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NOTICE TO SUBSCRIBERS.

Hereafter we shall follow the general rule regarding subscriptions, and shall continue sending THE TECHNIC to subscribers until notified to discontinue.

THE position of shop superintendent, recently made vacant by the resignation of Mr. Harris, is now being filled by Mr. A. W. Clement. Mr. Clement is a graduate of Worcester Polytechnic Institute, and since leaving that institution in '95 has been engaged in a variety of engineering work, which, together with his personal qualifications, thoroughly fits him for his present position. For some time after graduating, Mr. Clement was connected with the American Whellock Engine Company, being employed in the various departments of that concern. He then went to New York and was engaged there in experimenting with compressed air in connection with street car motors and automobile work. In March, '97, Mr. Clement accepted a position as engineer with the Draper Company, of Hopedale, Mass., in which capacity he has been employed till the present time.

⁂

THE lecture course which proved so beneficial in former years, has been decided upon again for this year, and the first lecture of the series, which will be delivered in the near future by F. H. Newell, will be upon some subject relative to hydrography. The lecture promises to be one of more than passing importance, as Mr. Newell has been connected with the U. S. Hydrographic Survey for some time, and has made a deep study of the subject.

⁂

THE members of the Junior Class are now busily employed on the *Modulus*, which is to appear May 1st. They are to be congratulated on their enthusiasm in the undertaking, and should be encouraged in every possible manner. It therefore becomes the duty of each student to at least subscribe for the *Modulus*. A publication of this class is decidedly expensive, and unless a certain number are sold the result will be financial embarrassment for the Junior Class. We are sorry to say that many of the Alumni have not yet subscribed and do not feel inclined to do so. Three years have elapsed since the appearance of the *Modulus*, and consequently there is plenty of material for an excellent publication, and we feel assured that no Alumnus will ever regret the nominal price charged. The pleasant memories aroused by reference to familiar landmarks and college relics will repay the purchaser many times.

⁂

THE question of gymnasium classes has again been unearthed, and there seems now some possibility of its being settled satisfactorily. The excuse usually offered by those objecting to the classes is that their time is already fully occupied and that thro their shop work enough exercise is derived to make it useless for them to spend their time in gymnasium classes. That there is much truth in the above must be admitted, but the exercise received in the gymnasium is of an entirely different character from shop work, and in fact is intended to prevent those deformities which fre-

quently result from too much shop work. Attendance at the classes, however, will not be compulsory. The classes will probably be from 5 to 6 on Tuesdays and Thursdays, and on Saturday afternoons. Mr. Huthsteiner, '01, will have charge of the work, and it is hoped that a large percentage of the students will avail themselves of the advantages offered for physical culture.

❧❧❧

DIRECTLY analagous to the statement which is often made that the engineering profession is overcrowded and that positions are hard to obtain, is the following, which appears in the *American Engineer and Railroad Journal*:

MASTER MECHANICS WANTED.

Why is it that four important railroads, and perhaps more, are having difficulty in securing satisfactory Master Mechanics? We have at present four such applications on file in this office, one of the positions having been vacant several months. The salaries offered are good, the openings are excellent and the prospects for advancement encouraging. In one of these cases $3,000 a year will be paid to the right man.

Is the fault with the roads, in neglecting to educate young men for promotion? Is it with the technical schools in any way? Is it with the young men themselves? It is clear that something is wrong, perhaps with one and perhaps with all of these. The questions are offered to those whose success and usefulness are closely concerned in answering them.

The questions asked are most timely, and are worthy of consideration by every aspirant to such positions. We are not in a position to give decisive answers, but the trouble is no doubt partially due to the railroad companies themselves, for too often a man capable of filling a much better position is kept in one of minor importance for the simple reason that he performs his work in a superior manner and it is hard to break another man in. Such treatment, while not to any great extent prevalent, is noticeable, and has a decided tendency to deaden the ambitions and aspirations of the young man who is thrown upon his own resources. The consequent relaxation from work and study, however, is not excusable on the part of the men in question, and if promotion does not come they are usually as much to blame as the railroad company. The technical schools also come in for their share of the blame, for the time devoted to such subjects as fit a man for positions of this class is in many instances entirely too short. Were the course of five years' duration instead of four, we have no doubt the graduates would be amply fitted to fill such positions shortly after graduation.

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THE members of the Senior Class taking the course in mechanical engineering are at present engaged in some very interesting and extremely practical work. It is a much-disputed question in many localities as to whether it is more economical in railway practice to lessen the grades, thereby cheapening the cost of operation by a decrease in the amount of fuel and water necessary to haul a given train over a given distance, and increasing the hauling capacity of locomotives, or whether the first cost of construction, or the expenditure necessary to make the change, is so large as not to warrant the construction or change. The conditions, of course, vary in different localities, but when the local peculiarities, such as the nature of the soil to be disturbed, the class of traffic to be considered, and the efficiency of the particular type or types of locomotives employed, become known, the problem assumes definite proportions.

The question presented to the Senior Class was in regard to the change of grade of a certain portion of the main line of the Vandalia. The estimated cost of the change in grade being known, the problem was to ascertain the commercial value of the increased hauling power of the locomotives resulting from this change and the decrease in the amount of fuel and water consumed. So far the experiments and tests have only been of a preliminary nature to ascertain the exact equipment necessary to secure the desired data and information. Problems, such as the above, or a similar nature, are constantly met with in engineering practice, and in order that the graduates may be prepared to cope successfully with them, it is the aim of the Faculty to present as many as possible for solution.

Friction Tests of a Locomotive Slide Valve.

PROF. FRANK C. WAGNER.

DURING some recent locomotive tests made at the Rose Polytechnic Institute, as a feature of thesis work by Messrs. Butler and Crebs, it was found desirable to operate one of the valves by means of an electric motor. It occurred to the writer that by making a few additional observations, some useful data upon the friction of a locomotive slide valve might be obtained. The tests were made accordingly, and it is hoped that the results obtained may be found both interesting and useful.

The changes made upon the locomotive to adapt it to the tests were as follows:

The steam valve on one side was disconnected and blocked in middle position, so that no steam could enter the cyclinder on that side. The locomotive was moved on the track until the piston on the other side was approximately in the middle of its stroke, and then the main drivers were securely blocked. At the same time the crosshead was also blocked. The back-up eccentric rod was then disconnected, and an extension piece was bolted to the link for the purpose of connecting with an external source of power for driving the link motion and through it the valve. The power in this case was furnished by an electric railway motor of 15 horse-power. On the end of the electric motor shaft was keyed a forged crank, with a one-inch steel crank pin. The pin worked in a link block, which, in turn, slipped in a suitable slot cut in the extension piece to the main link.

By this arrangement the forward eccentric-rod pin served as a fulcrum for the link, and a reciprocating motion was imparted to the link by the electric motor through the medium of the crank and slot. The link block of the locomotive mechanism was left in place, and imparted motion to the valve in the usual way.

The movement of the valve could be regulated slightly by raising or lowering the link. Additional regulation of the amount of steam admitted to the cylinder was obtained by opening and closing the throttle.

Indicators were connected both to the cylinder and to the steam chest. The motion of the indicator drums was obtained directly from the valve stem. The number of strokes of the valve was registered by a counter.

The power used to drive the valve was obtained by measuring the electrical power delivered to the electric motor, and making suitable allowances for the efficiency of the motor and the friction of the transmitting mechanism. This was done as follows: After the tests were completed the valve stem was disconnected, and the electrical power required to drive the electric motor and transmitting mechanism was determined for various speeds. The efficiency of the electric motor under various loads had previously been determined in the laboratory. By comparing the efficiencies at the two loads, the increased loss of power in the electric motor when driving the valve over and above the lost power when the valve was disconnected, was determined and allowed for.

No allowance was made for increased friction of the link-work. The crank pin and sliding block, used to transmit the power from the motor shaft to the link, were flooded with oil by dipping into a bath of oil and water with every revolution of the motor. The friction of other portions of the link-work and of the rocker arm was relatively small, and no great error can be

introduced by considering it to be the same for the different loads at the same speed.

The dimensions of the valve experimented upon, and the results obtained, are given in Tables I. and II.

TABLE I.

DIMENSIONS OF VALVE.

Type of valve	D slide
Width of valve, inches	9.25
Length of valve, inches	17.00
Width of port opening, inches	1.25
Length of port opening, inches	15.00
Width of exhaust port, inches	2 50
Width of bridge, inches	1.25
Steam lap, inches	0.875
Exhaust lap, inches	0.125
Gross area of valve, square inches	157.25
Balance area of valve, square inches	54.50
Unbalanced area of valve, square inches	102·75
Total bearing area of packing strips, square inches	86.00
Gross rubbing surface, bottom of valve, square inches	86.00
Average net rubbing surface, bottom of valve, for 3-inch stroke, square inches	58.20
Rubbing surface, top of valve, square inches	22.20

TABLE II.

FRICTION OF VALVE.

Number of test	1.	2.
Duration of test, hours	2.25	0.62
Number of observations	10.	3.
Double stroke of valve per minute	421.	410.
Speed of valve, feet per minute	210.5	205.
Average steam pressure in boiler, pounds per square inch	144.9	154.
Average steam pressure in steam chest, pounds per square inch	42.18	122.0
Downward force on valve due to pressure in steam chest, pounds	4,334.	12,534.
Average upward force on valve due to pressure in steam cylinder, pounds	373.	596.
Net force pressing valve upon its seat, pounds	3,961.	11,938.
Intensity of pressure between rubbing surfaces, face of valve, pounds per square inch	68.	205.1
Intensity of pressure between rubbing surfaces, packing strips, pounds per square inch	42.18	122.0
Average power delivered to electric motor during test, horse-powers	4.85	7.45
Power consumed in driving motor and link-work, horse-powers	3.30	4.14
Net power consumed in driving valve, horse-powers	1.55	3.31
Average power required to move valve, pounds	243.	533.
Drops of oil fed to valve per minute	20.	15.
Coefficient of friction	.050	.036

The average net rubbing surface on the bottom of the valve was found by substracting from the total rubbing surface, on the face of the valve, the average amount of such surface which was over the ports during one stroke of the valve.

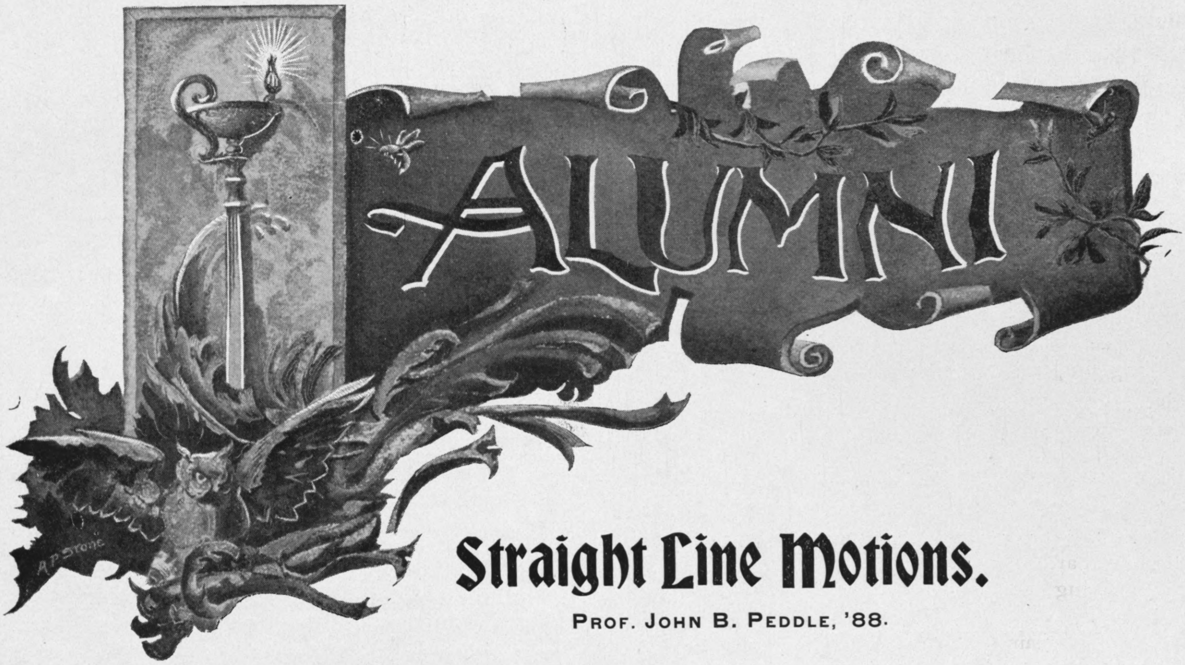
In calculating the force with which the valve is pressed upon its seat, allowance has been made for the upward pressure on the portions of the valve which extend over the steam ports. Both the area thus acted upon and the pressure vary during the stroke. It is not difficult, however, to obtain a sufficiently accurate average value for both quantities.

The oil used to lubricate the valve was a high grade cylinder oil, such as is regularly supplied by the Vandalia Railroad Company for use on its locomotives.

The indicator diagram taken from the steam chest was substantially a straight line, showing that with the valve speeds used, a constant pressure was maintained in the steam chest.

One interesting point disclosed by the indicator diagrams, is the time required for the opening or closing of the ports to make itself felt upon the pressure in the cylinder. The distance on the indicator diagram between closing to steam, and opening to exhaust, should be equal to the sum of the steam and exhaust laps, that is, one inch. The distances upon the diagrams vary from one and one-eighth to one and five-eighths inches, showing an appreciable lag between the actual closing and opening of the ports and the corresponding points on the indicator diagram.

It is to be kept in mind, however, that these indicator diagrams correspond with the motion of the valve, and not, as in the ordinary diagram, with the motion of the engine piston, and also that the piston remained stationary at the middle of its stroke.



Straight Line Motions.

PROF. JOHN B. PEDDLE, '88.

IT is not a little curious that, while exact methods of drawing circles, ellipses and other curves are matters of common knowledge, a knowledge of the exact methods of drawing a straight line (apparently the simplest of line forms) is much less frequently met with.

We are so accustomed to drawing our straight lines with the help of a straight edge that we are not apt to think of the possibility or desirability of ever doing it in any other way.

It is the purpose of this paper to briefly describe a few mechanisms by means of which a point may be given a motion in a straight line.

The statement is sometimes made that, until 1884, when the Peaucellier motion was invented, an exact method for drawing a straight line was not known. If the statement is limited to mechanisms in which the links are connected by turning pairs only, it is true, but if this restriction is not made it is not an accurate statement of fact.

The straight line motions which have been invented at different times may be roughly divided into three classes—those in which the motion is exactly rectilinear, and in which no other straight line is required for a guide; those in which the motion is exactly rectilinear, if we may be permitted to use one or more straight lines to guide certain parts of the mechanism, and those in which the rectilinear motion is only approximated. This last might also be divided into two classes—those in which a straight line guide is required, and those in which it is not—but it will be more convenient to discuss them together.

A large number of examples might be found in each class, but I shall only attempt a brief description of a few of them.

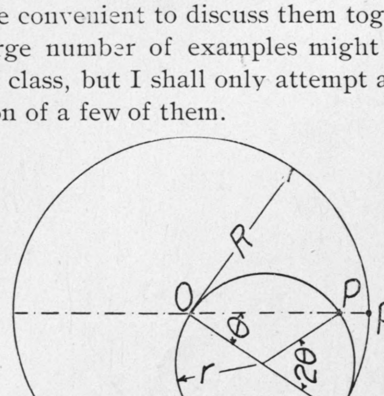


Fig. 1.

One of the oldest motions is that produced by the Cardan circles, so called from their having been first investigated by a mathematician named

Cardano, who flourished in the 16th century.

These circles are shown in Fig. 1, where the smaller one is half the diameter of the larger, and rolls on the inside of its circumference. Then any point on the circumference of the smaller circle will travel on a straight line which is a diameter of the larger one.

To prove this, let R be the radius of the large circle, and r that of the other. Let P be the point which is to trace the line, and P^1 the point on the large circle from which it started. Then PQ equals P^1Q, or $R\theta = r2\theta$.

In practice, to avoid slipping, and to make the motion positive, the circles might be replaced by an internal gear and a pinion, the center of the latter being constrained to move in a circle by a link from the center of the large gear. The point P would be located on the pitch circle of the pinion.

Another arrangement known as Cartwright's motion consists of two spur gears in mesh, to which are pinned two links, as shown in Fig. 2. If the pins move on circles of equal radius, and the gears are so meshed that the pins are always equally distant from the center line CP, and if the links are of equal length and joined at P, it is evident from inspection that the point P must travel on the straight line CP.

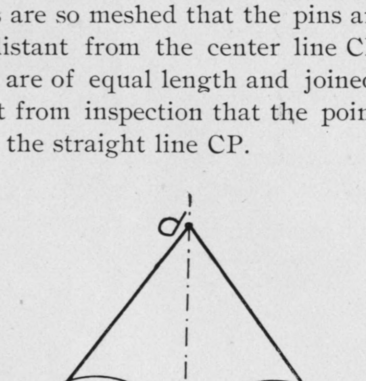


Fig. 2.

These are true straight line motions, although they might be called approximate in the sense that the unavoidable imperfections of the gear tooth outlines would make a perfect motion impossible. But so in the same sense would it be impossible to have a perfect motion for drawing a circle, for we are obliged to assume that the needle point of our compasses is truly cylindrical or that it works in a truly cylindrical hole.

The Peaucellier cell referred to above was, I believe, the first exact solution of the problem by means of turning pairs alone.

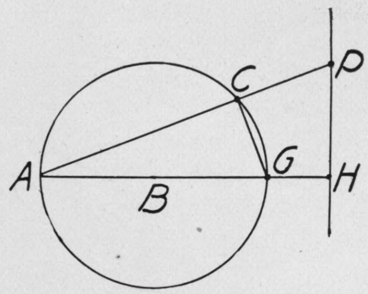


Fig. 3.

In Fig. 3, suppose HP to represent a straight line perpendicular to AH. Draw any line AP through A and intersecting HP in P. Also draw a circle with its center on AH and with A on its circumference. Connect C and G, the points where AP and AH cut the circle. We then have two similar triangles, AHP and ACG

$$\text{and } \frac{HA}{AC} = \frac{AP}{AG} \therefore HA.AG = AC.AP$$

or the product AP.AC is constant.

The Peaucellier cell consists of seven moveable links, joined as shown in Fig. 4, and attached

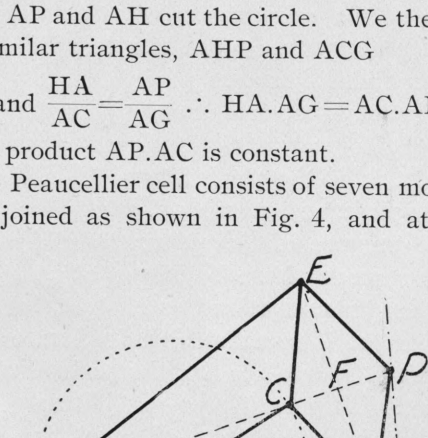


Fig. 4.

at A and B to a fixed link. If CD, DP, PE and EC are equal and also AE and AD, then A, C and P always lie upon the same straight line. Make AB equal to BC, and find the intersection F of the lines ED and CP. Then

$$EF^2=AE^2-AF^2=EC^2-CF^2$$

$AE^2-EC^2=AF^2-CF^2=(AF+CF)\ (AF-CF)$ or AE^2-EC^2 (a constant)$=AP.AC$.

The application to Fig. 3, in which the same letters are used for the same points, will be apparent at a glance, and we see that P must move on a straight line perpendicular to AB.

In 1874 some lectures by Prof. Sylvester aroused considerable interest in this subject in England and led to the discovery of several new forms of straight line linkages. Mr. A. B. Kempe was particularly successful in finding new forms, and he was ultimately able to show that they all, including the Peaucellier cell, were dependent upon a simple relation between a quadrilateral and its image.

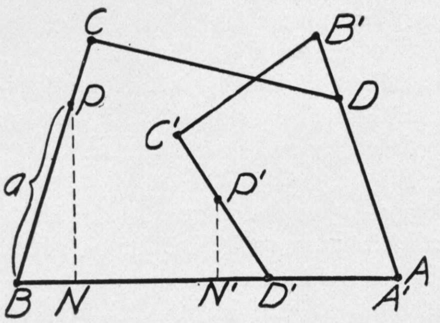


Fig. 5.

Suppose we have any quadrilateral ABCD. We know that the length of its diagonal AC is

$$AD^2+DC^2-2AD.DC\cos ADC=AB^2+BC^2-2AB.BC\cos ABC$$

or

$$2AB.BC\cos ABC-2AD.DC\cos ADC=(AB^2+BC^2)-(AD^2+DC^2).$$

Let us take a second quadrilateral similar to the first and with the lengths of its sides in the ratio k to the corresponding sides of the original figure. Let the corresponding points in the new figure have the same letters as were used in the first, but primed. Since the angles at A and A^1 are the same, we can lay side A^1B^1 on AD and have A^1D^1 lie on AB.

Take any point P in BC, and call $BP=\alpha$. Also take a point P^1 in D^1C^1 such that $D^1P^1=\alpha\frac{CD.DA}{AB.BC}$. Drop perpendiculars PN and P^1N^1 from P and P^1 to AB.

$$BN=\alpha\cos ABC$$

$$D^1N^1=\alpha\frac{CD.DA}{AB.BC}\cos C^1D^1A^1=\alpha\frac{CD.DA}{AB.BC}\cos ADC$$

$$BD^1=AB-kAD$$

$NN^1=BD^1-BN+D^1N^1$ (D^1N^1 in the figure being negative)

$$NN^1=(AB-kAD)-\frac{\alpha}{2AB.BC}(2AB.BC-\cos ABC-2CD\cos AABC)$$

which from our second equation becomes

$$NN^1=(AB-kAD-\frac{\alpha}{2AB.BC}\left\{\begin{matrix}(AB^2+BC^2)- \\ (AD^2+DC^2)\end{matrix}\right\}$$

or NN^1 is constant.

Assume $\alpha=\frac{(AB-kAD)\ AB.BC}{(AB^2+BC^2)-(AD^2+DC^2)}$

Then $NN^1=\frac{BD^1}{2}$

Now, if we suppose the original quadrilateral to be formed of four bars connected by turning pairs at A, B, C and D, and the second quadrilateral to be formed with the first by the addition of two more bars pivoted to AB and AD at D^1 and B^1 and to each other at C^1, and if we further suppose AB to be a fixed link, we have a mechanism which is completely constrained, as each of the component links will have a certain definite movement if either one of them is displaced.

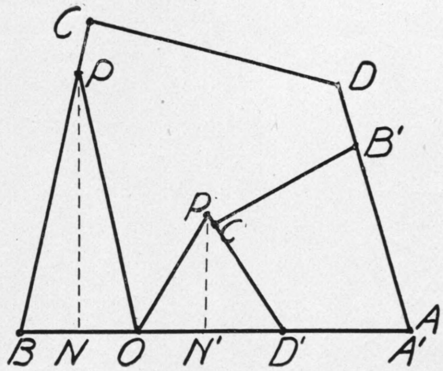


Fig. 6.

Let us add two more links PO and P^1O equal respectively to PB and P^1D^1 and join them to O. We then have two isosceles triangles POB and P^1OD^1 and an inspection will show that since B and D^1 are fixed and the horizontal distance between P and P^1 is constant and equal to $\frac{BO^1}{2}$

O must lie on BD^1 for all positions of the mechanism, or will trace a straight line.

This gives us the general solution of the problem, and Mr. Kempe has worked out a large number of particular cases from it.

Space will not permit us to take them up, however, but I will just refer to one in which BC=DC, and $k=\frac{AD}{AB}$ then $A^1B^1=kAB=kAB=AD$, and $\alpha=BC$.

B^1 therefore falls on D, P on C and P^1 on C^1,

As I said before, Mr. Kempe has shown that the Peaucellier cell is really a particular case of these linkage forms.

Let us now turn to the second class of motions referred to at the beginning, that in which a straight line guide is required for some portion of the mechanism.

These motions will, in general, depend upon the principle of the Cardan circles. If the smaller circle rolls inside the larger one, we have seen that any point P will trace a diameter of the larger circle. Likewise any other point P^1 will trace some other diameter. If now we suppose the outer circle to be removed and the points P and P^1 guided upon the straight lines OP and

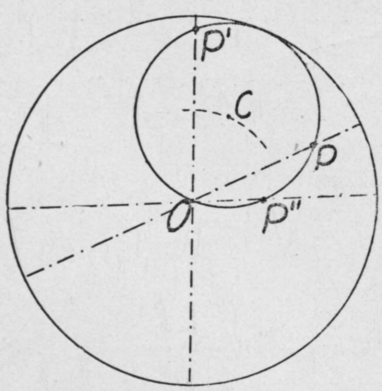


Fig. 7.

OP^1, it is evident, I think, that the smaller circle will have precisely the same motion as when it rolled within the larger one, and its center C will travel on a circle about O as a center. Now, suppose that O and C are connected by a link, so that C is constrained to travel on a circle of OC radius, and suppose point P to be constrained to move along a straight line OP, while P^1 is free. It will be seen that P^1 necessarily moves in a straight line OP^1.

P and P^1 may be connected by a bar of any form, and C may or may not be on the straight line connecting P and P^1, as OP and OP^1 do or do not meet at a right angle.

Any third point on the circumference of the smaller circle, such as P^{11} will also move on a straight line, and if we again suppose that the outer circle is removed and the inner one constrained only by the points P and P^1 which are to move on OP and OP^1 it is easy to see that P^{11} still has a rectilinear motion along OP^{11}.

A skeleton diagram of such a mechanism is shown in Fig. 8.

An almost endless variety of straight line motions may be constructed on this principle.

There is likewise another set of motions requiring a straight line guide in which the guide is merely copied by some sort of pantagraph arrangement.

When we come to the third class of linkages we find a bewildering variety of forms, but upon analysis it will be found that most of them fall into one of three subdivisions, which involves in

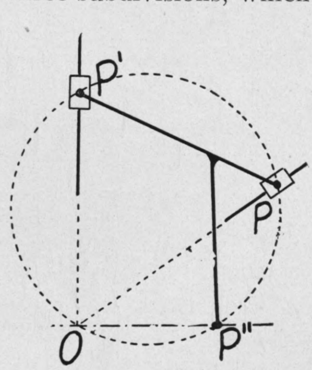


Fig. 8.

some way one of the three mathematical curves—the ellipse, the lemniscoid and the conchoid.

Taking them up in order, we find the Cardan circles again made use of in the first division.

If, instead of taking a point on the circumference of the inner circle, we take it either outside or inside of the circumference we will find its path to be an ellipse.

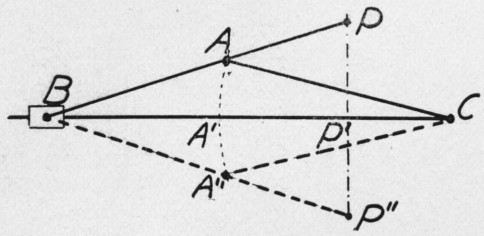


Fig. 9.

In Fig. 9, let points P and B move on the straight lines PP^{11} and BC, then the path of A, taken anywhere on PB, will be an ellipse, and if the movement of P is not too great we can find a circular arc closely approximating the elliptical arc. If, therefore, we constrain A by the link AC and give a rectilinear motion on BC, P will move on a line which is approximately straight. This mechanism has the constructive advantage that P's path does not pass through C, a matter of considerable importance in some cases.

In designing a linkage of this description PB should be drawn for the highest, middle and lowest positions of P, and the corresponding positions of A located. The center of an arc passing through these points is C.

It is evident that if, in Fig. 9, A is taken at the middle of BP its path becomes a circle with center at P^1, and we have one of the exact forms spoken of in class two. It is known as Scott Russell's motion.

If P does not move very far on either side of the center line BC, the motion of B will be small and the straight line guide may be replaced for most practical purposes by a link which will cause B to move on the arc of a circle.

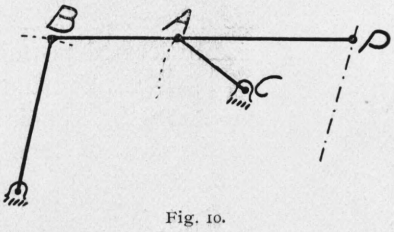


Fig. 10.

This movement, more or less disguised, appears in many indicator motions.

Two of the best known motions depending on this idea of approximate elliptical arcs are the Roberts and Tchebicheff linkages.

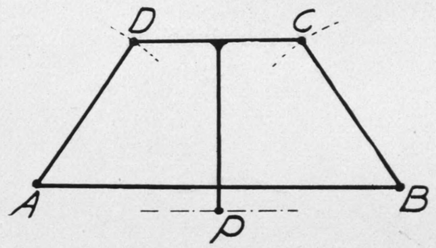


Fig. 11.

In the first, we have a quadrilateral linkage ABCD in which AB is fixed. P, the straight line point, lies on an extension from DC. AD and BC guide points D and C on arcs which approximate ellipses, and P is supposed to be on the circumference of the equivalent Cardan circle. When P falls on AB, DC is half of AB and AD=DP=CP=CB.

The Tchebicheff motion is illustrated in Fig. 12, where AB is a fixed link, and P, in the middle of CD, is the describing point. Here, too, C and D are given motions which approximate ellipses.

The various modifications of this ellipse idea may be multiplied almost indefinitely, and Reuleaux shows a great many of them "inverted," that is, the point which we have seen move in a straight line he makes stationary, and allows the former fixed points to move. Since their relative motion is the same in either case, we must again have a rectilinear motion.

In Fig. 9, for instance, suppose P to be fixed, and allow the link BC to move up and down.

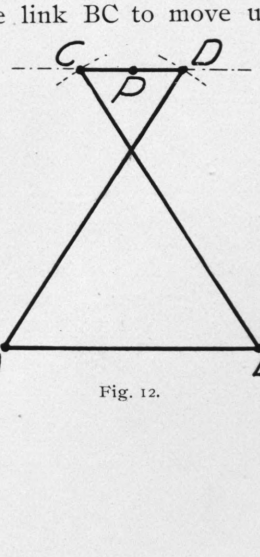


Fig. 12.

Some means must be provided to keep BC always parallel to its initial direction. This can be done, among other ways, by means of the sliding-turning pair at D (on the fixed link PD) acting on the extension bar DE. Fig. 13.

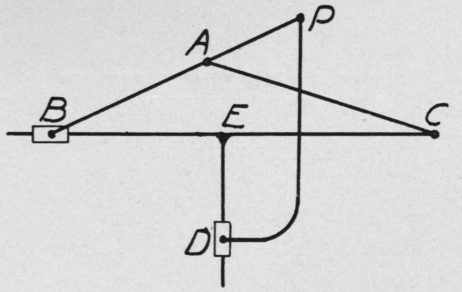


Fig. 13.

In such a case any point on the link BC will travel in an approximately straight line. In practice the extension bar DE would be the piston rod of a steam engine or pump, and the sliding pair at D would be the stuffing box.

Passing now to the lemniscoid linkages, the most famous is Watt's so-called "parallel motion." He used it quite extensively in his engine practice, and even now one occasionally runs across it in the older beam engines.

It consists of three moveable links, pivoted as

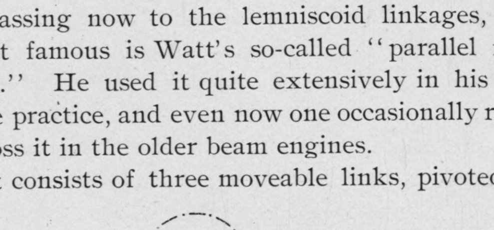


Fig. 14.

shown, to the fixed points A and D. A point on AC will trace a lemniscoid or sort of distorted figure 8. Part of the path under favorable conditions is very nearly straight, and this is used for straight line motion. The best results are obtained when AB equals DC, and when at mid-stroke they are parallel to each other and perpendicular to the path of P. P will then be in the middle of BC.

In practice the piston rod would be attached to P and AB would be the beam of the engine. In this form, however, it would require a considerable extension of the engine bed to include the fixed point D, and we generally find the mechanism modified as shown in the dotted lines, where AB is extended to, say, E, and the links EF and FG added to form the parallelogram EFGB. This evidently forms an enlarging pantagraph, and by finding the intersection of a line through A and P with one of these added links (in this case, F) we get a point which exactly reproduces the motion of P on a larger scale, and to which, therefore, the piston rod may be attached.

This last of the linkage forms to which I referred to above was that which involved the conchoid.

The conchoid is a curve traced by a point on a straight line which constantly passes through a fixed point called the pole, and which moves so that a given point on it is always on a second straight line.

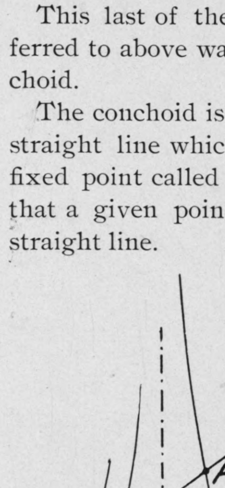


Fig. 15

In the figure D is the pole and P moves along the straight line. Then A, B and C each trace a conchoid. It is easily seen that if P does not move very far from its mid position the arcs traced by A, B and C may be represented approximately by the circular arcs, the centers of which may be readily located as in Fig. 9. By using links, then, to guide any of these points in a circular arc we are able to give P a motion which is approximately rectilinear.

In what has gone before I have made no attempt to give more than the barest outline of the subject, and many forms have been omitted

which are perhaps equally as worthy of attention as those I have described. I think, however, that these examples will illustrate fairly well the more important principles involved, and this is about all that can be done within the limits of a short magazine article.

ALUMNI NOTES.

Luther S. Rose, '92, visited the Institute recently.

R. A. Philip, '97, is now located in Tacoma, Wash.

Chas. H. Fry, Jr., '97, visited Terre Haute during the holidays.

Teddy Thompson, '99, recently visited his parents in Terre Haute.

To Mr. and Mrs. Theodore L. Condron, '90, a daughter, Helen, January 7, 1900.

H. C. Schwable, '99, is in the employ of the Electric Appliance Co., of Chicago.

Walter M. Wickham, '92, is now in the employ of the Westinghouse Co., at Pittsburg, Pa.

S. G. Brown, '95, has recently accepted a position with the Central Telegraph Co., of Pittsburg, Pa.

Harry T. Liggett, '96, was married New Years eve to Miss Nellie Mae Bemiss, of Louisville, Ky. Congratulations from THE TECHNIC.

Announcements have been received of the marriage of Cale Walmsley, '98, to Miss Mabel Carpenter, of Yates Center, Kansas. THE TECHNIC extends congratulations.

Roger M. Newbold, '97, writes that at present he is located at Paris, Tenn., where he has been since July, superintending the erection of the new $50,000 shops for the L. & N. Ry.

The Rose colony in Chicago is rapidly increasing, and at present there are twenty-five Alumni in the city, and ten more located in the immediate vicinity. The series of dinners arranged for the purpose of keeping the men in touch with each other has proven very profitable indeed. The next dinner occurs the 27th of this month, and a full attendance is expected.

Some of the Methods Used In Excavating the Chicago Drainage Channel.*

HENRY LESER, '00.

IT MAY be stated with perfect safety, that nowhere at any time in the history of modern civilization, have so many novel and unique machines for excavating and removing earth and rock been in operation within so small a territory as that through which the Chicago Drainage Channel has been constructed.

It was thought best to let the work in contracts comprising only small sections, instead of allowing the whole work to be done by one company. In fact, many sections were less than one mile in length, while a few were of somewhat greater length. However, it is not to be assumed that there was a different contractor for each section; on the contrary, many of the contractors had several divisions. The idea in letting the work in short sections was to insure greater competition, by making it possible for contractors to bid, who would not have had means, in finances and equipments, to compete had the sections been made in great lengths. It was also thought, that by subdividing the work in this manner, there was a possibility of having the work completed in a much shorter time, for, if for some reason or other, a contractor felt compelled to give up his section, the work on the whole channel did not necessarily have to be suspended until difficulties were adjusted. The last expectation, however, was not realized.

The greater the competition, the better were the chances that the work would be done at the lowest possible figures. In fact, some of the bidders did not realize what kind of work they were bidding upon. For many successful bidders soon found that the question of gravest importance to themselves was how to dig the most earth in the least time and at a maximum expenditure of money. Thus, each contractor was obliged to exercise his ingenuity to devise a method by which he could excavate earth and rock to an advantage. The amount of earth work was quite large, somewhat above 40,000,000 cu. yds. The material encountered was quite varied and quite equally distributed. From sand to ordinary black loam, from soft black loam to glacial drift, a hard impenetrable kind of clay in which bolders of great size and weight were frequently found securely imbedded, from this to solid rock. The great variety of material encountered of itself gave rise to many different methods of excavation.

It is my purpose to describe very briefly, without going into the exact mechanical details, some of the most striking and unique methods and contrivances used.

*The sources of information were a series of articles which appeared in the *Engineering News* from time to time, during the period of construction of the channel, and articles which appeared in *Engineering*. The methods of operation were described in detail, section by section in the *Engineering News*. From this rather extensive amount of literature on the subject, the most unique and striking methods of excavation were selected, and these descriptions were considerably condensed.—AUTHOR.

In some of these sections where earth or rather hard clay was the predominating soil, a devise known as the "Bates Earth Conveyer" was resorted to. It bears the name of its designer, Mr. Bates. This consisted essentially of three belts, each 22 inches wide, carried on a series of rollers and driven by engines carried on a car running on a track parallel to and about 40 ft. from the canal bank. The canal in this section is 202 ft. wide at the bottom, with side slopes of 2 to 1. Beginning at the side of the canal opposite the driving machinery, the first belt ran down the side slope and discharged on a second conveying belt, which ran across the bottom and up the opposite slope to the driving machinery. From the driving machinery the third belt ran over the spoil bank (e. g., the bank of earth which should form the lateral limit of the channel), where the load was discharged. The movement of the first two belts was toward the engine, while that of the third was from the engine. The system of belts and rollers extended transversely across the whole width of the canal, and was carried on a framework of steel, which could be moved longitudinally along the canal on a system of tracks. The steel truss extended over the whole spoil bank and rested on cars at either side of it, which were set upon tracks, thus allowing the whole structure to be pulled along as the work progressed. The conveyer was moved only a few feet at a time. The movement was accomplished by means of pinch-bars. In actual practice the belts were driven at a speed of 8 ft. per second, and the earth was deposited on it by hand or machinery and carried along over the spoil bank, where it was scraped off by a three-eighths inch steel plate clamped diagonally across the belt. After trying hand labor for a time to throw the earth on the conveyer, it was decided by the contractor to use steam shovels. As it was out of the question to empty the contents directly upon the belt, it became necessary to construct a so-called "reservoir" over the belt, which received the material from the shovel and delivered it in a continuous stream on the belt. In construction this was similar to a granulator used in freight yards. It was mounted on cars running on a track laid across the bottom of the completed part of the channel, at right angle to its axis. The granulator straddled the lower section of the belt and moved along as the shovel advanced. This system was able to handle 125 cu. yds. per hour, and deliver it to the spoil bank.

In another section where the material was also a very hard compact clay weighing 3,150 lbs. per cu. yd., and pieces of material broken out weighed very often several tons, another system was used: "The Bridge Conveyer System," as it was called. The canal here was 110 ft. wide at the bottom, with side slopes of 2 to 1. The cut to be taken averaged 38 ft. In this particular section the excavation amounted to 2,300,000 cu. yds., so four distinct and independent outfits were used. Each consisted of a truss bridge across the spoil bank, an approach incline and a set of dump-cars and steam shovel tracks across the bottom of the channel, with proper hoisting machinery to operate the cables attached to the cars. The excavation was made in two cuts and began at the center of the contract section and proceeded in opposite directions, two conveyers worked east and two west. Each conveyer con-consisted of a 210 ft. steel truss span, supported by a tower at one end and by an inclined approach at the other, both tower and approach were carried on cars running on tracks parallel to the canal. Across the bridge floor a track was laid which continued down the incline approach and across the bottom of the channel. On these tracks the dump-cars ran. The method of operation was this: The cars were filled by steam shovels and hauled by cables up the incline on to the bridge, where they were dumped, the earth falling through the floor on the spoil bank below. Two cars were used, one was dumped while the other was loading. Each plant was moved 15½ ft. for each new cut. Steel cables were attached to the tracks and bridge and the whole system was moved along by means of two capstans. The operation to move and re-adjust the track taking about an hour. The output of each plant was 65 cu. yds. per hour, a little less than one-half of

that of the first method mentioned. Each car held 9 cu. yds. The advantages of this system were the small number of men required to operate the plant, and the canal was finished as the work progressed. About 700 ft. of length was completed per month.

A method used very extensively in coal regions was used by some contractors. Here the cars ran up an inclined plane, were hauled to the top and dumped by a winding engine. The engine and incline proper were, as in the other methods, carried on a car. The conveyer consisted of a wooden trestle approach and a steel frame work incline. The one characteristic feature of this arrangement was the method of dumping. This consisted of a portion of track at the top of the incline so hung as to revolve over toward the spoil bank on a horizontal axis. The cars were pulled up the incline track on a pivoted platform until the front wheels struck a buffer, which prevented the car from going further. Since the car could go no further, the pull on the rope to the car had a tendency to revolve the platform on the axis. As the loaded cars very nearly balanced the counterweights to the platform, a slight pull on the rope revolved the cars and platform in an inclined position, so as to slide the load out. At this stage the pull on the rope ceases and the counterweights act to pull the platform into its first position. By means of gravity the cars ran down the incline. During the whole operation of hauling and dumping, the engineer does not see the cars. All movements were regulated by automatic signals. The device hauled 75 to 80 cu. yds. per hour. The advantages were simplicity, low first cost, and ease of handling. It could be moved to take a new cut in thirty-five minutes.

The most costly and elaborate device designed for work on this channel was termed a "Double Cantilever Conveyer." It consisted of a bridge 320 ft. long, spanning the channel, with a cantilever arm at each end, extending over the spoil banks. One arm measured 172 ft., the other 148 ft., the length having been governed by the specified dimensions of the spoil banks. The total length of the structure from tip to tip was 640 ft. The whole structure was supported on cars placed at the ends of the main span, which ran on tracks parallel to the channel. At the extremities of the cantilevers were large drums over which a steel belt, made up of a series of steel pans linked together, mounted on trunnions and travelling on a track between the trusses, was made to pass. The belt was endless. It was propelled by machinery placed on the cars running on either side of the channel. The belt saged to the bottom of the channel, and the material was loaded upon it by means of steam plows. These plows were hauled transversely across the channel, shaving down the bank against which the belt lay. When the belt reached the extremity of the cantilever and passed over the drums, the material fell out. This machine was capable of handling 94 cu. yds. per hour. Its first cost, about $30,000, made it a necessity for it to handle such a large quantity. It had great promises, but, unfortunately, after working but a short time, it was almost totally destroyed by storms. After rebuilding several times, it was finally so modified that it soon lost its distinguishing features.

Where water was encountered or in those sections which cut into the Desplaines river, methods like the former were out of the question. The earth conveyer with its pecularities and methods of operation gave way to an entirely different class of machines—the dredge. One dredge of particular interest was the Bates Hydraulic Dredge. The barge was a flat-bottomed vessel 105 ft. long, 33 ft. wide and 6½ ft. in depth. Steam was furnished by a battery of four horizontal boilers. The one distinguishing feature of the dredge was the cutter. This was a long hollow cylinder 5 ft. in diameter and 4 ft. long, armed with steel knives. These were so inclined as to throw the material inward toward the opening of the suction pipe as the cutter advanced. This suction pipe was 20 inches in diameter. Both it and the shaft which operated the cutter, were carried by a kind of ladder, 39 ft. long. At the top a vertical telescope joint connected the steel suction pipe to the cast-iron pipe on the barge. The cutter was op-

erated by a pair of horizontal engines mounted at the front end of the barge. Its function was to loosen the earth in its path. The work of lifting and transporting the material was done by water set in motion by a 6-foot centrifugal pump driven by a 250-horse-power engine coupled directly to the pump shaft. The discharge pipe from the pump was cast-iron, 18 inches in diameter as far as the stern of the barge, here it connected to an 18-inch riveted steel pipe, made in lengths of 33 feet each. These were floated on the surface of the water and extended to the shore to the place of delivery of the material.

The plan of work was as follows: A strong spud at the rear of the barge was forced into the bottom of the river, and on it as a pivot the barge swung, the cutter traversing the arc of a circle 150 feet in diameter. As the cutter rotates, the materal was undercut one way and overcut back. The swinging was done by two cables, one anchored to each bank, and both connected to a double reversing hoisting engine, which payed out one cable as the other was wound in. The same engine also hoisted and lowered the cutter, making it possible to make both motions simultaneously. The vertical spud was also raised and lowered by hydraulic power. The discharge from the dredge contained from 5% to 30% of solid matter, depending on the character of the material. It was capable of excavating about 446 cubic yards per hour, and under very favorable circumstances has taken out 585 cubic yards per hour.

Other methods for this kind of work were used, but this was practically the only successful one. Instead of a revolving cutter to loosen the material, a series of water jets were used. These jets were directed by hand by means of long poles to which the nozzles were fastened, and were furnished with water by a pumping engine. A centrifugal pump and suction pipe were used to take up the loosened material. However, while the jets unloosened the material, they also scattered it so much that it could not be gathered in sufficient paying quantities.

Quite a large part of the channel made its way through solid rock. This necessitated the use of another class of excavators and conveyors, whose methods of operation were quite different from those for earth or soft mud. Holes were drilled in the rock at frequent intervals and the rock was then blasted. To handle these some contractors used a "Double Boom Travelling Derrick," or high power derrick.

Such a derrick was erected on a platform, which in turn was carried on rollers, that traveled on temporary timbers laid on the bank of the channel. On this platform was a turntable which carried the main floor of the derrick to which the superstructure and machinery was attached. The rack of the turntable was 28 feet in diameter, and by its means vertical pinions revolved the derrick on its axis. The superstructure consisted of a center tower built like a pyramid. This was of timber framework 113 feet high. From the base of the tower two trussed steel beams 164 feet and 155 feet long extended. Two fall blocks were hung from each beam, the lines going to the hoisting engine on the platform. The object was to lift both skips on one beam and lower both at the end of the other beam simultaneously, while the derrick revolved. While one beam overhung the channel, the other overhung the spoil bank, so while two of the skips were being filled in the channel, the other two were being dumped.

Not many of the above derricks were in use, however, the Brown cantilever crane being by far the most desirable conveyor. This consisted of two cantilevers supported on a tower arranged to travel on a track on the bank. The cantilever trusses had an inclination of 12½° to the horizontal, so that one arm projected downward over the channel, while the other projected upward over the spoil bank. From end to end the trusses measured 355 feet, the height being sufficient to allow an 80 ft. spoil bank. Along the line of the lower chords of the trusses was a track on which a carriage traveled. This carried and dumped the skip. The carriage was operated by a cable from an engine placed on the tower car. The skip was of steel plate and had a capacity of 1¾

cubic yards of rock in place. The contrivance was able to handle 490 cubic yards of rock in place per day.

But one of the most extensively used mechanisms for hauling solid rock was the Lidgerwood travelling cableway. Nineteen of these were in use on the channel. The usual method of traveling and unloading by hand was not economical, so an aerial dump was devised. The largest of these cableways was 700 feet span, and extended over the channel and spoil banks. At each extremity was a tower 73 to 93 feet high. They were simple framed structures of wood, so counterweighted and built as to withstand the pull of the cables. The towers were mounted on cars running on tracks parallel to the channel. The tower beneath which the hoisting engine furishing power to operate the plant was located was termed the head tower. The one at the other end was termed the tail tower. To operate the carriage and skip it required the use of five cables—a main cable to carry the carriage, a traversing or endless cable for hauling the carriage, a hoisting cable for raising and lowering the load, a button cable for distributing and supporting the fall rope carriers. The main cable for carrying the carriage was made of crucible steel 2¼ inches in diameter, with a hemp center. Its breaking load was 115 tons. As stretched between the two towers, it had a sag of 5 feet per 100 feet. The fifth cable was the dumping rope; its function was to dump the skip in mid air. It was attached to a hoisting block, which in turn was fastened to the rear end of skip by a chain and hook and extended to the dump shears at the top of the tower, thence to the engine drum. The dumping rope and the hoisting rope were wound on the same drum, so their motions were exactly similar. When it was desired to dump the skip, the dumping rope was temporarily wound at a higher speed than the hoisting rope, thus raising the rear end of the skip high enough to permit the load to slide out of the front end. The higher speed was obtained by throwing the dumping rope on a drum of slightly larger diameter. The hoisting machinery gave the skip a hoisting speed of 250 feet per minute and the carriage a traveling speed of 1,000 feet per minute. Large rocks weighing six or eight tons were handled without any difficulty. The skip was made of boiler plate steel and measured 7x7x2 ft. Its weight when empty was 2,300 pounds. Its capacity about 1.9 cubic yards of rock in place. It handled 50 cubic yards per hour.

Madison's latest feat consists of making hydrogen from platinum and sodium hydroxide.

The Juniors have taken up the annual discussion of "Spific Gravity" and kindred subjects.

Mr. McCormick: "How long will it take to string eight beads on a string two at a time in the shortest possible time?"

No one volunteered an answer.

Dr. Mees soliloquizes: "And to think that these Freshmen who used to scare up so beautifully about examinations are already learning to appreciate a bluff!"

Fate and the powers that be dealt mercifully with us last term. Only six failures were reported. These were well distributed, the Junior Class being the only one that has no vacant chair.

Loofbourow will speak early in February before the Scietific Society on "The laws of contracts." The interest of this subject to engineers should attract a good audience from among the students.

Professor Wickersham was much surprised recently, while the Juniors were reading the opening scene of William Tell, to hear a sudden burst of applause from that enterprising class. It was readily explained, however, that the applause was a tribute to the first appearance of the hero.

At a meeting of the Athletic Association, held on December 16th, J. R. Riggs was chosen manager of the base ball team for 1900. Communications have been received from Bradley Polytechnic and DePauw in regard to arranging games. Huthsteiner was chosen captain and manager of the basket ball team, which, however, has not yet materialized. The accounts for the term were gone over, and it was found that after paying all bills outstanding, there would still be left a small cash surplus in the treasury.

At the meeting, as also at one held on December 21st, the question of regular gymnasium classes for the winter term was quite fully discussed. It was suggested that regular classes be organized, with instructors taken from the student body, and that the classes should meet two or three time each week for one hour. The Board was divided upon the question as to whether the work should be made compulsory, but the suggestion was finally dropped as being impracticable.

In this connection, it may not be out of place to call the attention of the student body to that much-violated rule requiring every one using the gymnasium to wear rubber-soled shoes. Although it may seem "hardly worth while" to change one's shoes for a few minutes' exercise, yet if the floor continues to receive the treatment it has so far, it will soon be ruined. Every student has to provide himself with instruments for use in all other departments of the school work; why does not the same rule hold in this case? Let us all be a little more careful in setting a good example for our neighbors, and then no one can plead as an excuse that "the other fellows all do."

From the Engineering Press.

It is natural that with the continuance of the war in the Transvaal a good many of the land telegraph lines should be interrupted. The Boers can do little in communicating with the outside world, and the British can do little to exchange intelligence with the beseiged places that were cut off in the first rush of Boer invasion. At such a time, the use of wireless methods will be attended with great importance and reports of their working will be awaited with great interest. Meanwhile it is curious to note that the British have resorted to the employment of carrier pigeons, and that the pigeon post between Ladysmith and Durban has worked successfully. There are said to be no fewer than 1,000 homing pigeons on the books of the British navy. Between them and the etheric telegraph will now wage a struggle akin to that which ensued lately between the trolley and the mule.—*Electric World and Engineer.*

Mr. W. H. Russell makes the following reply to a question before the Pacific Railway Club as to the effect of scale on the efficiency of locomotive boilers:

It is conceded that keeping a boiler clean and free from scale is conducive to economy. One authority claims that every $\frac{1}{16}$ in. of scale requires an expenditure of 15 per cent. more fuel. Thus ¼ in. scale would require an expenditure of 60 per cent. more fuel. An old boiler was removed a few months ago from one of our shops, where it had been doing duty for a number of years When the front flue sheet was removed it was found that the shell of the boiler had scale more than 3 in. thick, while the flues were encased in an almost solid mass. According to the authoriey mentioned above, this boiler would require an expenditure of 720 per cent. more fuel than a clean boiler, and yet it furnished the power for one of our largest division shops, and one man fired it. About ten years ago, when we were watching the consumption of fuel very closely, on a branch run where the water is bad and scale forms rapidly, where the life of a flue is from ten to twelve months, three enginemen were striving for supremacy in fuel economy. Not a pound of coal was wasted, if zealous care could prevent it. After a few months one of the engines began to show signs of weakening tubes The leaks were slight on account of the close watch kept by the boiler maker, who worked on them two nights out of three. This was kept up until it became necessary to remove the tubes and replace them with new ones. When the engine was again placed on the run, I looked for an improved record, but to my surprise no improvement was shown on the performance sheet, although the time and weight of the train was the same as before. Since then I have several times noticed practically the same result at other points, and I believe it will take a very close observer to note the difference in fuel consumption between the flue covered with scale and the clean flue, provided there are no leaks in the former. An evaporative test would show in favor of the clean flue, but I am convinced that the loss due to scale is very much overestimated.—*Railway Gazette.*

Cleaning bridges by sand blast has been tried on five structures on the Boston & Maine Railroad. The work is entirely satisfactory, being more thorough than hand cleaning, and will be continued next year. Mr. J. P. Snow, M. Am. Soc. C. E., bridge engineer of the railroad company, sends the following notes concerning the methods adopted: "We use a Fairbanks-Morse gasoline air compressor and a Tilghman's patent sand-blast machine with a pressure of about 15 pounds per inch. Occasionally, under certain conditions of weather and position of air pipes, there is trouble with water from condensation in the pipes. We get over this easily by means of a blow-off cock placed as conditions require. It is necessary to have the sand perfectly dry, and if a small amount of water gets into the machines, operations must be stopped and the wet sand cleaned out. There is not much trouble from this source if the men are experienced and careful. It is necessary to paint the iron very soon after it is cleaned. So far we have used it wholly on bridges over the tracks, the under sides of which are in very bad condition from the locomotive gases and very difficult to clean by hand on account of location."—*Engineerlng Record.*