sheath corresponds with the Y's of a theodolite, and carries the phial firmly upon the same principle as these carry the usual telescope. The upper bulb of the phial is brought into the field of two cross visioned microscopes, which are carried with the arm around the vertical arc, and which are kept truly in the same plane at every angle of inclination by a parallel motion. There are vertical lines drawn upon the object glass of each microscope, these being, of course, kept truly vertical by the parallel motion just mentioned. The phial is revolved in its sheath, and the arm is moved along the arc by the tangent worm, until the embedded plummet is made perpendicular from each point of view, or parallel with the vertical lines of reference just described, as viewed through the two cross telescopes. The phial is now at the same angle of inclination at which its contents solidified, and its lower bulb will be found nearly in the axis of the revolving arm and an inch or more above the center of a horizontal revolving circular mirror, having a system of parallel lines engraved across its face. Reflected in the mirror will be seen the image of the embedded needle, which, as we know, pointed north before it was fixed by congelation in the borehole. If we now revolve the mirror until the 270 deg. of the graduated circle is opposite the north (or notched) end of the needle, and until the reflected image of the needle is sensibly parallel with the engraved lines, an index at the side of the graduated mirror frame will give the exact angle between the needle and the vertical plane of revolution of the phial, which is, in fact, the magnetic bearing of the inclined phial and of the borehole which it occupied at the time of the application of the test. The same operation is repeated with the other five phials which complete the set, and then the results are combined and the mean taken in the same manner as if six separate determinations of the same horizontal angle and azimuth had been made with a theodolite or an altazimuth instrument. These six phials—or "self-registering compass clinometers" as they may be termed—are encased within and protected by the cylinder or guide tube.

Cylinder or Guide Tube.—This is a strong brass tube, about 6 ft. in length, into which the phials accurately fit (as will be seen on reference to Fig. 3, which shows part of its upper end with the phials in their brass slide in the act of entering). This tube or cylinder is securely closed against the heaviest water pressure likely to be encountered even in bores of 2,000 ft. depth; the glass clinostats being of too fragile a construction to bear exposure unprotected to such a pressure. The guide tube is passed down the bore by means of half-inch diameter service piping jointed in measured lengths, the effect of the iron being kept from the magnets by the interposition of a distance tube of brass, terminated by the solid plug which screws into the upper end of the guide tube (see Fig. 6). For use in hot strata, where cold water must be poured down this small piping in order to cool the cylinder below, the upper part of this solid plug is pierced with holes out of which the cooling stream from the tubing may issue and flow down the outside of the cylinder, thus congealing its contents. Where the bore is approximately perpendicular, and the strata comparatively cool, these may be dispensed with, and the survey of the bore be accomplished by lowering the guide tube with small wire rope. The eye, which replaces the iron pipe, and screws into the upper end of the distance piece, as seen in Fig. 6, being provided for that purpose. Where the bore approaches the horizontal, as in testing ground ahead of drives or levels in mines, the iron piping or "application rods" must be used to force the guide tube to the desired distance; and in any case these must be employed where it is desired to extract a piece of standing core with the test attached. This is an easy and certain way of obtaining, not only the true direction of the borehole, but also the true dip and strike, underlie and bearings of strata, lodes, reefs, and deposits of all kinds. To accomplish this desirable end, there may be affixed to the lower end of the guide tube (in such fashion as to close it hermetically and at the same time grasp one of the phials within it) a contrivance termed the core extractor (see Fig. 4).

Core Extractor.—This is a brass tube set eccentrically, and furnished with a bell-mouth below, the office of which is to receive the extremity of any piece of core left standing at the bottom of the bore, and, as the apparatus is forced down, to press on one side and break off the piece of core. The core extractor, which is of brass, contains a spring-like inner tube, slotted from end to end, which expands as the core enters, and grasps it firmly. The whole apparatus being now left unmoved for two or three hours, until the fluid in the phials has cooled and set, is withdrawn, and the core extractor unscrewed. At the lower end of this will be found the core (projecting beyond the lower end of Fig. 4, but not shown in engraving), at the other a phial, both of these being firmly grasped and kept in the same relative situations as in the borehole. The phial, by means of its internal indications, will enable the piece of core to be replaced in its natural position for observation, and thus there may be readily ascertained (by examination of the markings) the true dip and strike of the strata, or the underlie and bearing of the reef, of which it originally formed a part. The importance, not only to geologists but to miners, of this information, will be readily acknowledged. At the same time the other five or six phials join with this one in affording very exactly the inclination and bearing of the borehole at that part, and by a series of such observations, say at every 50 ft. of boring, information could be obtained, nearly as useful and complete as if from a prospecting shaft, or level, or winze, and at a fraction of the cost. And there would be a direct saving also in bores. For example, the Magdala Mine, at Stawell, in one bore pierced an auriferous reef. Partly because the underlie and bearings of the reef could not be ascertained from cores which, of course, had been whirled round the compass many times before extraction, and partly because the rectitude of the path of the drill, from former experiences, was distrusted, the directors decided to put down a check bore at some distance to intersect the reef. This bore cost between 500*l.* and 1,000*l.* according to the general average of boring, and yet a previous application of the test and core extractor would have rendered it quite unnecessary. This is but one of many instances of a like nature, both in reef and alluvial boring, where hundreds of pounds have been spent in the absence of apparatus

such as that just now described, and which has been submitted for our inspection.

[Continued from SUPPLEMENT, No. 509, page 8134.]

ON THE CONSTRUCTION OF ROLLING CAMS AND SYMMETRICAL LOBED WHEELS.

By Professor C. W. MACCORD, Sc.D.

II.

THE circumstance that the contours of a pair of rolling cams are but parts of the pitch lines of a pair of non-circular wheels, was mentioned in the preceding article. Indeed, it is a sufficiently familiar fact that teeth are added to circular wheels only because without them the rotation of the follower would not be compulsory, since the contact radius of the driver is constant; and not because the pitch circles roll together without sliding. In the rolling cam, on the other hand, the rotation is compulsory because the contact radius of the driver is on the increase; and the more rapidly it increases, the more perfect is the driving action, the flatter is the curve, and the more acute is the intersection with the line of centers; while if the rate of increase be slow, the curve approaches more nearly to the form of a circle cutting the line of centers normally: and consequently the driving action becomes less pronounced, so that, as already pointed out, it may become necessary to make use of teeth in order to maintain it at all. And it is quite apparent that if teeth be provided on the whole contour, the driver may be turned in either direction, as well as that, if this contour be a curve that returns into itself, like the ellipse, the rotation may be continuously maintained without reversal.

And even if it be not, this is still possible under some conditions. Thus in Fig. 16 the acting outlines are arcs of the logarithmic spiral, which is not a closed curve, yet it is apparent that if both these lobed wheels be provided with teeth, either of them will drive the other continuously in either direction. Considering the upper one as the driver, and supposing the rotation to be always in the direction of the arrow, it will be seen that teeth would be necessary on only one side of each lobe; PA would drive PB until A and B meet on the line of centers, but AF would not drive BG. Now, PDA and PCB are simply two rolling cams, or spiral sectors, precisely like those discussed in the preceding article, and ADF, PCE, are merely the same sectors reversed.

In this way it is clear that from any given pair of rolling cams, a pair of lobed wheels may be constructed by repeating their contours in alternate reversion; provided that the total angle subtended by each at the center be contained in the circumference an even number of times. When this is the case, the conditions, so far as the angular movements are concerned, may often be satisfied by the direct construction of elliptical arcs. Take for instance the angles of 60° and 45° as in Fig. 16; then in Fig. 17 take any two points as D, O, for the foci, make the angle PDA = 60° and the angle POA = 45°, and the intersection A of these lines is a point on the ellipse whose major axis PH is equal to AO + AD; the angle PCB at the farther focus of its rolling mate will be equal to POA, that is, 45°, if we set off PB equal to PA; so that PDA, PCB, are a pair of rolling cams, and the trilobe and quadrilobe are completed by simple repetition of the arcs PA, PB, as above explained. But the velocity ratio is determined by the eccentricity of the ellipse, and will vary between the

limits $\frac{PD}{PC}$ and $\frac{DA}{BO}$; neither of which is arbitrary if this process be adopted.

Of course if these sectors be employed as cams, teeth will be necessary as previously pointed out, at least at the first parts of the arcs PA and PB; and this figure serves well to illustrate the fact that while there is this close relationship, indeed absolute theoretical identity, between the rolling cam and the lobed wheel, yet the better suited a curve is for one purpose, the worse it is for the other. The flatter the curve and the more rapid the increase of the contact radius, the better is the driving action in one direction of the toothless cam; but the same curve, if the lobed wheel be completed, must drive in the opposite direction by the aid of its teeth only, and the obliquity of their action becomes less the more nearly normal the contact radius is to the pitch line. Keeping this in mind, then, we proceed, not to discuss the construction of lobed wheels in general, but to consider one or two processes which are applicable both to them and to cams which may not constitute exact lobes.

In Fig. 18, the angles ADP, AOP, are to each other in the same ratio as in the preceding diagram, viz., that of 4 to 3; HP is equal to AO + AD, and making the elliptical arc PB equal to PA, we have two sectors which will roll together as before about the foci D, C.

Now if ADP be contracted until it becomes equal to 60°, and BCP be contracted in the same proportion, the latter will evidently become 45°; the new curves PK, PL, will still roll together, and we may construct by repeating them another pair of symmetrical but dissimilar lobed wheels, the velocity ratio now varying between the limits $\frac{PD}{PC}$ and $\frac{AO}{OD}$, which values are different from those of Fig. 17, supposing the distance CD between centers to be the same in each case.

In this way it is evident that a great number of different ellipses can be made, from each of which a pair of rolling cams or a pair of lobed wheels may be derived; but if we assume the angles ADO and AOD, neither value of the velocity ratio can be assigned, for both depend upon the eccentricity of the resulting ellipse.

Now of course there must be a determinate relation between this eccentricity, the angular motions, and the limiting values; if three of these five elements be given, the other two will be thereby determined; and even in assigning the three, it will be seen that there are restrictions beyond which we cannot go without rendering the solution impossible.

In Fig. 19, the curve AGBD is determined as follows: Assuming any two points A, C, upon the indefinite line HD, construct the angles BCD, BAD, having to each other any given ratio, say that of m to n , m being the greater, then the intersection B of the lines making these angles with HD will lie upon the curve; similarly let ICD be to IAD as m to n , then I is a point of the curve, and so on. Since the intersections may become so acute as to render the exact location of the points

unreliable, the following property may be made use of to fix them more precisely. The center of the circle circumscribing any one of the triangles whose base is AC and vertex in the curve, as for instance ABC, must lie on the line LM perpendicular to and bisecting AC. Then we have:

$$\begin{aligned} BCD &= m, \\ BAC &= n, \\ ABC &= m-n. \end{aligned}$$

And in the circumscribing circle we have:

$$\begin{aligned} m-n &\text{ measured by } \frac{1}{2} \text{ arc AC,} \\ n &\text{ " " } \frac{1}{2} \text{ arc CB,} \\ m &\text{ " " } \frac{1}{2} \text{ arc ACB,} \end{aligned}$$

that is to say,

$$\text{arc CB} : \text{arc AC} :: n : m-n.$$

If then we had taken the center O at pleasure on LM, and, describing the circle through A and C, had set off the arc CB in the above ratio to AC, the point B would have been thus located without drawing the lines BA, BC.

This curve springs from the point A; for when m becomes 180°, the arc ACB must equal the whole circumference, so that the point B will fall at A; AC will then divide the circumference into two segments such that the one above the line will be to the one below it as n is to $m-n$, and the curve will be tangent at A to the circle whose diameter is thus determined.

The limit D of the curve will be reached when m becomes zero, that is, when the center O is infinitely remote and the circumference coincides with the right line ACD. By analogy we then have:

$$CD = AC \left(\frac{n}{m-n} \right),$$

$$\begin{aligned} \text{but } AD + CD &= 2CD + AC, \\ &= 2AC \left(\frac{n}{m-n} \right) + AC \\ &= AC \left(\frac{2n}{m-n} + 1 \right) \end{aligned}$$

$$\text{or, } AD + CD = AC \left(\frac{m+n}{m-n} \right),$$

$$\text{whence } \frac{AC}{AD + CD} = \frac{m-n}{m+n}.$$

Now if from any point, as E, upon this curve we draw lines to A and C, the angles ECD, EAD will be to each other in the ratio of the original magnitudes m and n , and the sum EA + EC being taken as the major axis HP of an ellipse of which A and C are the foci, the arc PE will, evidently, be the contour of one of a pair of cams which will roll together as in Fig. 17; and a pair of lobed wheels may be formed from them by expansion or contraction if the ratio of m to n be that of two whole numbers. And conversely, if A and C be taken as the foci, any ellipse which cuts the curve will by that intersection determine an elliptical arc that may be thus employed in the construction of either the cams or the lobed wheels; and it is now clear that the extremity P of the major axis must lie between C and D.

If then the numbers of lobes of two proposed wheels, or the angular motions of two proposed cams, be assigned, we can readily find, by drawing such a curve, the limit of the eccentricity of the ellipses from which they can be made.

And so long as this limit is not transcended, we may also assign either the highest or the lowest value of the velocity ratio. When the point of contact is on the major axes of the ellipses, as in Figs. 17 and 18, the angular velocities are to each other in the inverse ratio of the segments into which the major axis is cut by the fixed focus. Suppose the value of this ratio to be given, as for instance $\frac{a}{b}$; then in Fig. 19, in order to find HP, we have, noting that HA = CP, and putting CP = x , the proportion:

$$x : AC + x :: b : a.$$

$$x : AC :: b : a - b;$$

$$\text{or, } x = AC \left(\frac{b}{a-b} \right),$$

whence the length of HP may be ascertained either by computation or by graphic construction; and this being done, the intersection E of the ellipse, whose eccentricity is thus determined, with the curve ABD, fixes the value of the other limit, which is the inverse ratio of the distances EC, EA.

But that other limit may be assigned instead of the first; in which case the solution may be effected by the aid of the construction illustrated in Fig. 20. Let it be required to draw a series of triangles having a common base LM, and the ratio of the other two sides equal to that of two given lines a, b . Divide LM at I, so that

$$MI : IL :: a : b;$$

also produce LM to K, making

$$MK : KL :: a : b;$$

then the locus of the vertices of the required triangles will be the circumference of the circle on IK as a diameter; thus

$$a : b :: MT : TL :: MS : SL :: MR : RL :: MN : NL.$$

If then in Fig. 19 the ratio of EC to EA had been assigned, AC would have been the base of the triangle in the preceding construction, and the point E would have been determined by the intersection of the circle with the curve AGBD, as shown in dotted lines.

We perceive then that no matter which limit of the velocity ratio is assumed, we are obliged to use an elliptical arc, of which one extremity lies upon the major axis, which cuts the arc normally. In that immediate neighborhood, therefore, the introduction of teeth is indispensable, as stated in the preceding article; and this is equally true whether the sectors be made in the form of the elliptical curve itself, or derived from it by the process of expansion or contraction previously explained.

As an example of the application of these principles in effecting a definite purpose, we will take the problem of laying out the pitch curves of the irregular wheels for an intermittent planetary train, like that described in the SCIENTIFIC AMERICAN SUPPLEMENT, No. 482.

In Fig. 21, C is the center about which the train-arm CD and the sun-wheel a , f , revolve. Let it be required that the driven wheel, F, shall remain at rest while the train-arm moves through the angle PCQ of 90° , the wheel A being fixed; then the wheel F must be a circular one, of which the radius PC may be assumed, and the arc PQ of the irregular wheel A must also be circular and of the same radius.

It was shown in the article referred to, that the object in view may be attained by making the wheel f , which is circular, half as large as F; this makes the other segment PD of the train arm equal to $\frac{1}{2}PC$, which is also the radius of the semicircular portion PSO of the irregular sun-wheel a . Draw DK perpen-

dicular to the diameter PO, and RCG bisecting the angle PCQ; it is then seen that the problem reduces to the construction of two curves PK and PG, equal in length and capable of moving in rolling contact about D and C as fixed centers. The angles PCG, PDK, being respectively 135° and 90° , are to each other as 3:2, and the ratio of PC to PD is that of 2 to 1.

Now, referring to Fig. 19, the curve AID there shown is the one adapted to this particular case, the angles formed with HD, by lines drawn to C and A respectively, from any point of the curve, having the ratio of 3 to 2, and the dotted circle being so determined by the process of Fig. 20 that the lines drawn to any point of its circumference from C and A respectively

shall be to each other as 2 to 1. This circumference cuts the curve in E, and $EC+EA=HP$, the major axis of the ellipse having the proportions required for our present purpose; and the elliptical arc EP is now to be contracted around the focus A until it subtends an angle of 90° , and around the focus C until it subtends an angle of 135° . We have thus two curves, of which the forms are correct; the first corresponding to PK, the second to PG, in Fig. 21. But as in the construction of Fig. 19 the distance AC must be assumed arbitrarily, it probably will not happen that HP, thus determined, will prove to be exactly of the same length as the given distance CD of Fig. 21; so that it will in general be necessary to reduce either the original

FIG. 16.

FIG. 19.

FIG. 17.

FIG. 21.

FIG. 18.

FIG. 22.

FIG. 20.

FIG. 23.

THE CONSTRUCTION OF ROLLING CAMS.

ellipse, or the curves derived from it, to such a scale as to make these dimensions the same.

The only condition assigned in regard to the action of this train was that relating to the duration of the period of rest. But there are two other elements not yet mentioned, viz., the maximum velocity of the driven wheel while it is in motion, and the magnitude of the angle through which it shall turn during a revolution of the train-arm. And without altering the first stipulation, these two elements may be varied to some extent, by changing the relative diameters of the circular wheels. The duration of the period of rest depends upon the angle subtended by the circular portion of the fixed wheel A, which in Fig. 22 is 90° as before, but in this case the diameters of F and f are as 4 to 3.

One-fourth the circumference of the larger is then equal to one-third that of the smaller, so that the circular arc PSO of the wheel a measures 120° . Bisecting this angle by the line SDK, and the angle PCQ by the line RG as before, we find that the curves PK, PG, are now to subtend angles of 120° and 135° respectively; which have the ratio of 8 to 9. In Fig. 23 are shown that portion of the auxiliary curve which it is necessary to draw in order to fix the proportions of the ellipse, and the process of contracting the arc EP about the foci into the working curves. This ellipse, it will be noted, is very different from the one shown in Fig. 19; and

turn in the same direction, the maximum velocity being again $\frac{63}{74}$ that of the arm.

There are many other curves which are capable of working in rolling contact about fixed axes, and therefore of being used either as frictionless cams or as the pitch lines of non-circular wheels. Our object, however, is not to discuss methods of determining such curves in general, but to facilitate the practical operations of laying them out for specific purposes. And many if not most of those curves above alluded to are of a complicated nature, not well adapted to graphic processes, it being necessary in the majority of cases to calculate the values of the radiants by the aid of a mathematical formula. Now, given the total angular motions of two pieces in contact, and the limits of variation in the velocity ratio, it is clear that a change in the forms of the two rolling curves can affect only the *law* of variation between those limits, and that not to a very great extent. It is of course supposable that this precise law should be of prime importance; but such a case is seldom met with, and usually the requirements of the mechanism can be satisfied by a proper proportioning of the other elements just named.

If under these circumstances this proportioning can be effected, the curves determined, and the whole movement laid out by graphic processes without resorting to calculation, that fact will prove acceptable

THE CONSTITUTIONAL CLUB, NORTHUMBER-
LAND AVENUE.

THIS new club house, now in course of erection, next to the Grand Hotel in Northumberland Avenue, will be a very striking and handsome addition to the buildings in the street. The style of the new building is a free rendering of early Renaissance, with high pitched roofs and boldly shaped gables breaking up the skyline. The front toward Northumberland Avenue, which is over 200 feet in length, is finished with a boldly treated circular end to suit the requirements of the site; it will be entirely faced with red and buff terra-cotta, with elaborately modeled figures and enriched ornament.

The architect, Mr. R. W. Edis, F.S.A., of Fitzroy Square, has adapted a free treatment of domestic Renaissance to get over the difficulty of the large and small fenestration necessary for the different rooms; the general club rooms requiring large and lofty window openings, while the upper floors, which are entirely devoted to bed rooms for the club members, have openings of a much smaller scale, to suit the various rooms. On the ground floor will be a handsome and lofty entrance hall, off which there will be a reception room 36 feet by 27 feet. From the outer hall there will be a wide corridor leading to the octagonal inner hall, 30 feet in diameter. From this inner hall the principal

THE CONSTITUTIONAL CLUB, NORTHUMBERLAND AV CHARING CROSS ARCHITECT, MR. R. W. EDIS. F.S.A.

the action of the new combination differs from that of the first in every particular except in the length of the time of rest.

In Fig. 21, CG is to DK very nearly as 11 to 37, the maximum velocity of F is $\frac{2}{3}$ that of the train-arm, one revolution of which turns F half way round; while in Fig. 22, CG:DK :: 2:3, F makes one-fourth of a turn per revolution of the train-arm, and its maximum velocity is one-half that of the latter; the driven wheel revolving in the same direction with the arm in both cases.

But again, it may be worth while to point out that the four wheels composing such a train may be arranged in four different ways, each combination producing, for one revolution of the arm, a different result. Taking Fig. 21 for example, the sun and planet wheels may exchange places, and, considering a to be stationary instead of A , the effect will be as follows: The driven wheel will remain at rest during one-half the revolution of the train-arm, and during the other half will turn once in the opposite direction, attaining a maximum angular velocity $5\frac{8}{9}$ times as great.

Or F may be fixed, A becoming the follower, which, starting from the position given in Fig. 21, will remain at rest during the first quarter of the revolution of the train-arm, during the next quarter will make a half turn in the opposite direction, its maximum velocity being $\frac{1}{2}$ that of the arm, and so on alternately.

If, finally, f be made stationary, a will remain at rest during a half revolution of the train-arm, which must then revolve once and a half in order to carry a one

to many. We have therefore aimed at enlarging the scope of those processes, so that by simple manipulations with the familiar ellipse, we can solve in a practical as well as rigidly demonstrable manner, mechanical problems which we believe had not hitherto yielded to that mode of treatment.

COMPARISON OF GREAT GUNS.

THE following table, taken from the *Armeeblatt*, gives an interesting comparison between the largest guns at present existent :

Type of Gun.	Caliber.	Length of Gun.	Weight.			Initial Velocity.	Total Energy at the Muzzle per Kilogramme of the Weight of Gun.
			Gun.	Shot.	Charge.		
		Min.	Met.	Kilogrammes.		Met.	
Krupp 35-cal., 30·5 cm.	305	10' 70	48,550	455	141	530	0' 104
35·5 " " " " " " " " " " " "	555	12' 40	81,350	725	225	530	0' 103
German 30·5 cm., mar.	305	6' 70	36,600	325	72	488	0' 103
Russian 12 in. (Long)	305	9' 14	45,341	344	136	597	0' 140
French pat., 1870, 32 cm.	320	6' 15	32,300	341	78	470	0' 104
English b., 30 ton m., 1 "	406	8' 15	62,300	771	204	498	0' 114
89 ton b., 32 " " " " " " " " " "	343	10' 97	64,000	567	283	624	0' 175
Italian 100 ton b., 1 "	432	10' 10	103,100	908	300	558	0' 118
French pat., 1875, 34 cm.	340	6' 70	48,340	420	117	480	0' 101
Bange 34 cm. " " " " " " " " " "	340	11' 20	37,500	450	180	600	0' 221

rooms on the ground floor will be approached; and a double marble staircase, 10 feet wide, will lead up to the principal rooms on the first floor.

On the ground floor there will be a reading room, 120 feet long by 30 feet wide, having the central portion recessed with circular bays at each end, giving a break of 50 feet by 27 feet in the center of the room. There will be a smoking room, 45 feet by 26 feet, on the ground floor, with the grand staircase and the necessary offices and service rooms.

On the first floor, in the main building, will be a large general coffee room, 140 feet long by 30 feet wide, with the central portion recessed, similarly to the reading room on the ground floor, and finished at the narrow end with a circular open loggia, facing the river. There will be a large billiard room and library, and various offices, on the first floor. The second floor is devoted to committee rooms, house dining rooms, and billiard and card rooms. The three upper floors will be entirely devoted to club bed rooms; the servants' rooms being provided for in the various mezzanine floors facing Northumberland Street.

The building will generally be fire-proof throughout; it will be fitted up with every modern convenience, including hydraulic lifts to all parts, and a large elevator to all floors for the use of members. The general offices, including kitchen and rooms for the boilers, engines, and the dynamos for electric lighting and steam power, will be in the basement, and mezzanine over them. All parts of the building will be well lighted and heated, and thoroughly ventilated.