“The Land Surveyor's Calculator.” By George Heald.

The instrument to which the above name is assigned was invented for the purpose of avoiding the necessity of performing long arithmetical calculations in surveying estates; the results are given at once by the adaptation and inspection of the instrument. It may also be applied to extracting the square roots of numbers, and to the other purposes to which the Gunter's scale is applicable.

Land Surveyor's Calculator.

The instrument consists of five concentric circles, whereof the four inner ones are on the outer edge of a card moveable about a centre, and the fifth on the outer circle is fixed. The circumferences of the two outer circles—that is, of the fixed circle and the circle at the edge of the moveable card—are divided into 1000 logarithmic portions representing links, the divisions being carried round in a contrary order, on the two circles. The third circle is divided to represent acres; the fourth to represent perches, and the fifth, or innermost circle, expresses the area in acres, roods, and perches.

The author then describes the method of using the instrument for the solution of questions similar to the following. Knowing the diagonal and the two perpendiculars of a quadrilateral, or the base and perpendicular of a triangle, to determine the areas of the respective figures; the result is known at once in acres, roods, and perches, on inspecting the fourth or fifth circle, according as the area is greater or less than half an acre. The instrument may also be applied to computing square yards; to extracting square roots of numbers; and to the ordinary operations of multiplication and division, in the same manner as other logarithmic lines.

A great advantage of this instrument results from the graduation being on the circumference of a circle. Great enlargement of the divisions is thus obtained, and in a far more convenient form than by drawing a slide, as on the common sliding rule; the diameter of the outer circle in this instrument is sixteen inches. The author considers that a circle of eight inches' diameter would be sufficiently accurate for practical purposes; and such an instrument would be extremely compact and portable.

Professor Willis gave a brief account of his investigations on the forms best adapted for the teeth of wheels, and exhibited several models of teeth. The subject might be conceived to be worn almost thread-bare, so much has been written and said about it; and practical

Teeth of Wheels.

men seemed well satisfied with the forms already in use ; and the principles on which they were made. These did not, however, appear to him as the best suited to the wants of modern practice. It was a general opinion that only certain curves were adapted for the teeth of wheels—namely, the epicycloidal ; he trusted he should be able to shew that there were many others. He believed he had laid down a method of drawing a curve suited to all the wants of modern practice ; in general, teeth are epicycloidal with radial straight lines. The consequence is, that a wheel of 50 teeth made in the usual manner to work with one of 30, will not work with one of 60 ; and to effect any other combination the founder must make a new set of patterns for every new combination, instead of having but one pattern of tooth ; and he should endeavour to shew how the epicycloid might be adapted so that the same wheel may drive two or more whose number of teeth is different. Another most important problem was, that having a tooth of any given form to determine a tooth which would work correctly with it.

Such were some of the general features to which his attention had been directed, and the practical method of effecting these objects being fully set forth in his paper, he should merely shew the application as made for the workshop.

March 27, 1838.

The PRESIDENT in the Chair.

The following were duly elected :—G. A. Jermyn, N. Beardmore, as Graduates ; Captain R. Dawson, R. E., Henry Handley, M. P., and W. Nicholson, as Associates ; Dr. Roget, as an Honorary Member.

The Canal Lifts on the Grand Western Canal. By James Green, M. Inst. C. E.

Green's
Canal
Lifts.

The Lift which is the subject of the following paper was erected by Mr. Green in the year 1835, on the Grand Western Canal, and has been in operation ever since. Lifts are not intended to supersede the use of canals in all cases, but in those in which a considerable ascent is to be overcome in a short distance, and in which the water is inadequate to the consumption of a common lock, or in which the funds are inadequate to the execution of the work on a scale adapted to such locks.

The paper is accompanied by a table, shewing the proportionate parts of 112 lbs. of coal burnt in heating water from 32° to 212° with that burnt in evaporating it from 212°. It is constructed on the established principle of the sum of the latent and sensible heat being constant, and is of great use in reducing the results of numerous experiments to one common standard, and ascertaining the value of fuel; and in comparing one set of experiments with another; when the water has been supplied to the boilers at different temperatures.

The evaporation of water as stated by Mr. Manby, in the experiment with Collier's boiler, being reduced to the same standard as others in his paper, it appeared that 20·24 cubic feet were evaporated from 212° F. with 112 lbs. of coal. The quantity evaporated at the Fowey Consols was 21·37 cubic feet.

It appeared on comparing the value of the Locomotive Engine and the Cornish Engine by the quantity of coals consumed, per horse power, they were as 1 to 35.

The difference in the heating effects of coke and coal having been observed, Mr. Parkes remarked that the heat generated depended on the ratio of the rate of absorption of the oxygen; there must be more space betwixt the bars when coke than when coal is consumed, and the quantity of oxygen required is much greater in the former than in the latter case. More air however may be drawn through the bars than can possibly enter into combustion, and the general temperature is lowered in consequence.

Heat of
Coke and
Coal.

The comparative value of coke and coal in melting glass had been observed by Mr. Pellatt, and it appeared that 21 tons of coke produced the same effect as 26 tons of the best coal.

April 3, 1838.

The PRESIDENT in the Chair.

The following were balloted for and elected; C. R. Buckle, as a Graduate; J. Ignatius Massie, as an Associate.

On the Teeth of Wheels. By Robert Willis, Jacksonian Professor of Natural Philosophy in the University of Cambridge.

Teeth of
Wheels.

The geometry of the subject of the teeth of wheels may be con-

sidered as complete, but it appears that important additions may be made to its practical applications. The general problem is, having given a tooth of any form to determine one which shall work correctly with it. The method of effecting this may be shewn in a simple practical manner. The curve to be traced out, which is the shape of the required tooth, is the locus of the intersections of all the outlines of the tooth in every one of its positions. The motion produced by the mere contact of the curve so traced out with the given tooth will be uniform. This then is a practical mode of shewing the practicability of the problem.

The epicycloids and involutes have hitherto, from the facility with which they can be described, been almost universally employed, and practice has been confined to the class of epicycloids which work correctly with straight lines or circles. The defect under which such wheels labour is, that a wheel of fifty teeth of the same pitch will not work correctly with a wheel of one hundred teeth of the same pitch; since the diameter of the describing circle by which the epicycloid is formed, must be made equal to the radius of the pitch circle of the wheel with which the teeth are to work, and will therefore be twice as large in the second case as in the first. Also, if the teeth be epicycloids, generated by a circle whose radius is equal to that of the wheel with which it is to work, which is equally correct, the same remark applies.

This defect was of no great consequence when the teeth were wooden, but it is of great consequence in iron wheels, since the founder must have a new pattern of a wheel of forty teeth for every combination that it may be required to make of this wheel with others. It is desirable that the teeth of wheels be formed so that any tooth may work correctly with any other of the same pitch. This is the case with involute teeth, but the obliquity of the action is an objection to their introduction. The requisite property may be given to epicycloidal teeth, by employing the following proposition. If there be two pitch circles touching each other, an epicycloidal tooth formed by causing a given describing circle to roll on the exterior circumference of the first, will work correctly with an interior epicycloid formed by causing the same describing circle to roll on the interior circumference of the second.

From this Professor Willis deduces the corollary, that if for a set of wheels of the same pitch a constant describing circle be taken and employed to trace those portions of the teeth which project beyond each pitch line by rolling on the exterior circumference, and those which lie within it by rolling on its interior circumference, then any

two wheels of the set will work correctly together.* This corollary is new, and constitutes the basis of the system already alluded to.

It only remains to settle the diameter of this constant describing circle. The simplest considerations serve to shew that the diameter of the constant describing circle must not be greater than the radius of the pitch circle; hence, as a convenient rule, make its diameter equal to the radius of the least pitch circle of the set. This rule is perfectly general, applying to racks and large wheels, as well as to annular or internal wheels. The simplicity of this above the old system is obvious, for on the old every epicycloid requires two circular templets; also there must be as many templets as pitch circles in the set, whereas on this system but one describing templet is required.

For machinery in which the wheels move constantly in the same direction, the strength of the teeth may be nearly doubled for the same quantity of material, by disposing it so that the backs are an involute or the arc of a circle, the acting faces being of the usual form.

In the preceding the exact forms have been described; the author then proceeds to ascertain forms sufficiently accurate for practice, and which are arcs of circles. Euler suggested the substitution of arcs of circles of curvature instead of the curves themselves. The portion of a curve employed in practice is so small that a circular arc is sufficiently accurate, provided the centre and radius with which it is struck be determined by some more accurate method than by mere trial. With this view Professor Willis was led to investigate a method in which the nature and properties of curves proper for teeth are entirely neglected, and a simple construction shewn by which a pair of centres may be at once assigned for a given pair of wheels, whence arcs may be struck that will answer the purpose of enabling these wheels to work correctly together.

The nature of the motion produced by the pressure of one circular arc against another is then examined and reduced to that of a system of three rods, the middle one of which is jointed to two others, moveable at their other extremity about a fixed centre; and a simple construction is arrived at by which we may always

* For there is both before and after passing the line of centres an exterior epicycloid working with an interior epicycloid; for before passing the line of centres, the part of the driving tooth *within* the pitch line works only with the portion *without* the pitch line of its follower; and after passing the pitch line the part of the driving tooth *without* the pitch line works with some portion of the following tooth which is *within* the pitch line.

find a pair of centres for which two circular arcs may be struck through any point, which will drive each other truly for a small distance on each side of that point. This point, when the side of a tooth consists only of a single arc, should be on the line of centres. It is however more advantageous that the tooth should consist of two arcs, for then there will be two points at which the action is exact—one a little before reaching the line of centres, the other a little after passing it.

From these investigations the author was led to construct an instrument for setting out the teeth of wheels, which may be used with perfect facility by the workmen, and which has been termed an Odontograph; the application of which is fully described. The paper contains many practical observations connected with this subject, tables, &c., and concludes with some directions for ascertaining the correct form of cutters.

On the Ventilation of Tunnels. By W. West.

Ventilation
of Tunnels.

This paper contains an account of some experiments on the temperature of the air in a tunnel on the Leeds and Selby Railway. There are three shafts in the tunnel; and he observes, the temperature of the external air being 34° , the temperature at the mouth and as far as the first shaft was $34\frac{1}{2}^{\circ}$, but that immediately beyond this shaft it rose to 35° , and increased uniformly up to the farther end, at which point it was 57° . From this fact the author infers that the air passed up the shaft, and that the tunnel would be more completely ventilated without any shafts; and that shafts generally are an impediment to perfect ventilation.

Transfer
of Letter
Bags.

Mr. Carpmael described and illustrated by a model the apparatus invented by Mr. Worsdale for changing the letter bags on the railways without diminishing the speed at which the carriages are travelling. The bag to be taken up is hung on an arm projecting from a post, generally a lamp-post, and the bag to be left is suspended at the end of a rod projecting from the back of the railway carriage. The guard knows the exact distance to which this rod is to be pushed out; and the projecting iron of the lamp post receives the bag to be left at the same instant as a projecting iron on the guard's rod sweeps off the bag to be taken up. This exchange is certain, and effected without any loss of time.