement is of little practical value except for measuring the charge given to a Leyden jar or battery of jars. For this purpose a small Leyden jar, called a *unit jar*, is arranged "in cascade" with the jar whose charge is to be measured. If more jars than one are to be charged they are all connected in multiple arc with their outer coatings to earth, and the unit jar is supported on an insulating stand, its outer coating being connected with the inner coatings of the battery. The inner coating of the unit jar receives the charge from the machine. Two knobs, one connected with the inner coating and the other with the outer coating of the unit jar, are arranged so that the distance between them can be varied at pleasure. As soon as the unit jar is charged to a potential sufficient to produce a spark it is discharged, and ready to be re-charged by the machine, but the charge which has entered the jar or battery connected with the outer coating of the unit-jar remains unaffected. By counting the number of spark discharges which take place between the knobs of the unit-jar the charge which enters the battery can be estimated. Thus, if C denote the capacity of the unit jar and V the difference of potential necessary to produce a spark between the knobs, the charge communicated to the unit jar before each spark is CV, and this is sensibly equal to the charge which leaves the outer coating of the unit

HYDRAULIC CRANES FOR STEEL WORKS.

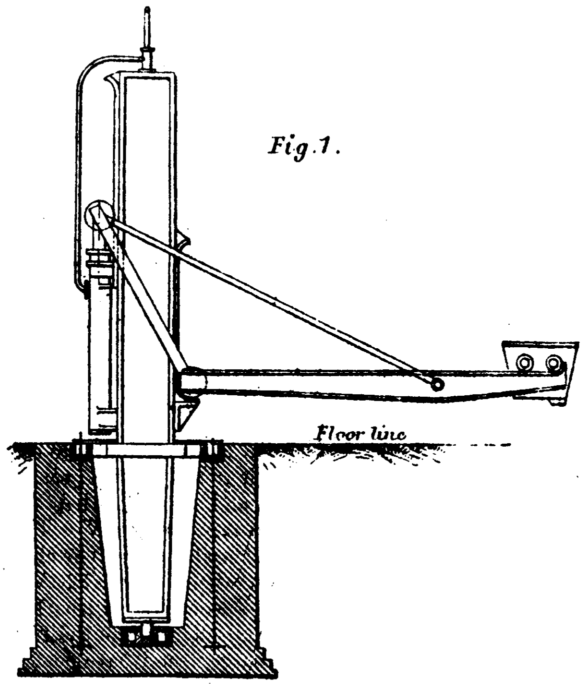


Fig. 1.

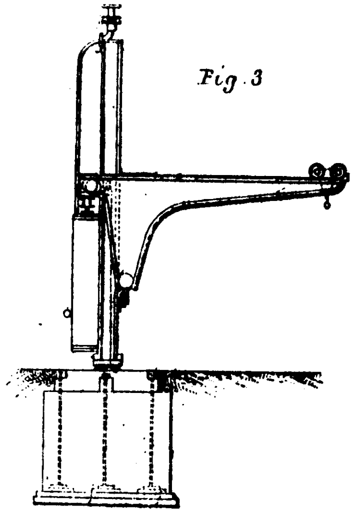


Fig. 3

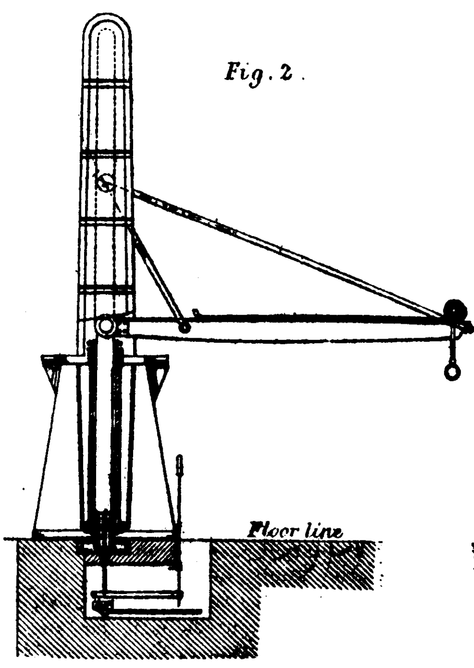


Fig. 2.

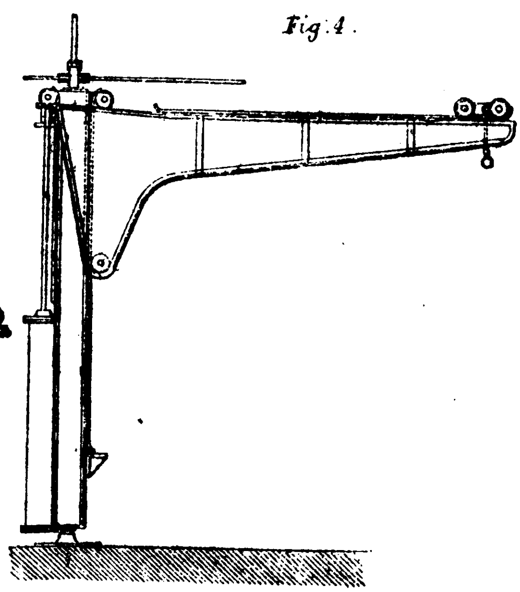
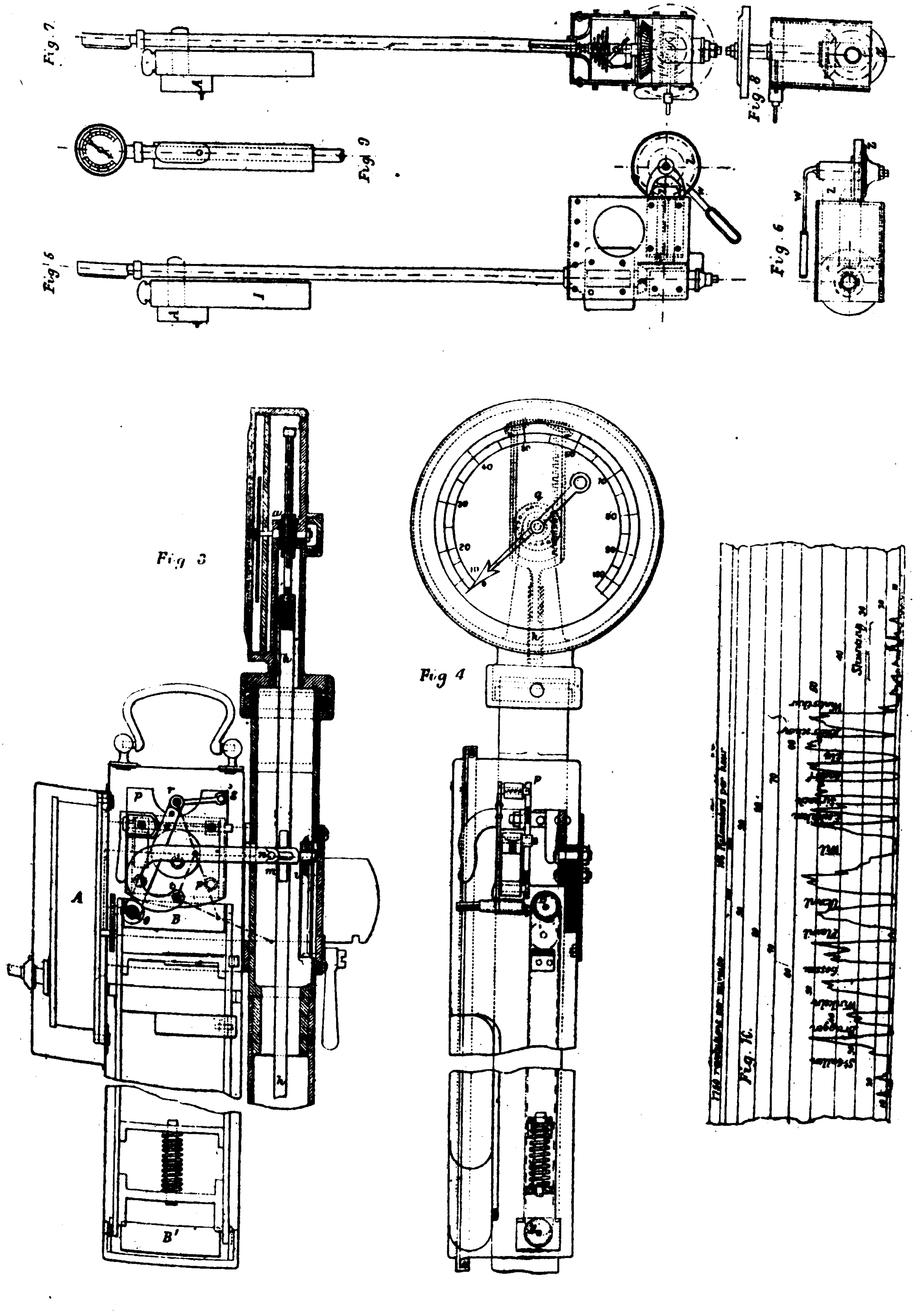


Fig. 4.

KLOSE'S SPEED RECORDER FOR LOCOMOTIVE.



jar and enters the battery. If n sparks take place the whole charge entering the battery will be nCV. The potential to which the Leyden battery can be charged is not equal to the full difference of potential which the machine can produce by the quantity V, which is the potential to which the unit-jar must be charged to produce the spark.

According to Sir Wm. Thomson, it requires an electromotive force equal to that of about 5510 Daniell's cells to produce a spark one-eighth of a centimetre (about one-twentieth of an inch) in length between two slightly convex metallic surfaces; and at greater distances the force required is greater, but not quite in the same proportion.

When a conductor is placed inside a closed hollow conductor and in metallic communication with it, it of course acquires the potential of the hollow conductor, but is always found to be completely discharged. Conversely, if a conductor is uncharged and placed within a closed hollow conductor, whether in contact with it or not, it will have the same potential as the conductor. The same will be true if the conductor be nearly but not quite closed, provided the openings do not subtend large angles as seen from the interior body. (A vessel of wire gauze is practically as good as a continuous piece of metal for the purpose.) Hence, if a conductor of capacity C be placed inside a hollow vessel which is maintained at potential V, and the conductor be put to earth, it must receive from the earth a charge sufficient to reduce the potential from V to 0, that is, it must receive a negative charge represented by —CV. Similarly, if the conductor be placed in a vessel whose potential is negative, and equal to —V, the conductor will receive a positive charge of CV units.

This principle was employed by Dellman for measuring the potential of the air at the top of a mast. A metal ball was raised to the top of the mast by an insulating silk string. It was then placed in contact with the earth, and after breaking the earth connection the ball was lowered by its insulating string, and its potential observed by an electrometer in a place where the potential of the air was sensibly zero. Suppose that V denotes the potential of the air at the top of the mast and C the capacity of the ball. The ball will then receive a charge represented by —CV, and on bringing it into a region where the potential of the air is zero the ball will have a potential—V. that is, a potential equal and opposite to that of the air at the top of the mast.

Sir Wm. Thomson's water dropping accumulator may be constructed by suspending four copper cylinders, open at each end, by means of silk strings. Two of the cylinders are placed vertically below the other two, and a small funnel rest in each of the lower cylinders to intercept the drops of water before allowing them to fall through. The cylinders are connected diagonally by wires, so that if A, B, C, D denote the four cylinders, of which C is vertically below A, and D below B, then A and D are connected by a wire, and B and C by a second wire, but the two pairs, A D and B C, are insulated from each other. A stream of water, continuous with the ordinary water supply, is allowed to flow from a jet suspended within each of the cylinders A and B, and the jets are so arranged that the streams break up into drops before leaving the cylinders. The drops of water then fall into the funnels which are placed in the cylinders C and D, and after coming in contact with the funnels the water falls through the cylinders and is allowed to flow away. To start the action a small difference of potential is produced between the pair of conductors A D and the pair B C. Suppose for the sake of symmetry and simplicity that A and D are raised to potential V, while C and B are at potential—V. The stream of water in A being in connection with the earth so long as it does not break up into drops must be at zero potential, and the water must therefore be electrified negatively, since A is at a positive potential. Similarly the stream of water flowing through B must be positively electrified. As the stream breaks into drops each drop will fall away with its positive or negative charge, as the case may be, and the drops now being insulated their charges will be imprisoned upon them until they strike the funnels below. If C denote the capacity of a single drop each drop falling from A will bring with it a negative charge —CV, and each drop falling from B will have a positive charge denoted by CV. But the negatively electrified drops falling from A come in contact with the funnel in the conductor C, and being inside a hollow conductor and in contact with it they lose practically the whole of their charge before they fall away on the lower side of the funnel. They therefore communicate a negative charge to the conductors B C, which are already negatively electrified, and thus increase their charge and the numerical value of their potential. In the same way each drop of water falling from B strikes the funnel in D, and communicates to it a positive charge, so that the conductors A D, which are already positively charged, receive constant additions of positive electricity, and thus the charge and potential of each pair of conductors become numerically increased. As the potentials of the conductors increase the charges on each drop also increase in proportion, so that the increase of charge and potential is in geometrical progression, the ratio depending on the relative capacities of the drops and the conductors.

The energy of the charge is derived from the work done by gravity against electric forces on the falling drops, for the negatively electrified drops falling through A will be attracted by A and repelled by the negatively electrified conductor C, so that their fall will be resisted by both these actions, and their velocity on reaching C will be less than if no electric forces had acted. The positively electrified drops falling from B will be similarly affected. At length the electric forces on the drops become so great that instead of falling into the funnels they split into fine spray, and the small drops so produced mutually repelling one another their paths diverge, and they fall all round the lower cylinders without entering them. The electrification of the system then ceases to increase. It is unnecessary for the streams of water to be connected to earth, provided that the jets are connected with one another.

The action of the replenisher is essentially the same as that of the water dropping accumulator. In place of the four copper cylinders two pieces of brass called *inductors* are employed. The inductors are so shaped and adjusted as to form parts of the same cylinder, being insulated from one another by a small space, and supported on glass pillars. The falling drops of water are replaced by two brass *carriers*, which are, of course, employed over and over again, and which revolve within the cylinder formed by the inductors. When the carriers are about to leave the inductors they are connected together by a wire through two springs, which touch them when in a particular position. During the rest of their revolution the carriers are insulated from each other. When in the middle of the inductors the carriers are connected with the inductors themselves, by springs which rub against the carriers.

To start the apparatus a small difference of potential is produced between the inductors. As in the case of the water dropping accumulator, suppose that one inductor, A say, is at potential V, and the other B, at potential —V, though B may be, and usually is, put to earth. Let *a b* denote the carriers, and suppose to begin with that *a* is in contact with the inductor A and *b* with B. Then *a* and *b* are practically discharged. Now let the carriers be turned till they touch the springs which put them in communication with one another. They will then be reduced to the same potential. But *a* when uncharged was at the positive potential of A, that is, V, and *b* when uncharged was at the negative potential —V possessed by B, because it was inside it. Hence when *a* and *b* are connected by the springs, *a* will receive a negative charge and *b* a positive charge. The carriers are then insulated, and continuing their revolution the carrier *b* enters the inductor A and the carrier *a* enters the inductor B, and presently a communication is made between each inductor and the carrier within it. The carrier *b* then gives up its positive charge to the already positively charged inductor A, and the carrier *a* gives up its negative charge to the already negatively charged inductor B, thus increasing the charge and the difference of potential of the inductors in geometrical progression. This increase goes on until the rate of loss from defective insulation, brush discharge, &c., is equal to the rate of production.

Varley's machine differs in no essential particular from the replenisher. Instead of one pair of carriers it possesses several pairs, which consist of pieces of tin foil attached to the edge and each side of a revolving disc of ebonite or glass near its circumference. The two inductors are bent pieces of metal, which embrace the edge of the plate and so nearly surround the carriers when the latter are within them. The contacts are essentially the same as in the replenisher.

It should be noticed that the object of Varley's machine was to supply large quantities of electricity, and hence the inductors were made to nearly surround the carriers, and thus afford the strongest possible action. In the case of the replenisher the object was to increase the charge of a Leyden jar very slowly and steadily, so that the most powerful action was not sought after.

In all the machines working on this "compound interest principle," as it is sometimes called, the energy of the charges supplied is derived from the work done in overcoming the electrical attractions and repulsions between the inductors and carriers or the corresponding parts. If the replenisher be turned backwards work will be done by the electric forces, and the charges of the inductors will be reduced.

The action of Voss's machine for a short time after it is first started is precisely the same as that of the replenisher. In it two paper armatures with small pieces of tinfoil beneath them are attached to the back plate of the machine, and serve as inductors. The carriers consist of six circles of tinfoil attached to the revolving table. The contacts are made upon metallic buttons attached to the carriers by little brushes of gold tinsel. Two of these brushes are attached to a cross arm, or diagonal conductor, and serve to put the opposite carriers into connection with one another. The others are connected with the paper armatures by means of a metal arm. A very small difference of potential between the paper armatures, which they generally acquire by unknown or incidental causes, is sufficient to start the action of the machine, and to charge up the armatures to a high potential.

When the armatures are strongly electrified, a new action begins to take place. Not only does the electricity pass from the metallic brushes to the metal carriers, but it begins to stream from the rows of points, which are attached to the diagonal conductor on each side of the brushes, upon the glass plate, so that the portion of the plate which is opposite the negative inductor becomes positively electrified, while that which is opposite the positive inductor becomes negatively electrified. The revolving glass plate thus begins to act as a carrier itself, and presently its positively electrified surface comes in front of the negatively electrified armature. The carrier comes in contact with the brush when it is between it and the armature, and thus gives up its charge to the armature; but the glass cannot dispose of its charge in this way, but retains it until it comes opposite the points of the prime conductor, when negative electricity streams off the points upon the plate, neutralizing the positive charge of the plate, and even electrifying it negatively under the inductive action of the armature. This causes the prime conductor to become positively charged. The opposite prime conductor becomes negatively charged at the same time and in the same way. The circuit of the electricity is completed in the sparks which pass between the conductors. The portions of the glass plate which we are considering having passed in front of the prime conductors, now come opposite the diagonal conductor, when the same action takes place as before, unless the revolving plate has been charged by the prime conductor to the full extent which the armature can induce, in which case the diagonal conductor becomes inoperative. If the discharging knobs of the prime conductors are placed in contact so that there is no resistance to the passage of electricity from one to the other, the prime conductors take the place of the diagonal conductor in charging the glass plate and carriers by radiation, but if the conductors are separated, and happen to be charged nearly to the same potential as the armatures, then very little discharge will take place from the points of the prime conductors, and the diagonal conductor alone will maintain the action. If the machine be worked in the dark, it will be observed that if the prime conductors are in contact, or separate but uncharged, the brushes and glows will appear on the points of the prime conductors, and not on the diagonal conductor. If the prime conductors are separated by a considerable distance, the brushes and glows on their points will diminish as they become charged, and will appear on the points of the diagonal conductor, where they will steadily increase in intensity; and if the prime conductors be separated to the full striking distance of the machine, the diecharge from their points will disappear just before a spark passes, but it will reappear on the prime conductors and disappear from the diagonal conductor immediately after the spark

(To be continued.)

THE EVOLUTION OF FLOWERS.

By Grant Allen.

II.—FIRST STEPS.

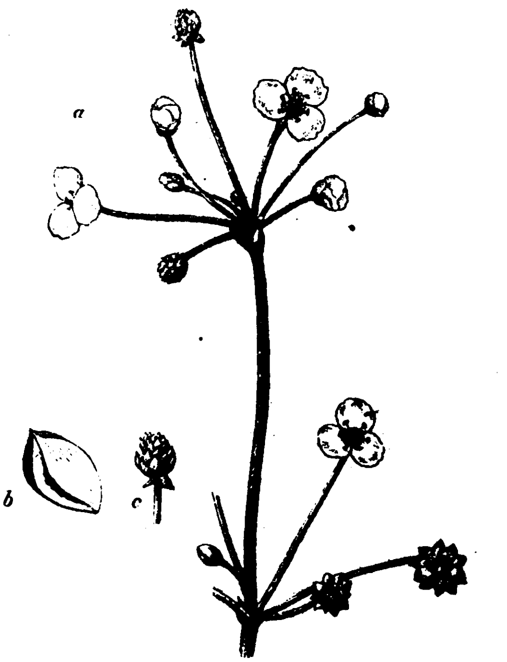
BEFORE we go any further on our upward course in tracking the development of the lily group, I should like to point out the sort of goal towards which we must be gradually tending; and I don't think this could be better done in any way than by taking three typical stages in the evolution of the lilies on the one hand, and of the buttercup family on the other. The special interest of such a comparative view depends upon the fact that while the lilies are monocotyledons, belonging to the great class whose flowers are arranged in rows of threes, the buttercups are dicotyledons, belonging to the great class whose flowers are arranged in rows of fives. Yet in spite of this primordial distinction, we shall see that the two groups progress along exactly similar lines, and that in each we can find almost exact analogues of the grade of development reached at each stage by the other. A tabular statement set side by side will enable us to observe this close parallelism in the clearest and most interesting manner.

Buttercup Group.	Lily Group.
1. The Buttercup has: five distinct greenish sepals; five coloured petals; numerous whorls of stamens; numerous whorls of carpels, all separate, and each containing one seed.	1. The Water-Plantain has: three distinct greenish sepals; three coloured petals; two whorls of stamens; numerous whorls of carpels, all separate, and each containing one seed.
2. The Columbine has: five coloured sepals; five coloured petals; numerous stamens; five carpels, forming a single group, and each containing several seeds.	2. The Tulip has: three coloured sepals: three coloured petals; two whorls of stamens; three carpels, united into a single capsule, and each containing several seeds.
3. The Monkshood has: irregular flowers, with five very peculiar coloured sepals; two to five very peculiar coloured petals; several stamens; and only three united carpels, each containing many seeds.	3. The Orchids have: irregular flowers, with three very peculiar coloured sepals; two very peculiar coloured petals; one or two stamens; and three united carpels, each containing many seeds.

This little comparative table must serve us for the time being as a rough and general guide to the direction that evolution in flowers has generally taken. The why and wherefore of each upward step must be a matter for future explanation piecemeal.

And now let us hark back to our friends the water-plantains, and consider further what are the peculiarities which each of the best-known British kinds presents after its own fashion.

We have in England two other species of Alisma besides the one which formed the text for our first paper. One of these, the lesser Alisma (*A. ranunculoides*), a much rarer plant, is so remarkably like a buttercup that Linnæus gave it its Latin name in commemoration of the close resemblance. And, indeed, the name conveys more meaning than any mere outer likeness of parts could convey: it testifies to the great botanist's underlying appreciation of the fact that the two flowers are in reality exactly analogous to one another. The lesser Alisma holds among the lily group of three-rowed or trinary flowers just the same place that the buttercup holds among the larger group of five rowed or quinary flowers. In both, the carpels are very numerous, and they are arranged, not in a ring round the centre of the flower (as is the case with the water-plantain), but in a big globular head, which forms a central boss inside the petals and stamens. The meaning of this curious arrangement is probably this: the whorls of carpels have become so numerous and so crowded that they have crushed one another out of shape altogether. In the water-plantain, as a rule, if you count the carpels, you will find there is a rough approximation to an arrangement by whorls of three; either there are eighteen, that is to say, six whorls (the smallest number I have ever noticed), or there are twenty-one, twenty-four, twenty-seven, or thirty,



Alisma ranunculoides.

that is to say, seven, eight, nine, or ten whorls (the largest number I have ever noticed). Often enough one or two carpels have become abortive, and so the number test fails; but, even so, it is always easy to see that the carpels fall into three rough groups, each group representing the carpels of six or seven separate whorls.

But nothing of this sort can be traced in the lesser Alisma. There the carpels are simply all jumbled together into a head, as in the buttercup, and no trace at all is left of the primitive arrangement in rows of three.

Now, this singular resemblance of the lesser Alisma to the buttercup is not a mere casual accident, but is due to the fact that both plants stand at the very bottom of the evolutionary scale in their own division of flowering plants. We cannot say how or why the primitive flowering plants split up into the two great bodies (monocotyledons and dicotyledons) respectively provided in their most regular forms with whorls of three or of five members each; and we have now no links remaining between the two bodies, though there are a few plants in each which approximate slightly in one or two points to the peculiarities of the other. But we may be pretty sure that the Alismas and the buttercups represent a very early stage of the two bodies shortly after they had begun to diverge from one another in the direction of their own particular peculiarities. Other plants in each great body have undergone wider and ever-wider changes in adaptation to altered circumstances; but the Alismas and the buttercups have continued to preserve the same features unchanged during all the long series of intervening ages. They stand to other flowers in somewhat the same relation that the Australian black-fellows stand to the remainder of humanity, or that the duck-billed ornithorhyncus stands to the fully-developed mammals.

Alisma natans.

As I intend these notes on the lilies to be a sort of explanatory companion to the ordinary botany books, it may be well to say a few words as to some other points in the English Alismas. The lesser Alisma has larger and more solitary flowers than the water-plantain; it trusts more to size and less to number than its commoner ally. Its leaves also, when submerged, often have no blade; there is no more of them developed than the bare leaf-stalk. This is a common peculiarity of submerged plants, which almost always have very long, narrow, or much-divided waving foliage. Leaves of such a sort, I believe, are better adapted for catching and utilising the carbonic acid in the water than the large broad flat blades which succeed best in the open air and sunlight.

Our third English species, the floating Alisma (*A. natans*), found only in a few western counties, displays the peculiarities of a born water-plant in a still more striking degree. It has long lithe stems which trail at great length through the still waters of quiet ponds. It has adapted itself to an aquatic existence far more thoroughly than its two half-marshy neighbours; yet it is very closely allied to the lesser Alisma, from which it only differs in habit and in one or two minute or unimportant particulars. Like a great many other thorough-going water-haunters, the floating Alisma has two kinds of leaves. The one sort, though small, is broad and oval in shape, and lolls lightly on the surface of the water, where it can catch the full sunshine unimpeded and drink in the free carbonic acid at all its pores. The other sort grows below the water, and is reduced to a mere footstalk, sometimes slightly dilated at the end, where the blade or expanded part of the leaf ought to be. Evidently, the development of the leaves here depends entirely upon the question whether they can reach up to the free air or not; the root leaves being always submerged and narrow, while the leaves that spring from the upper joints are floating and oval in outline. Exactly the same sort of thing happens again with the water-crowfoot (*Ranunculus aquatilis*) which is a water-haunting buttercup, exactly analogous to the floating Alisma; only in that case, while the upper floating leaves are broad and five-lobed, the lower waving ones are reduced to numerous long, narrow, much subdivided segments. Observe in every case that the floating leaves are analogous to the broad round foliage of the water-lily, and the submerged ones to the hair-like waving foliage of water-milfoil, and other common freshwater weeds. Almost all aquatic plants have leaves belonging to one or other of these types, or else both to one and the other in different parts. Botanical readers will remember that the pondweeds (*Potamogeton*) offer many excellent examples of all three conditions. It is interesting to observe, however, in the case of the Alismas, that the lesser Alisma preserves for us an intermediate stage in the establishment of this peculiar aquatic habit.

The carpels of the lesser Alisma have four or five little ribs each; those of the floating Alisma have from twelve to fifteen. Can anybody say why this should be so? It is one of the numerous small points of difference one always finds even between closely-allied species, points which are generally far more difficult to account for than more conspicuous matters of habit or structure, in obvious adaptation to the circumstances of the plant.

The flowers of both these kinds are nearly identical. As in most other of our English water-plants, they are whitish in colour, a peculiarity well observed also in the water-crowfoot, which (with its variety the ivy-leaved crowfoot) is our only white British buttercup. I suppose white is a favourite colour with waterside insects; certainly it is a very conspicuous one among the lush green leaves of most aquatic plants. Both in water-plantain and water-crowfoot, the petals are yellow at the bottom, which shows that yellow was their original colour; for petals always acquire new tints from outside inward. The water-plantains secrete honey at the root of the stamens, in little round drops, which can be easily seen with a small pocket lens. All the English species are fertilised by flies, especially flies of the family of Syrphidæ, the very same insects that visit and fertilise the water-crowfoot. This is a very important fact as helping to explain the close similarity in colour between these various water-side weeds. It is also interesting to note that when floods are out, the flowers of water-crowfoot and of floating Alisma both alike remain closed under water, and fertilise themselves, the closed petals compelling the stamens to shed their pollen on the stigmas of their own blossoms. (*Knowledge.*)

CIRCULATION OF SAP IN PLANTS.

BY PROF. PENHALLOW.

(*Continued from page* 57.)

The second movement of water in plants is physiological, and has direct connection with the nutrition and growth of the structure.

In aquatic plants, when all parts are constantly immersed, and in which there is but little diffinutiation of structure, absorption of water is more or less common to all the structure, and there is but little tendency to the development of currents which are directed from any one part towards some other part; on the other hand, the distribution of water, like its absorption, is more or less general or indefinite. With terrestrial plants the case is quite different, since we then have structures chiefly growing in the air, a medium which tends to promote a constant loss of moisture, and the special organs of absorption (the roots) are diametrically opposed to the special organs of transpiration (the leaves). In such plants, therefore, the general tendency is to the development of a current or series of currents more or less clearly defined, which move from the roots through the stem and branches to the leaves. In the vascular plants, this tendency to special direction of movement, is most clearly defined, since the water ascends or moves chiefly along the lines of woody tissue, which may be isolated as bundles, as in many herbaceous plants, or aggregated in extensive structure as in trees. In these latter, moreover, which, from their highly differentiated and developed structure are the best adapted to observations of this kind, we observe that the woody portion of the stem may be separated into two well defined parts, according to the presence or absence of sap proper. They are known as the "heart wood"—that which is practically dead and occupies the center of the trunk, and the sap wood—that which surrounds the heart, is lighter in colour, contains the moving sap and is nearest to the centre of vitality and growth. The heart wood may be entirely removed without materially affecting the vitality of the tree, as is often seen in very old trees where the center has decayed out, leaving a mere shell. If, however, the sap wood be removed or injured in such a way that it can no longer convey moisture from one part to another, the vitality of the tree is at once affected, and the structure dies, (1) because of insufficient supply of water and (2) because of dificiency of food. This may be easily demonstrated by cutting out the wood of a small, woody plant, leaving the bark as the only connection between roots and leaves, the effect will be immediate and decisive, as seen in the drooping foliage.

We thus find that the water containing plant food in solution, which is absorbed by the roots from the soil, passes thence through the sap wood of the stem upwards to the branches and finally to the leaves. As these organs are the final divisions of the plant, and as they are specialised for the performance of definite functions, we find that the sap here undergoes most important chemical and physical changes. A very large portion of the water is directly given off into the atmosphere in the form of aqueous vapor, while another very considerable portion is used up in the promotion of chemical changes, as in the formation of starch from carbon dioxide and water. The necessary result of this is a concentration of the sap by which its density is very much increased. At the same time, the soluble constituents, previously in a form not capable of entering into the plant structure, undergo important chemical changes and are brought into new combinations which render them directly available in the process of nutrition and growth. We now speak of the sap as elaborated or digested. In this form it passes back from the leaves, and is distributed to all parts of the plant where it is required by the demands of growth, but it now chiefly follows the bark, and so may be considered as returning towards the roots through this part of the structure. This may be demonstrated in a variety of ways. If we tie a cord tightly around a young branch, it will be found that no enlargement occurs below the ligature, but that above, the increase in diameter is normal. This is commonly to be observed in forests, where vines twine tightly about young saplings. Again, if we girdle a tree and take proper procautions to retain the moisture of the parts, and at the same time, also, the greater part of the combium tissue, the injury will be repaired. Yet again, we may repeat a very old experiment by carefully lifting the bark during the early part of the growing season,—as early in June—inserting a thin strip of metal and carefully binding the parts. At the close of the season it will be found that all the new growth of wood and bark is external to the metal. These laws have a most tmportant practical bearing, as must be evident from the illustrations cited, and should be well considered and understood by all those who are at all concerned in the growth and presevation of trees.

We may now ask, are the currents, ascending and descending, to be easily observed? What causes this movement and how may it be determined?

The movement of sap through the various parts of the plant cannot be directly observed. It is developed through a process of diffusion which operates in the cells and cavities, and also in the substance of the cell walls, and there is no localization of fluid in appreciable quantity which would enable us to observe and study the phenomenon as in the veins and arteries of animals. True, in certain cases we may determine the rate and direction of movement by the introduction of certain strongly defined pigments, but the information to be obtained in this way is extremely meagre and unsatisfactory.

The upward movement of water from the roots is due to the combined operation of several causes. First of all, the constant loss of water from both leaves and branches, tends to produce a vacuum in all the tissues below, and this must be met by an influx of fluid from below. As this process is repeated in all parts of the structure downward, the influence of transpiration is felt from branches to roots, and the sap is drawn upward in much the same way as oil ascends the wick of a lamp to replace that exhausted by combustion. Capillarity necessarily enters here as a more or less important factor, especially with reference to the movement of water through long vessels. The influence of transpiration in this way, may be easily determined by cutting off a plant when in full leaf, and at a time when transpiration is active.

At once present water to the cut surface of the stump and it will be absorbed in considerable quantity for a time, after which it will be expelled, or the stump will bleed.

The extremities of roots are largely composed of large, thin-walled cells which directly act upon the water of the surrounding soil to absorb it. All of these cells are in an active state of growth, and the fluids which they contain are much more dense than the water of the soil around them. According to natural laws, these two fluids tend to mingle with one another through the intervening membrane of cellulose —the cell wall—and there is thus established an osmotic action whereby the water of the soil is taken up by the cells in excess. The cells are now brought into a high state of tension and there follows a re-action upon the fluid contents, whereby these latter are forced out in the direction of lost resistance, which is found to be into adjoining cells, rather than back into the soil. This process is repeated in all the living tissues of the root and for some little distance up the stem. The sap is thus forced up by what is known as *root action.*

The movement of sap up the stem cannot be determined and measured exactly, since if we attempt to apply a manometer, such as described in the preceding article, the only result will be a constant, though varying suction, as must be evident from what has already been said. The movement as determined by root action, however, may be easily measured, by simply cutting off the plant and securing the manometer to the extremity of the stump. We will now first of all observe a suction as already indicated, but this will be followed, after a short time, by a constantly increasing pressure, which often reaches a surprising height. Thus the root of the grape vine has been found to give a pressure of 78.3 inches of mercury—or 88.74 feet of water, and the root of the black birch, a pressure of 68.0 inches of mercury—or 77.07 feet of water.

THE COMPARATIVE LIABILITY TO AND DANGER FROM CONFLAGRATIONS IN NEW YORK AND LONDON.

BY E. B. DORSEY, M, AM. SOC. C. E.

The following were among the reasons given for the comparatively smaller number of fires in London as compared with American cities, and especially with New York: The comparatively damp climate of London, which prevents sparks, or weak flames from igniting wood; the much higher temperature of the winter months, and, consequently, the smaller number of domestic fires. Statistics were given showing that lower temperature always largely increased the number of fires. The population of New York, south of Fortieth Street, is more dense than in an equal area of London, New York averaging 208 persons per acre, and London 191½ per acre for the same area. New York averages for the same area 16 1-3 persons per dwelling. Another comparison of about 750 acres of the mose densely populated portions of London and New York, gives for London 249 persons per acre, and for New York 352 persons. The size of the houses in London is in general considerably less than in New York. Many London houses do not exceed 15 feet wide, 25 feet deep and 22 feet high, and a very large number do not exceed 16 feet wide, 30 feet deep and 40 feet high. All the London houses have fire-proof roofs, and in all cases there is proportionately much less wood and more brick or stone than in New York buildings. There are also fewer and smaller windows than in New York. The walls are short, low, and generally well tied together, and so built that they will not fall after the little wood-work in them has been burnt, thus rendering it easier to confine a fire to the house in which it begins. There are no wooden roofs on buildings, and but little wood in the yards, in fences, or outbuildings. The ash-barrel, or ash-box, so frequent a cause of fire in New York, is unknown in London, each house being required to have a vault built of masonry for ashes. Lumber yards, large stables, carpenter shops, furniture makers, wooden manufacturers, places for storage, the manufacture of combustible material, are not found in the thickly-built portions of London. The river Thames and the parks divide London in such a way as to greatly aid in preventing the spread of conflagrations. The numerous railroads running into London form effective barriers against the spread of fires. These railroads, with the exceptien of the Metropolitan and District Underground roads, are built upon heavy viaducts of brick or earthen embankments, not less than 60 feet wide, or are in open cuts not less than 80 feet wide.

Some explanation of the unsatisfactory state of the laws in regard to structures in New York were given by Mr. Wm. P. Esterbrook, Inspector of buildings, who was present.—*Trans. Am. Soc. Civil Engineers.*

WILD BEES.

BY S. A. BUTLER, B.A., B.Sc.

To most people, in all probability, the expression "*wild* bees" is nothing more than a name. We are all familiar enough with the honey-collecting and comb-formind propensities of the industrious communities which have for so many ages been domesticated, so to speak, by man; and as these particular habits of this particular species form its sole commercial recommendation, the word "bee" usually suggests, in this utilitarian age, only ideas of that "little busy bee," which, according to the poet, if not according to the naturalist, delights to—

> "Gather honey all the day
> From every opening flower."

At the outset, therefore, let me say that I shall make no reference to the species *Apis mellifica*, the Honey, or Hive Bee. which is the inhabitant of the hives of our thrifty villagers, These are not really *wild* bees; they can scarcely merit the epithet while their convenience and wellbeing are so carefully studied as in the modern apiarium. But there are to be found in the woods and fields of our country upwards of 200 different kinds of insects which structurally bear a close resemblance to our friends of the hive, but lead an existence entirely independent of the cherishing care of man, and are, therefore, truly "wild bees." Many of them are somewhat obscure-looking insects, and, when on the wing, might readily be mistaken for hive bees, or even for flies. The minute details of structure, which are of the greatest significance with respect to the habits of the insects, and which, on an attentive and close examination, sufficiently separate them from the hive bee, cannot, of course, be discerned by the hasty glance which is all that is possible as the insect buzzes past on its industrious flight. To gain an intimate knowledge of these insects, as of all others, we must cacth them, minutely examine them, even with the aid of a microscope, pull them to pieces, compare them with one another part by part; and when we have done this, we shall be struck with the extraordinary diversity that exists under the external aspect of similarity. It will be well to notice some structural points that all bees have in common, that we may form a clear conception of what a bee is really like, and may be able to recognise such insects when we meet with them in our country rambles—not so easy a task, perhaps, as it may seem at first sight.

In the first place, a bee is an hymenopterous insect, *i.e.*, it has four membranous wings, the fore pair being much larger than the others. Now, this alone will serve to distinguish bees from certain two-winged flies that are very generally mistaken for bees. It should be mentioned, however, that when the wings are expanded, the hind pair are so closely hooked on to the fore pair that the two may easily be mistaken for a single wing. But it will not do to rely wholly upon the number, relative size, and texture of the wings; there are hundreds of other insects that have wings of the same kind; there is one point about these organs, however, that should be attended to, as it will often help to show what insects are *not* bees, even if it does not determine what are; I refer to the neuration of the wings. The rays which form the strength and support of the wings are very constant in their arrangement in the same species, and generally in the same genus, while differing considerably in different genera. They are not, as many might suppose, set in the wing at random; but there is always some definite arrangement of them—so definite, indeed, as to redder possible the giving of names both to the nervures and to the cells they form by their intercrossing. Towards the tip of the fore-wing

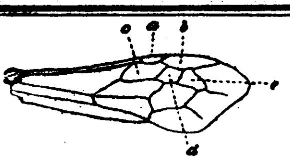


Fig. 1.—Fore-wing of Andrena pilipes.
a, stigma. *b*, marginal cell.
c, *d*, *e*, submarginal cells.

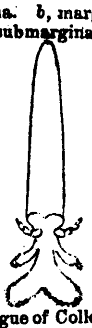


Fig. 2.—Tongue of Colletes Daviesana, a Plastering Bee.

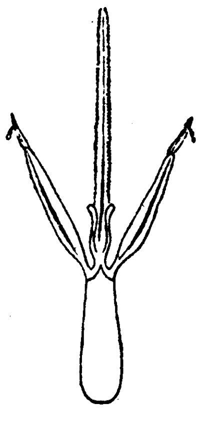


Fig. 3.—Tongue of Bombus terrestris, a yellow-tailed Humble-Bee.

(Fig. 1), on the front margin, there are two such cells, the one nearer the body opaque, and called the stigma; and the other transparent, and called the marginal cell. Below these there are always two or three other cells placed one after another in a row; these are called submarginal cells, and no bee has less than two or more than three of these; if, therefore, you find an insect that, in other respects, looks something like a bee, and yet has only one submarginal cell, you will know that this is the key to other important differences which a careful inspection will reveal, and which remove the creature—not, indeed, from the Hymenoptera, but from that section of the order which contains the bees. All the most familiar bees, such as the hive bee, the humble-bee, the Andrenæ, Halicti, and Anthophoræ, have three submarginal cells; it does not follow, however, that if a hymenopterous insect has two or three submarginal cells, it is therefore a bee.

Bees have a pair of powerful mandibles, accompanied by a licking apparatus of somewhat complicated structure, and often of considerable length, and called popularly the tongue, technically the labium (Figs. 2 and 3). This structure, especially in its longer forms, is very characteristic of the group. The antennæ are stout, and generally of moderate length, but longer in the males than in the females. The sting is a curiously modified ovipositor, and therefore exists only in the females. The males, which may generally be recognised by the superior length of their antennæ, may be handled with impunity, for they are quite unable to inflict any injury. All bees are vegetarians, their food consisting principally of pollen. The three so-called sexes—viz., males, females, and neuters—are to be found only among those few bees that are social—*i.e.*, form large communities living in the same nest. You will look in vain in the nests of other bees for neuters; only males and females are to be found. The greater number of bees have some part or other of the body clothed with hairs, longer or shorter, called collectively "pubescence." One very important use of this is to assitt in the collection or conveyance of pollen. Such are the principal characteristics of bees, and attention to them can scarcely fail to lead the observer to the correct separation of bees from the rest of the Hymenoptera.

But the creatures are not always thus. During the course of their life they pass through a series of marvellous changes. There is first the egg, then the grub or larva, then a motionless little doll or pupa, and then, finally, the fully-developed bee. Before the little creature commences its existence as an egg, however, many preparations have to be made by its mother for its reception into the world, and its nourishment therein; in fact, with the deposition of the egg the maternal duties cease. First, a suitable situation has to be selected for the home of the expected offspring. The nature of the spot fixed upon will vary with the species; some choose a sandy bank, others a dead bramble-stick, others again the chinks in a wall, and yet others an old snail shell; in fact there are very few things that offer cavities of any kind which may not be selectad by some species or other. If there is no cavity ready-formed, in which to place the egg, the mother must set to work to make one; this she does by means of her powerful mandibles, and a substance must be hard indeed to resist the incessant attacks of these powerful weapons. By dint of continuous snippings, she bites out fragment after fragment of the rock or wood, until a hole large enough to admit her body is made. Using this as a starting-point, she tunnels out to the depth of several inches—sometimes a single burrow, sometimes a number of ramifying channels—carefully smoothing off all asperities as she proceeds. The burrows are frequently lined, either with a kind of silk secreted by the insect, or with fragments of leaves, all cut most carefully to pattern, and laid so as to overlap.

The next business is to provide a store of food sufficient for the support of the young during the whole period of its growth that is, throughout its larval existence; for as the grub is completely destitute of limbs, it is utterly unable to go forth into the world to seek its own living, and, therefore, if no provision were made for it, starvation would immediately ensue. The careful mother, however, relaxes not her efforts till she has provided against such a calamity; an excellent manager is she; for though she has hitherto had no experience in providing for the wants of bee-grubs (unless, indeed, she has some recollection of the days of her own larvardom, and remembers the store laid up for her by her own mother), she knows exactly the amount of food that will be needed by each one of her expected offspring, and provides for each the requsite amount, even before it is born. The food consists principally of the pollen of flowers, that golden dust with which the central organs of flowers are so abuntantly supplied; this she collects from the flowers, and passing it from hand to hand, packs it up amongst the pubescence of her hind legs, or underneath her abdomen, and so conveys it home. Here it is mixed with a little honey and made up into a ball, in many cases about the size of a garden pea. One of these pellets is placed at the end of each burrow, and then a single egg is deposited upon each, after which the burrows are closed up, and when all the stock of eggs has been deposited, the mother's work is ended. Though she has lived only through one season, she is now in the decrepitude of old age. She can look back with calm satisfaction at at the successful accomplishment of her important work, and can, therefore, philosophically compose her mind to her rapidly-approaching demise. The eggs are small, some very minute, and are usually slightly curved and tapering at one end. Left to themselves, they soon hatch; a wormlike, footless grub issues from the shell, and begins a vigorous attack upon the store of rich and most nutritious food provided for its sustenance. Its sole object now is to eat, and its persistent efforts in this direction receive their due reward in a growth so rapid as very speedily to bring it to the close of its larval existence, and at the same time to the end of its appointed store of nutriment. This sensuous life over, if the time of year be suitable, the creature becomes transformed into the chrysalis or pupa. This is at first semi-transparent, and through the skin can be seen the gradually-developing body of the bee, with its wings, legs and antennæ devoutly pressed lengthwise along its breast. On reaching perfect maturity it bursts through its shroud, casts asids its grave-clothes, and crawls forth, a feeble, tottering thing, to the light of day.

Warm sunshine and fresh breezes soon raise its drrooping spirits, and it spreads its wings and, for the first time in its life, leaves the sordid earth and soars away, rejoicing in the beauty of its newly-acquired garb, and exulting in the possession of faculties far superior to those with which it has hitherto been endowed. And now commences the serious business of its life—that which all its previous stages have had in view, and for which they have been preparatory—the perpetuation of its kind. Soon mated, and almost equally soon widowed, the female bee devotes herself most assiduously to those labors I have already referred to as preceding the deposition of the eggs, and thus the whole cycle is again passed through.

Such is the general outline of the life-history of the majority of our wild bees. But there are some kinds which are structurally incapacitated for the life of unremitting toil that forms so conspicuous a characteristic of the industrious bees. The so-called Cuckoo-bees are quite unprovided with the pubescence necessary for the collection of pollen, and consequently, totally unable to obtain by their own personal exertions the sustenance needful for their young. But still the maternal instinct is strong within them, and they cannot quit liie until their helpless young have been, in some way or other, provided for. They adopt, therefore, the only resource left to to them; they watch for the burrow of some industrious bee, and as soon as they see that it has been furnished with a supply of pollen, they dart in during a temporary absence of the rightful owner and deposit an egg on the mass. From this habit, which is parelleled by the cuckoo among birds, they have received the name of Cuckoo Bees. They are frequently very brilliantly coloured, their bodies being banded and striped something like that of a wasp (Fig. 4), and they are not necessarily at all like the bees on which they are parasitic. Each species of Cuckoo Bee usually confines its visits to the nests of one particular species of industrious

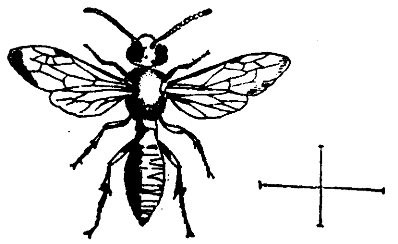


Fig. 4.—Nomada alternata. A Cuckoo Bee parasitic upon several species.

bee, though sometimes it rings the changes on two or three; each kind of industrious bee, however, may have several kinds of Cuckoos parasitic upon it. The egg of the Cuckoo Bee hatches before that of its host, and the larva consumes the pile of pollen before the other poor creature is able to prevent it, so that when the legitimate owner awakes to consciousness he finds his larder empty and himself a ruined being, with no alternative but starvation.

This is not the only way in which the careful exertions of the industrious mother on behalf of her offspring are liable to be frustrated. There is a most brilliantly-coloured hymenopterous insect, with bright red body and green head and thorax, which may often be seen lurking about in the neighbourhood of the burrows of bees. It is no very distant relation of the bees themselves, but it is their

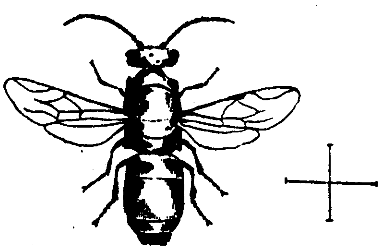


Fig. 5.—Chrysis neglecta. Firetail.

inveterate foe. It is called the Ruby-tailed Fly, Firetail, or Golden Wasp (Fig. 5). Unlike the Cuckoo Bees, its grubs are carnivorous, and attack, not the store of food laid up by the industrious bees, but the larvæ themselves. The young grub of the Firetail seizes the much larger grub of the bee, and appears, at first, to suck out some of its juices, thereby gradually rendering the poor creature flaccid and feeble. After these sucking operations have gone on some time, and there is not much vitality left in the poor victim, though the destroyer has flourished grandly on the juices abstracted, the latter proceeds to complete the filling out of its own bulk by adding the solid parts, as it has previously the fluid of its victim, to its own body, and so the hapless bee-grub is devoured, and scarcely a fragment is left behind.

Not only are the nests of bees liable to the invasion of parasites, but their very bodies are not exempt from attack. There is a most curious little insect which is nourished within the bodies of many bees; so quaint a being is it that much debate has taken place as to its systematic position in the animal kingdom, and its relationship to other insects. By some naturalists it is considered to be an outlying member of the great order of beetles, but by others it is regarded as of so curious a type as not to fit well into any of the ordinary groups of insects, but to necessitate the formation of a division exclusively its own. The creature is named *Stylops;* the male is a little, black, impish-looking thing, with milky-white wings (Fig. 6), but the female is a worm-like creature without wings, and never leaves the body of its host.

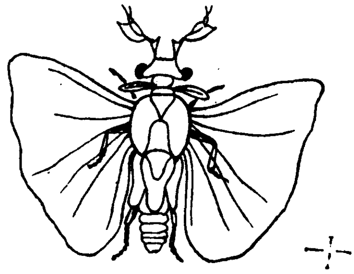


Fig. 6.—Male Stylops.

These curious little insects were discovered by Mr. Kirby, well-known as one of the earliest of the historians of our British bees. Seeing a small protuberance on the body of a bee, he endeavoured to remove it with a pin, supposing it to be a mite of some kind, such creatures being often found on bees. Instead of a mite, however, he drew forth from the bee's body a whitish grub, about ¼ in. long, the head of which had formed the protuberance observed. Surprised and interested he made further search with a result which is best told in his own words: "After I had examined one specimen, I attempted to extract a second, and the reader may imagine how greatly my astonishment was increased, when, after I had drawn it out but a little way, I saw its skin burst, and a head as black as ink, with large staring eyes, and antennæ consisting of two branches, break forth and move itself briskly from side to side. It looked like a little imp of darkness just emerged from the infernal regions. I was impatient to become better acquainted with so singular a creature. When it was completely disengaged and I had secured it from making its escape, I set myself to examine it as closely as possible; and I found, after a careful inquiry, that I had not only got a nondescript, but also an insect of a new genus, whose very order seemed dubious." It is possible to breed these little creatures from the bodies of the bees they frequent. The following directions were given by the late Mr. F. Smith, the zealous Hymenopterist of the British Museum:—Place a bee which contains in its body a female Stylops, and is, therefore, said to be stylopised, in a box 5 in. or 6 in. square, and covered at the top with gauze; supply the bee daily with fresh flowers, such as it is accustomed to visit; in a few days she will probably appear as though her abdomen were covered with dust; this dust, on microscopical investigation, turns out to be a vast number of minute creatures, the larvæ of the Stylops, which have been hatched within their parent's body. If a bee, covered in this way with the larvæ of the Stylops, should happen to settle on a flower, many of the tiny creatures may perhaps be deposited; if another bee then visit the flower, they may be able to attach themselves to its body by clinging to its pubescence, and so get carried to its nest, where they will attack the bee-larvæ, boring into their bodies.

(To be continued.)

A CHEAP INSULATING SUPPORT.—(*Nature.*)

Insulating supports are so indispensable in the work of an electric laboratory that several forms have come into extensive use. The plan devised by Sir W. Thomson for securing high insulation by surrounding a glass stem with concentrated sulphuric acid to absorb the moisture which otherwise would condense from the air and form a conducting film over the surface of the glass is remarkably efficient, and has many advantages. Modifications of this form of insulator have been largely used by Prof. Clifton, F.R.S., in the Clarendon Laboratory, and by Profs. Ayrton and Perry in the laboratories of the Technical College at Finsbury. Another modification due to M. Mascart, was described in *Nature* vol. xviii., p. 44; and this pattern has come into extensive use under the name of the *support isolant Mascart* Though excellent in every way it is very expensive, as its manufacture necessitates a special piece of glass-blowing. The central support of glass is solidly fused into the bottom of a glass vessel with a very narrow neck into which acid is poured through a tubulure at the side.

The insulating support which I have recently described before the Physical Society of London is a much simpler affair, and can be made very quickly and cheaply from the materials at hand in every laboratory. The figure page shows the form of the support. A wide-mouthed glass bottle, E, about 10 cm. high, and from 5 to 6 cm. diameter, is selected. A piece of stout glass tubing about 20 cm. long is then taken. One end is closed in the blowpipe flame, and blown into a thick bulb; and while yet hot the bulb is flattened, so as to form a foot for the stem. The flattened bulb should be as large as is compatible with its insertion into the mouth of the bottle. To hold it in its place some paraffin wax is melted in the bottle—from 50 to 70 grm. is quite sufficient—and when it has cooled so as nearly to have become solid the stem, previously warmed, is inserted. When cool, the paraffin holds the stem firmly in its place. To keep out the dust a disk cut out of sheet gutta-percha is fitted on as a lid. If dipped into hot water for a minute it can be moulded to the required form. It fits loose-tight upon the stem, as shown at C, and when the stand is not in use is slid down over the mouth of the bottle. A brass disk, A, having a short brass stem, B, below it, slips into the upper open end of the tube, and forms the top of the stand. It is also found convenient to make from rods of glass other supports, shaped at the top in the form of hooks, which can be slipped down into the central tube. These are very useful for holding up wires that pass over the experimenting table and require to be well insulated. The bottle is let into a wooden foot, G. In cases where very perfect insulation is required I have poured a little strong sulphuric acid into the bottle above the paraffin. In practice, however, the insulation of the paraffin is amply sufficient for most purposes, provided dust is properly excluded.

Sir Joseph Bazalgette in his inaugural address before the Institution of Civil Engineers, stated that in the United Kingdom alone there then existed 8,000 miles of railway, on which £286,000,000 had been expended. There were now upwards of 18,000 miles of railway, having an authorized capital exceeding £800,000,000, on which the gross annual receipts were £67,000,000, and the annual working expenditure £35,000,000. These railways carried 623,000,000 passengers annually, besides 500,000 season-ticket holders, and 246,000,000 tons of minerals and general merchandize. Contrary to the anticipations of Telford and of Walker, the demand for engineers of a more highly educated and trained class, and the number of these, had continued rapidly to increase, notwithstanding the competition was keen as in all other competitions in this country. The discovery of some of the latent energies in nature, and their application for the use of man, was tending still further to the devolopment of engineering.

A new kind of vertical steam boiler has been invented by Mr. Armer. The object of the design is to obtain the greetest possible efficiency in the steam-heating surfaces. In order to effect this the tubes have a helical twist given them, which does not interfere with the ease with which they may be cleansed, but which causes greater impingement of the gasses against the tube walls, and gives more freedom for expansion than straight tubes.

BUDDHISM IN RELATION TO CHRISTIANITY.

At the last meeting held in February, by the Victoria (Philosophical) Institute, 7, Adelphi Terrace, London, a paper was read by the Rev. R. C. Collins, M.A., on Buddhism in relation to Christianity. Referring to the parallels between the persons and characters of Buddha and Jesus Christ, he said:—Take as a prominent instance, the birth stories. I need not here give details, which are to be found in any modern work on Buddhism. The supposed miraculous conception; the bringing down from Budda from the Tusita heaven; the Dèvas acknowledging his supremacy; the presentation in the Temple, when the images of Indra and other gods threw themselves at his feet; the temptation by Mara—which legends are embellished by the modern writer I havr already quoted, under such phrases as "Conceived by the Holy Ghost," "Born of the Virgin Maya," "Song of the heavenly host," "Presentation in the Temple and temptation in the wilderness"—none of these is found in the early Pâli textt. The simple story of ancient Buddhism is that an ascetic, whose family name was Gautama, preached a new doctrine of human suffering, and a new way of deliverance from it. There is no thought in the early Buddhism, of which we read in the Pâli texts, of deliverance at the hands of a god; but the man Gautama Buddha stands alone in his striving after the true emancipation from sorrow and ignorance. The accounts of his descending from heaven, and being conceived in the world of men, when a preternatural light shown over the worlds, the blind received sight, the dumb sang, the lame danced, the sick were cured, together with all such embellishments, are certainly added by later hands; and if here we recognize some rather remarkable likenesses in thought or expression to things familiar to us in our Bibles we need not be astonished, when we reflect how great must have been the influence, as I have before hinted, of the Christian story in India in the early centuries of the Christian era, and, perhaps, long subsequently. This is a point which has been much overlooked; but it is abundantly evident from, among other proofs, the story of the god Krishna, which is a manifest parody of the history of Christ. The *Bhagavat-Gita*, a theosophical poem put into the mouth of Krishma, is something unique among the productions of the East, containing many gems of what we should call Christian truth wrested from their proper setting, to adorn this coeation of the Brahman poet andicating as plainly their origin as do the stories of his life in the *Maha-Bharata;* so that it has not unreasonably been concluded that the story of Krishna was inserted in the *Maha-Bharata* to furnish a devine sanction to the *Bhagavat-Gita*. If then, as there is the strongest reason to believe, the Christian story, somewhere between the first and tenth centuries of the Christian era, forced itself into the great Hindu epic, and was at the foundation of the most remarkable poem that ever saw the light in India, can we be surprised if we find similarly borrowed and imitated wonders in the later Buddhist stories also? Several Home and Colonial applications to join the Institute as guinea subscribers were received, and its object being to investigate all philosophical and scientific questions, especially auy said to militate against the truth of the Bible,—a discussion ensued in which Mr. Hormuzd Rassam, Professor Leitner, from Lahore, Mr. Coles, an earnest student of the question, during 25 years' residence in Ceylon, Professor Rhys Davids, and others took part. All agreeing in and confirming the statements of Mr. Collins' paper. Dr. Leitner brought a large number of photographs of early Indian and Tartan sculptures, showing the first introduction of the Christian story into those monuments between about the second and tenth centuries, and he pointed out the value of such additional confirmation of Mr. Collins' statemenst.

Scientific Notes.

It is true beyond any doubt thao underdraining mitigates the effects of a dry season. A drained soil is always loose and porous, and no matter how little the rainfall, it seldom bakes hard. The reason is that the air circulates freely through it, as temperature and atmospheric pressure vary, and thus it readily absorbs the dews and moisture which are never entirely absent from the earth's surface in the night season.

An interesting fact in relation to the benefits of tile draining has been developed at the sugar works near Champaigne, Illinois. It is found that the cane grown on tile drained lands even in low places was not injured by the recent frosts in the least, while that on undrained land even in elevated locations was more or less damaged. The effect of drainage is to produce a higher temperature than would otherwise prevail. This is a most important advantage to many crops besides sorghum.

The clay selected for terra-cotta is that composed of silicate of alumina and a small percentage of iron, oxides of iron, as in bricks, producing a red color when fired. The clay is stacked in sheds until it is dry; it is then ground to fine powder, and mixed with powdered old terra-cotta or with ground flint, granite sand, or other vitrifiable substances. The mixture is then ground with a certain small proportion of water, to obtain a perfectly homogenous, ductile modelling clay free from the smallest air cavities. The proportion of water determines the shrinkage that must occur in burning, and this shrinkage can be relied upon as one-twelfth.

Messrs. Crossley Brothers, of Manchester, have recently added an important improvement to their "Otto" gas-engine. This consists of a self-starting apparatus by means of which the engine can be put in motion by simply opening a valve. The apparatus consists of a small receiver into which the engine exhausts for a very short portion of its strokes the burnt gases which result from the ignition of the charge in the cyllnder. These gases fill the receiver, and in the course of half a minute raise a pressure in it nearly corresponding to the pressure in the cylinder during the moment of ignition. These stored burnt gases are admitted again to the cylinder at the moment of starting by a very simple piece of mechanism, and thus put the engine in motion in much the same way as steam moves a steam-engine, thus saving the trouble of pulling the wheel round to get in the first charges.

It appears from a notice published in the last issue of the *Izvestia* that stone-age implements were used by Russians in Siberia at a time very near to our own. Thus, owing to the difficulty of having iron imdlements, and eden iron, the Cossacks who occupied the valley of the Irkut at Tunka availed themselves of the numberless stone implements they found scattered on the hills around Tunka, where lorge manufactures of stone implements have been discovered. There are still people who remember also that their grandfathers were compelled to follow the advice of the Mongols, and to make use of nephrite hatchets; the tradition says also that there were Cossacks who understood themselves the art of making jade implements. Any one who knows the difficulties of obtaining iron in Siberia some thirty years ago, and even now, will not doubt the trustworthiness of the tradition. We may add also that the late Prof. Schapoff has found the settlers at Turukkansk largely using stone pestals and hammers, some of which were exhibited at the Irkutsk Museum, before it was destroyed by fire.

THEOREM OF THE THREE MOMENTS.

BY PROF. J. A. WADDELL, M.E., TOKIO UNIVERSITY, JAPAN.

The investigation of this problem is generally so long and tedious, owing to the fact that most writers upon the subject wish to make their investigations as general as possible, that few practical men care to wade through such an amount of calculation, so they usually accept the statement of the equation upon faith. Our object in treating such a hackneyed subject as the theorem of the three moments, is to give a simple demonstration applicable to all cases which occur in the every day practice of the engineer, and which can be easily understood by those who have neither the time nor the patience to enter into more elaborate investigations. Our method is essentially a simplification of that of Prof. Burr, as given in the appendix to his valuable work upon "Stresses in Bridge and Roof Trusses."

The object of the theorem is to find the relation between the bending moments at any three consecutive points of support in a continuous beam.

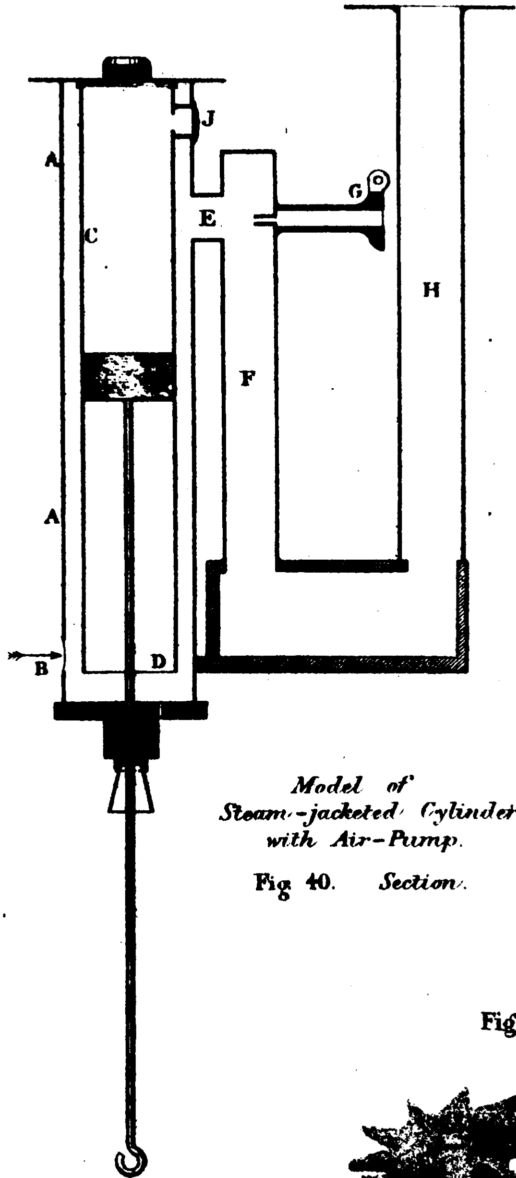
The most general case which can be taken—that investigated by Prof. Burr—is where the section of the beam is supposed to be variable, the points of support not in the same level, and at any or all points of support, there may be constraint applied to the beam external to the load which it is to carry, or in other words, the beam may not be straight at any point of support before flexure.

The most common application of the theorem of the three moments, in fact we might say the only one, which occurs in the ordinary practice of the engineer, is to find the stresses existing in the members of bridges of continuous spans, more especially in this country swing bridges; for American engineers are almost unanimous in condemning the use of continuous spans wherever it can be avoided. Now, in nearly every case of continuous spans, the points of support may be taken in the same level, the section of span although not exactly constant is nearly so, and, in fact, is nearly always so assumed in figuring the stresses, even when the top chord is curved: and the spans are straight at all points of support. Making these assumptions will greatly simplify matters.

Before proceeding to establish the theorem, some preliminary investigations will be necessary.

Let A C, Fig. 1, be the centre line of any bent beam whose section is uniform and material homogeneous. Let A be the origin of co-ordinates from which also the deflections are measured, let x be the horizontal and y the vertical ordinate, and let z be the horizontal distance from the vertical line A F to the point of application of any load P. Let M be the moment of the external forces about A, S the shear at A, c the compression or extension per unit of length of a fibre parallel to the neutral surface and at units distance therefrom, I the moment of inertia of any section of the beam about a horizontal line through the centre of the section, in this investigation coinciding with the centre line of the neutral surface, E the co-efficient of elasticity for the material of the beam (assumed the same for both compression and extension), and M the moment of the loads about any section of the beam. Taking any section, for instance the one at B, perpendicular to the neutral surface, let us assume a temporary origin of co-ordinates at that point, the axes being in and perpendicular to the neutral surface, u' being the horizontal and y' the other ordinate, as shown in Fig. 1, to the right. The area of any differential portion of the section is $du'\,dy'$, and if p' be the intensity of stress at that point, the stress on that area will be $p'\,du'\,dy'$ and its moment about the neutral surface $p'\,y'\,du'\,dy'$ integrating which will give for the total resisting moment:

INVENTIONS OF WATT.



Model of Steam-jacketed Cylinder with Air-Pump.

Fig 40. *Section.*

AN INSULATING SUPPORT.

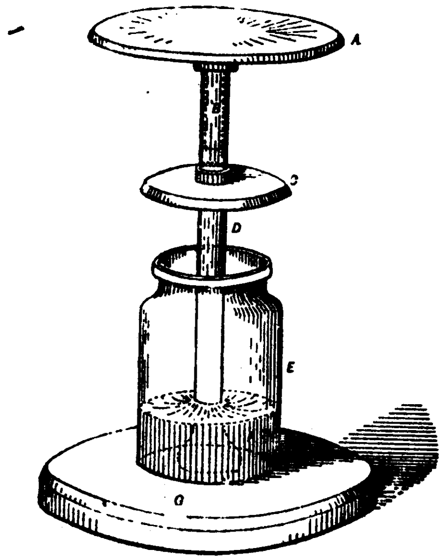
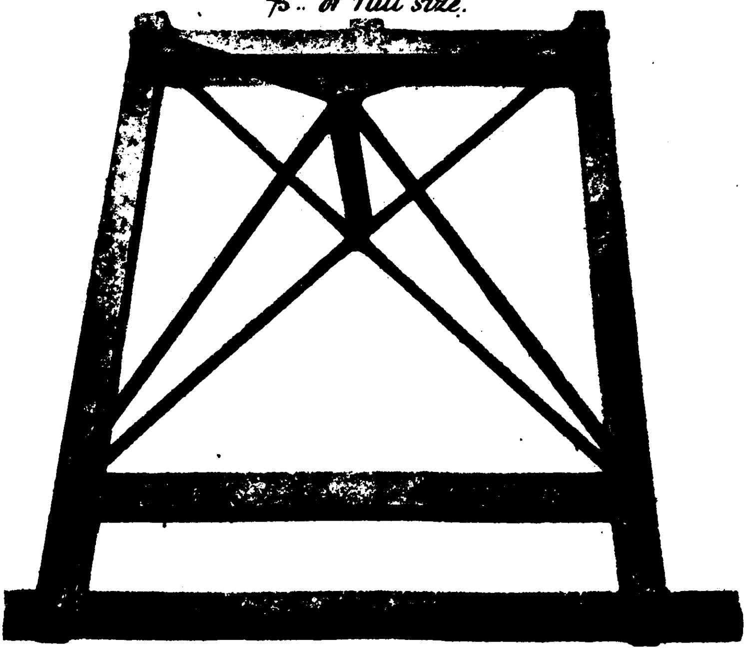


Fig. 41. *Intermittent Counter.*

INVENTIONS OF WATT.

Fig. 42. *Trussed Frame for Copying Machine.*
1/5th of full size.



Geared Counter, Patent Office Museum.

Fig. 43. *Elevation.*

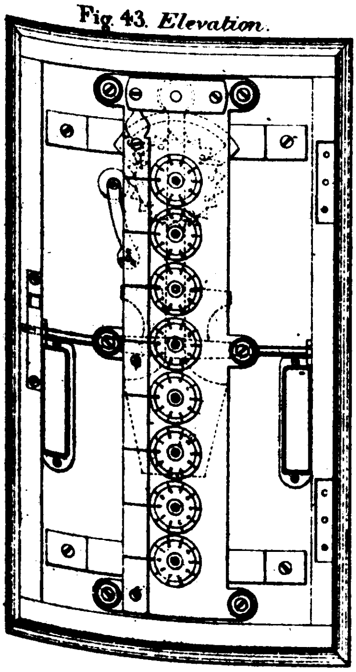


Fig. 44. *Side View.*

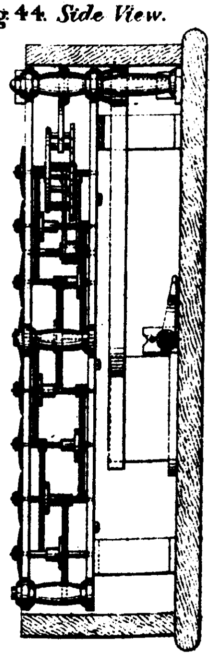


Fig. 45. *Arrangement of Gearing.*

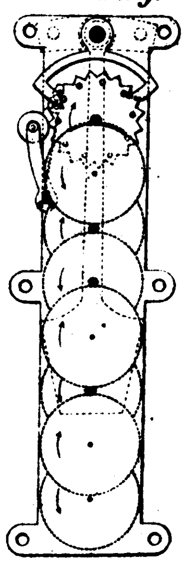
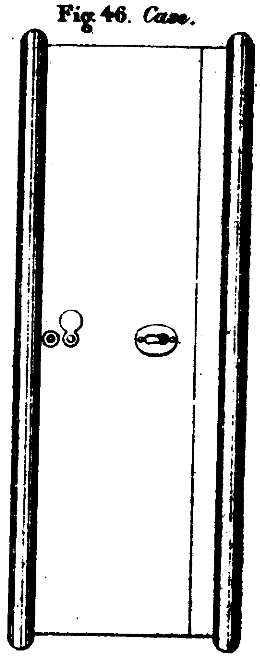


Fig. 46. *Case.*



$$M = \int\int p' y' du' dy'. \quad \text{(Eq. 1.)}$$

Now, let us consider a unit section of fibres situated at unit distance from the neutral surface. The extension or compression of fibres per unit of length being c, the force producing it is $E c = p =$ intensity of stress at unit's distance. According to the common theory of flexure, the intensities are directly proportional to the distances from the neutral surface, therefore $p' : p :: y' : 1$ or $p' = p y' = E c y'$. Substituting this in Eq. 1., gives $M = \int\int E c y'^2 du' dy' = E c \int\int y'^2 du' dy' = E c I$ and $c = \frac{M}{E I}$

Now, remembering that in actual practice the curvature of a beam is very slight, let us consider an indefinitely short portion of the neutral surface, the length of which is dx; the strain for such a length at unit's distance would be $c\ dx$.

In Fig. 2, which is, of course, greatly exaggerated, A B $= dx$, C is the centre of curvature of the beam, A D is equal to unity, therefore F E $= c\ dx$, B K and A L are tangents to the neutral surface at the points B and A respectively, G H is drawn parallel to D C, K M perpendicular to A L and L N is a vertical line through the origin O. B O being a finite distance, while A B is indefinitely small, and the curvature being so very slight we can say without any sensible error that A B K is a straight line equal in length to A M, or the curve A B O which is also equal to A K or x. The two triangles E B F and M A K are similar, the sides being mutually perpendicular, therefore,

$$F E : F B :: K M : M A \text{ or } c\ dx : 1 :: K M : x,$$
$$\text{or } K M = x\ c\ dx.$$

But K M does not differ sensibly from K L, therefore K L $= x\ c\ dx$. But the summation of the consecutive values of K L between O and A is equal to the distance O L $=$ D, which we may term the vertical deflection of the tangent at the point A (not necessarily equal to the deflection of the beam in the ordinary acceptance of the term).

We may now write the following equations which are true under the assumed restrictions.

$$S = \Sigma P \quad \text{[Eq. 2.]}$$
$$M = \Sigma P z \quad \text{[Eq. 3.]}$$
$$C = \frac{M}{E I} \quad \text{[Eq. 4.]}$$
$$D = \Sigma x\ c\ dx = \Sigma \frac{x M}{E I} dx. \quad \text{[Eq. 5.]}$$

Let us next investigate some general considerations in regard to a portion of a continuous beam between two consecutive points of suppoot.

If the beam were simply supported at the ends, the reactions at those points could be ascertained by applying the principle of the lever; but, if one or both ends are not simply supported, the reactions will differ from those found according to that law; this difference may be accounted for by supposing a portion of the reaction at one end to be transferred to the other, by means of the application of a couple whose lever arm is equal to the length of span between the points of support, and whose forces are each equal to the difference between the actual reaction at one end and the reaction as calculated by the law of the lever.

As this change of reaction is caused by a partial fixing of the end or ends of the beam, it is evident that the bending of the supposed couple will be of an opposite kind to that which exists in a beam simply supported at the ends.

In addition to this couple, we can suppose two equal and opposite couples, applied to the beam at each end, which balance each other by means of the beam, thus subjecting it to another moment, without at all affecting the reactions. For example, in a bridge truss we might apply a certain tensile force at each end of the top chord, and an equal compressive force at each end of the bottom chord, producing a constant moment throughout the span equal to the product of one of the forces by the depth of the truss, without at all affecting the reactions due to the loads upon the span. A practical instance of this would be the case of three continuous spans, the outer ones being equal in length and similarly loaded.

In Fig. 3, let A and B be the supports of the beam A B, which is loaded at K by the weight P, giving the reactions A R and B R′. R F $=$ R′ F′ is the force of the couple, making A F and B F′ the reactions after the couple is applied. For the reactions A R and B R′ the ordinates parallel to C K in the triangle A C B give the bending moments due to the weight P.

Let the ordinates parallel to A H in the rectangle A H Q B represent, according to the same scale, the constant moment due to the balanced couples; and let the ordinates in the triangle Q H G represent the moments of the force R′ F′. The resultant moment at any point will be the algebraic sum of the ordinates in the rectangle and the two triangles.

Take the origin of coordinates at A, and let x be measured horizontally towards B.

Let G A $= M_a$ and B Q $= M_b$. Join A Q.

Then the moment at any point S is equal to

$$+ S T - S U - U W =$$

$$+ M_1 - M_b \frac{x}{l} M_a \frac{l - x}{l} = M. \quad \text{[Eq. 6.]}$$

It is to be noticed that ordinates above A B are positive and tend to bow the beam downward at the centre, while the ordinates below A B are negative and tend to bow the beam upward at the centre. In Fig. 3, the moment produced by the balanced couples was assumed to act in conjunction with the moment of the single couple. Had these moments acted in opposite directions, as in Fig, 4, where A Z, the difference between A G and A H, is M_a, we would have had

$$M = + S T - U Y + S U,$$
$$\text{or } M = + M_1 - M_a \frac{l - x}{l} + M_b \frac{x}{l} \quad \text{[Eq. 7.]}$$

Thus we see that the second members of Eqs. 6 and 7 differ only in the signs of the terms, and if we consider the signs inherent we may write them both

$$M = M_1 + M_a \frac{l - x}{l} + M_b \frac{x}{l} \quad \text{[Eq. 8.]}$$

These preliminary investigations being made, we are now prepared to establish the general equation of the three moments.

In Fig. 5, let A, B and C be three consecutive points of support of a continuous beam, the spans considered being, as shown, l_a and l_c. R_a, R_b and R_c are the reactions at A, B and C; and S_a', S_a, S_b', S_b, S_c', S_c are those portions of R_a, R_b and R_c caused respectively by the loads on the span to the left and those on the span to the right; this can be understood by examining the diagram. Let us call the moments at A, B and C respectively M_a, M_b and M_c, and let us take the origin of coordinates for the span l_a at A and for the span l_c at C.

Referring to Eq. 5, the value of D will reduce to zero if the points considered be two points of support, for they are upon the same level; we can then write

$0 = \Sigma_b^a \frac{x\,M}{E\,I}\,dx$, the Σ_b^a denoting that the points considered are A and B.

As E and I are both finite quantities, we must have $0 = \Sigma_b^a x\,M\,dx$. Substituting the value of M from Eq. 8, gives:

$$0 = \Sigma_b^a \left[x\,M_1\,dx + M_a \frac{(l_a - x)\,x}{l_a}\,dx + M_b \frac{x^2}{l_a}\,dx \right]$$

or writing the integral sign instead of Σ

$$0 = \int_0^{l_a} \left[x\,M_1\,dx + M_a\,x\,dx - M_a \frac{x^2}{l_a} dx + M_b \frac{x^2}{l_a} dx \right]$$

$$0 = \int_0^{l_a} M_1\,x\,dx + M_a \frac{l_a^2}{2} - M_a \frac{l_a^2}{3} + M_b \frac{l_a^2}{3}$$

or multiplying by $\frac{6}{l_a}$

$$0 = M_a\,l_a + 2\,M_b\,l_a + \frac{6}{l_a} \int_0^{l_c} M_1\,x\,dx. \quad \text{[Eq. 9.]}$$

Passing to the span l_c, we can establish in a similar manner the following equation:—

$$0 = M_c\,l_c + 2\,M_b\,l_c + \frac{6}{l_c} \int_0^{l_a} M_2\,x\,dx. \quad \text{[Eq. 10.]}$$

Adding Eqs. 9 and 10, gives

$$0 = M_a\,l_a + 2\,M_b\,(l_a + l_c) + M_c\,l_c + \frac{6}{l_a} \int_0^{l_a} M_1\,x\,dx + \frac{6}{l_c} \int_0^{l_c} M_2\,x\,dx. \quad \text{[Eq. 11.]}$$

Let us suppose for an instant that there is only one weight P which produces the infinite number of moments represented by M_1 in the expression $\int_0^{l_a} M_1\,x\,dx$,

The reaction at A will be $P \frac{l_a - z}{l_a}$ and the value of M_1 for any point between A and the point of application of P will be $P \frac{l_a - z}{l_a} x$: the reaction at B will be $P \frac{z}{l_a}$ and the value of M_1 for any point between B and the point of application of P will be $P \frac{z}{l_a} (l_a - x)$;

whence we can write the equation

$$\int_0^{l_a} M_1\,x\,dx = \int_0^{z} P \frac{l_a - z}{l_a} x^2\,dx + \int_z^{l_a} P \frac{z}{l_a} (l_a - x)\,x\,dx$$

$$= P \frac{l_a - z}{2} \frac{z^3}{3} + Pz \left(\frac{l_a^2}{2} - \frac{z^2}{2} \right) - P \frac{z}{l_a} \left(\frac{l_a^3}{3} - \frac{z^3}{3} \right)$$

$$= \frac{1}{6} P\,z\,(l_a^2 - z^2)$$

and for any number of loads

$$\int_0^{l_a} M_1\,x\,dx = \frac{1}{6} \Sigma^a P\,z\,(l_a^2 - z^2).$$

Similarly $\int_0^{l_c} M_2\,x\,dx = \frac{1}{6} \Sigma^c Pz\,(l_c^2 - z^2)$

Substituting these values in Eq. 11, gives

$$0 = M_a\,l_a + 2\,M_b\,(l_a + l_b) + M_c\,l_c + \frac{1}{l_c} \Sigma^a P\,z\,(l_a^2 - z^2) + \frac{1}{l_c} \Sigma^c P\,z\,(l_c^2 - z^2)$$

which is the ordinary form of the equation of the three moments, Σ^a and Σ^c denoting that the summations are each to extend over one span from A and C respectively.

Taking moments about the right hand end of l_a, gives $S_a\,l_a - \Sigma^a P\,l_a - z + M_a = M_b$ from which we have

$$S_a = \Sigma^a P \frac{l_a - z}{l_a} - \frac{M_a - M_b}{l_a}$$

Taking moments about the left hand end of the same span, there results

$S_b'\,l_a - \Sigma^a Pz + M_b = M_a$ from which we have

$$S_b' = \Sigma_a P \frac{z}{l_c} - \frac{M_a - M_b}{l_a}$$

Similarly $S_b = \Sigma^c P \frac{z}{l_a} + \frac{M_c - M_b}{l_c}$

and $S_c' = \Sigma^c P \frac{l_c - z}{l_c} - \frac{M_c - M_b}{l_c}$.

By inspecting Fig. 5, as before stated, we can see that

$$R_a = S_a' + S_a$$
$$R_b = S_b' + S_b$$
$$R_c = S_c' + S_c$$

THEOREM OF THREE MOMENTS.