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The Wisconsin Engineer

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GRAPHICAL DETERMINATION OF BEAM DEFLECTIONS

JESSE B. KOMMERS, e '06

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In this article numerical problems have been worked out for the common cases of beam loading, showing the detailed application of graphic methods which are simple and practical. The general theory of these methods may be found in books on graphic statics, and the theory upon which some particular methods are based may be found in Morley's "Strength of Materials."

It can be proved that when the area of the load diagram of a beam is treated as the load on the beam and a funicular polygon is drawn, the ordinates of this polygon will be proportional to the bending moments; and if this moment polygon is treated as a load on the beam and a second funicular polygon drawn, the ordinates of this funicular polygon are proportional to the deflections of the beam.

In Figure 1 is shown a simple beam carrying uniform and concentrated loads. The uniform load is broken up into equal strips and the weight is assumed to act at the middle of each strip. The concentrated loads act at their points of application. When the first funicular polygon has been obtained as shown in the figure, the area of this polygon is broken up into equal strips and the mid-ordinate of each strip is used to represent the area in the second force polygon. The second funicular polygon is then drawn as shown. Only half of it is completed because of symmetry. The scales indicated are those used in the original drawings.

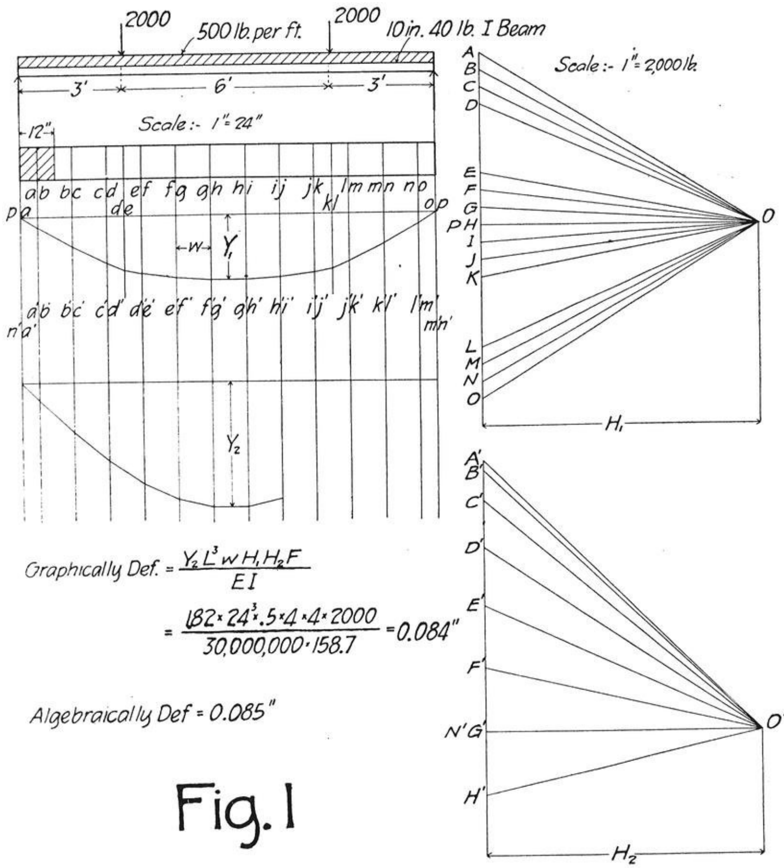


Fig. 1

The following notation will be used to determine the deflection of the beam:

E = modulus of elasticity.

I = moment of inertia of cross section.

L = linear scale in the two funicular polygons.

F = force scale in the first force polygon.

H_1 = pole distance in the first force polygon in inches.

W = width of a strip in the moment diagram in inches.

H_2 = pole distance in the second force polygon in inches.

Y_1 = ordinates in the first funicular polygon in inches.

Y_2 = ordinates in the second funicular polygon in inches.

The moment at any place in the beam will then be:

$M = Y_1 \, 1 \, H_1 \, F$

The deflection at any place in the beam will be:

$$\text{Def.} = \frac{Y_1 L^3 H_1 F H_2 W}{EI}$$

It should be noted that if $\frac{Y_1}{2}$, or $\frac{Y_1}{3}$ are used to represent the moment area in the second force polygon, then the result must be multiplied by 2 or 3 respectively. Conversely, if 2 Y_1 or 3 Y_1 be used then the result must be divided by 2 or 3 respectively. It should also be noted that the true deflection curve

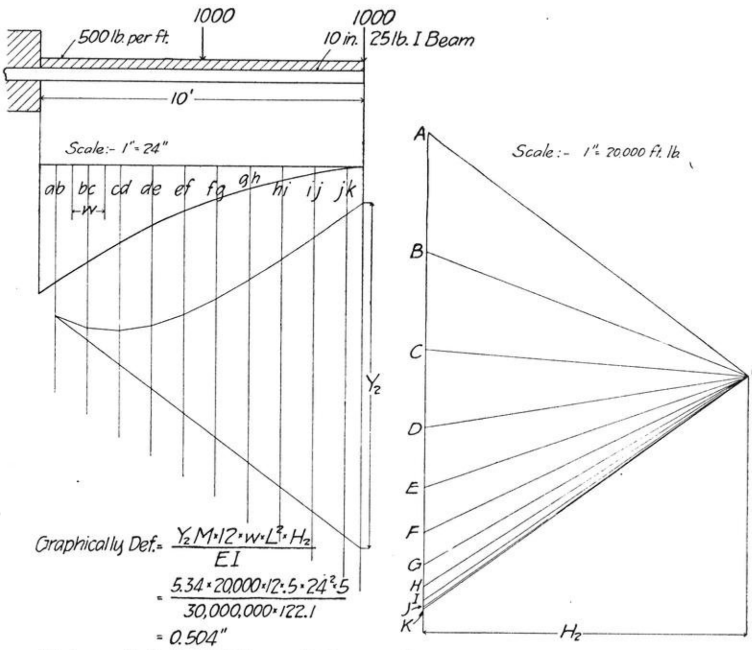


Fig. 2

will be an inscribed curve tangent to the sides of the funicular polygon.

It may be mentioned here that one of the great advantages of the graphical method lies in the fact that the problem is no more difficult for complicated loading than for simple loading. In the numerical case, which is here considered, a comparatively simple loading was chosen so that the deflection could be checked algebraically, but the problem would have been no more difficult even if the load diagram had been as irregular as one could possibly make it.

When we deal with a cantilever beam we will again need the bending moment diagram. If the loading is made up of uniform loads and concentrated loads, the bending moment diagram is most easily drawn by first calculating algebraically the values of the bending moment, say, for every foot of length. In Figure 2 is shown a numerical case in which the maximum deflection is found by determining graphically the moment with respect to the free end of the bending moment area. As shown in the figure, the bending moment area is again broken up into strips and a force and funicular polygon are drawn. If M is the scale, in foot pounds, used in plotting the bending moment diagram, then the deflection, using the same notation as in the previous case, is:

$$\text{Def.} = \frac{12MY_2wL^2H_2}{EI}$$

Here Y_2 must always be the intercept of the first and last strings in the funicular polygon, on a line drawn parallel to the forces thru the point in the beam where the deflection is wanted. If the deflection is wanted at some place x distant from the wall, then only the bending moment area between the wall and the point x is used.

If the loading on the cantilever is very irregular so that the algebraic calculation of bending moment would be tedious or perhaps impossible, the graphical method may be employed. The free end of the beam may be taken at the left end, and the load diagram is broken into strips of equal width, as was done in Figure 1. Each force is assumed to act at the middle of each strip, and a funicular and force polygon are drawn. The moment at any distance from the free end will be proportional to the intercept on a line through this point parallel to the forces, of the first and last strings for all the forces to the left of the point in question, or in other words, to the intercept of the funicular polygon. As in Figure 1

$$M = Y_1LH_1F$$

Figure 3 shows a numerical case illustrating a beam overhanging its ends. A simple loading was chosen so that the results could be checked algebraically. If we consider only the bending moment diagram between supports and treat this as a load on a beam, a funicular polygon may be drawn which will have ordinates which are proportional to the deflections. Figure 3 makes the method plain.

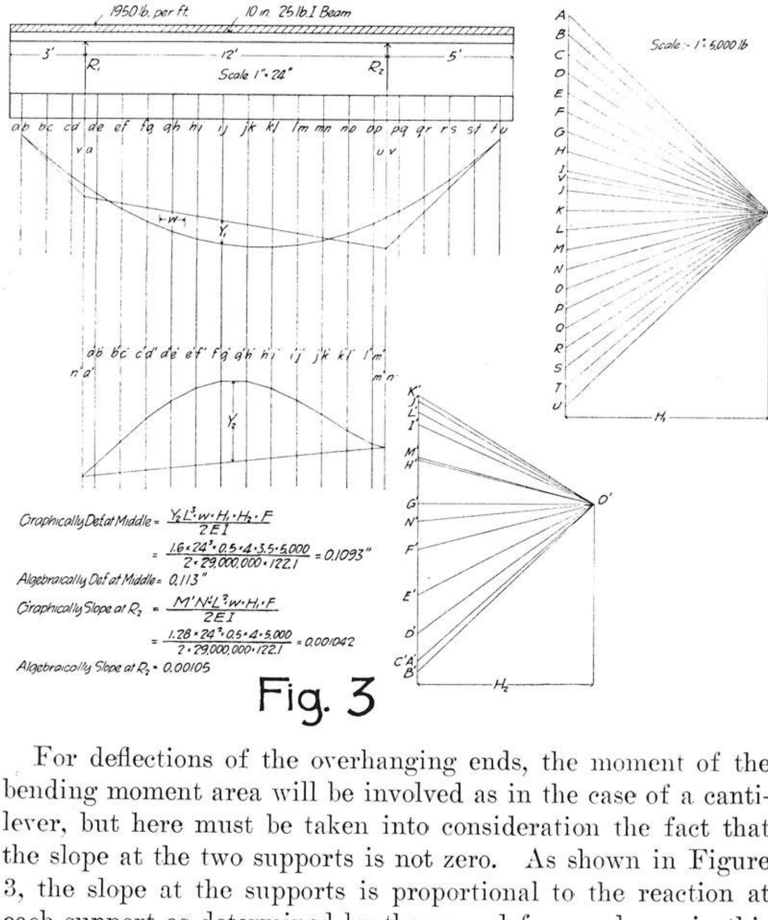


Fig. 3

For deflections of the overhanging ends, the moment of the bending moment area will be involved as in the case of a cantilever, but here must be taken into consideration the fact that the slope at the two supports is not zero. As shown in Figure 3, the slope at the supports is proportional to the reaction at each support as determined by the second force polygon in this figure.

$$\text{Slope at right support} = \frac{M'N'L^2 wH_1 F}{EI}$$

Here the notation is the same as before and M′ N′ is the reaction at the right support in inches, scaled from the second force polygon. In the figure the 2 appearing in the denominator of the equation is due to the fact that in drawing the second force polygon the Y_1 lengths in the first funicular polygon were doubled.

It can be seen that if the slope at the right support is positive the effect on the beam will be to reduce the deflection due to the overhanging end, while negative slope would increase

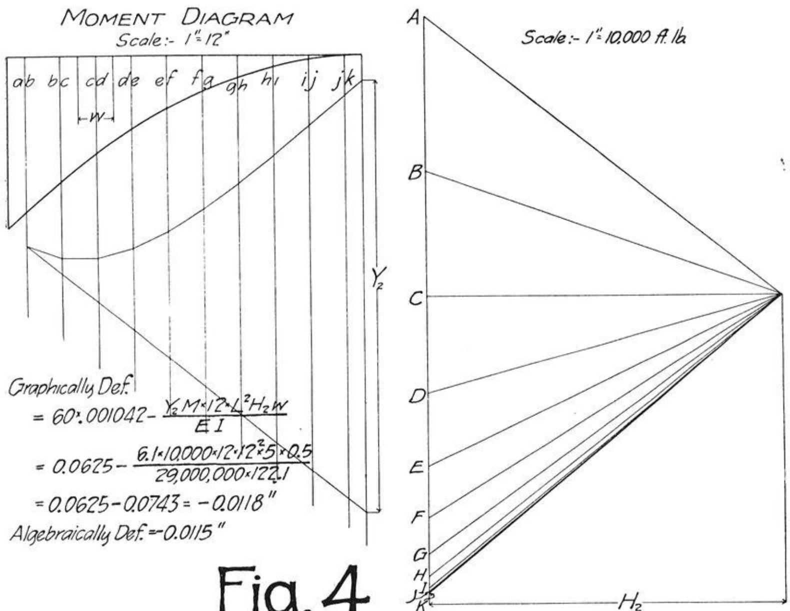


Fig. 4

the deflection. We know that in a simple beam treating positive bending moment area as a downward load on the beam we would get upward or positive reactions and the slope at the right support would be positive. So if on this basis the reaction at the right support is positive we know the slope is positive. Conversely, if positive moment is treated as an upward force, then the reaction at the right support would be negative, and then negative reaction would mean positive slope.

For the part of the beam overhanging at the left end we can see that here positive slope would increase the deflection and negative slope would decrease the deflection of the overhanging end.

It can be seen in Figure 3 that the first funicular polygon would not give very accurate values of moment. It is better, therefore, to proceed as in the case of the cantilever beam, cal-

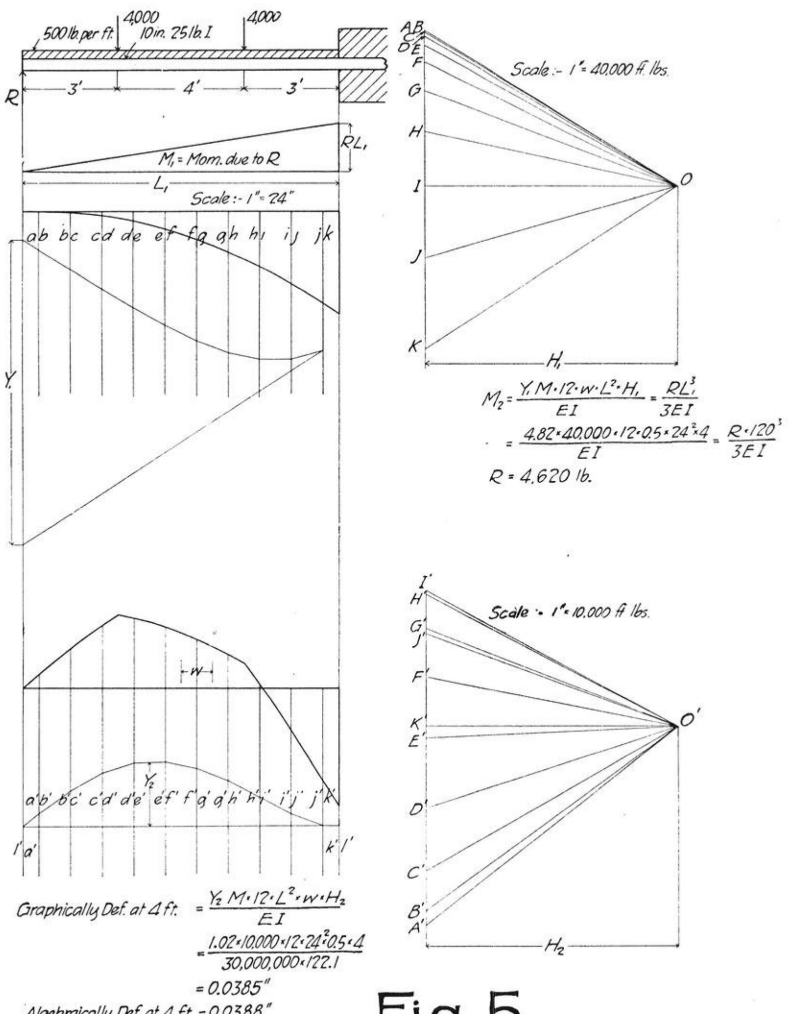


Fig. 5

culate the moments in the overhanging part algebraically, and thus determine the moment diagram. The moment of this area with respect to the free end is then found graphically, as shown in Figure 4. This quantity must have added to it or subtracted from it the product of the slope at the right support times the distance from the right support to the free end of the beam. Since the slope at the right support is positive the effect is to decrease the deflection. Thus the product is subtracted as shown in Figure 4.

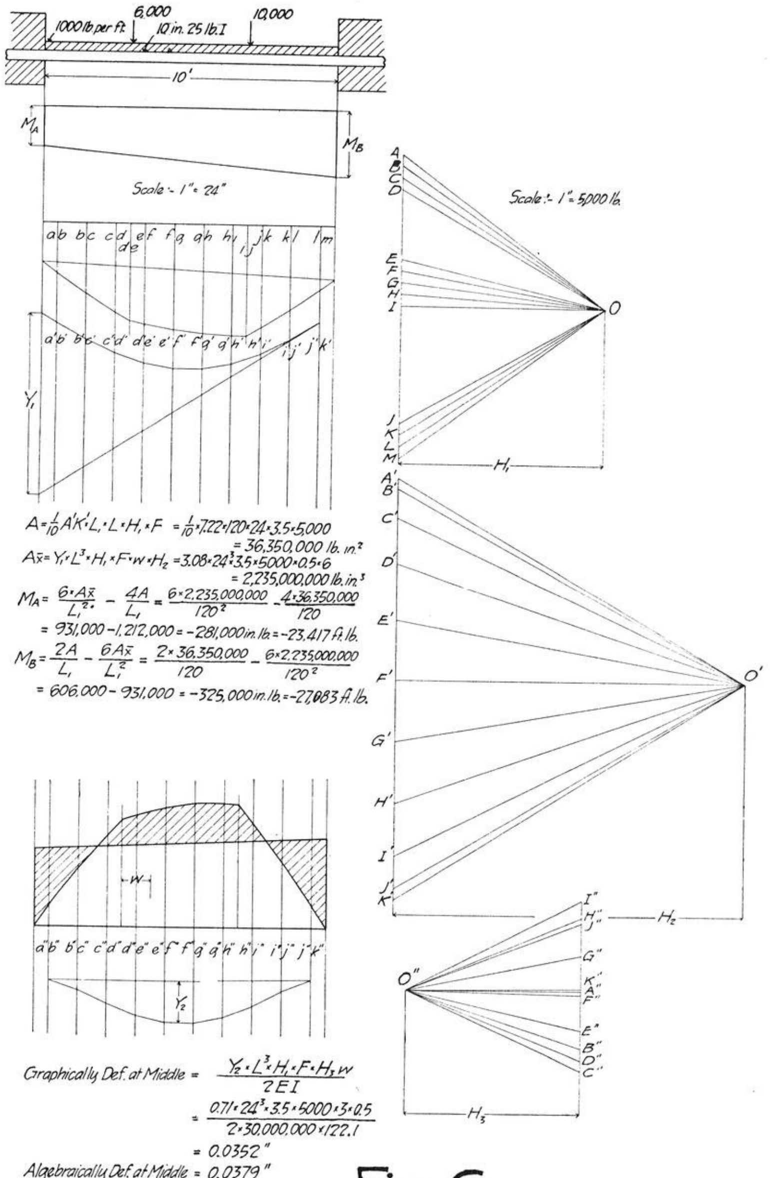
If the deflection is wanted at any point x distant from the right support, the product of the slope times the distance x is added or subtracted from the moment of the bending moment diagram from the right support to the point x, with respect to the section at x.

Figure 5 shows the case of a beam fixed at one end and supported at the other. To determine deflections graphically probably the best way to proceed is to determine R, the reaction at the supported end, and then calculate algebraically the moments, say, for every foot of length. The moment diagram can then be plotted and from this a deflection curve may be obtained, as was done in the case of the overhanging beam between supports.

Since in the case before us the supported end of the beam does not deflect, the deflection caused by R must be exactly equal to the deflection caused by the loads on the beam. Or since the deflection of a simple cantilever beam at the free end is proportional to the moment of the bending moment area with respect to the free end, it follows that the moment of the bending moment area due to the loads, which we will call M_2, is equal to the moment of the bending moment area due to R, which we will call M_1. It can be seen from the figure that

$$M_1 = \frac{R L^2}{2} \times \frac{2 L_1}{3} = \frac{RL^3{}_1}{3}$$

For the general case M_2 can be found most easily by graphic methods. The moment diagram is plotted, using only the loads on the beam, and from this M_2 is found graphically in the usual way. Then since $\frac{R L^3}{3} = M_2$, the numerical value of R



$$A = \frac{1}{10} A'K' \cdot L_1 \cdot L \times H_1 \times F = \frac{1}{10} \times 7.22 \times 120 \times 24 \times 3.5 \times 5{,}000 = 36{,}350{,}000 \text{ lb. in.}^2$$

$$A\bar{x} = Y_1 \times L^3 \times H_1 \times F \times w \times H_2 = 3.08 \times 24^3 \times 3.5 \times 5000 \times 0.5 \times 6 = 2{,}235{,}000{,}000 \text{ lb. in.}^3$$

$$M_A = \frac{6 \times A\bar{x}}{L_1^2} - \frac{4A}{L_1} = \frac{6 \times 2{,}235{,}000{,}000}{120^2} - \frac{4 \times 36{,}350{,}000}{120}$$

$$= 931{,}000 - 1{,}212{,}000 = -281{,}000 \text{ in. lb.} = -23{,}417 \text{ ft. lb.}$$

$$M_B = \frac{2A}{L_1} - \frac{6A\bar{x}}{L_1^2} = \frac{2 \times 36{,}350{,}000}{120} - \frac{6 \times 2{,}235{,}000{,}000}{120^2}$$

$$= 606{,}000 - 931{,}000 = -325{,}000 \text{ in. lb.} = -27{,}083 \text{ ft. lb.}$$

$$\text{Graphically Def. at Middle} = \frac{Y_2 \times L^3 \times H_1 \times F \times H_3 \, w}{2EI} = \frac{0.71 \times 24^3 \times 3.5 \times 5000 \times 3 \times 0.5}{2 \times 30{,}000{,}000 \times 122.1} = 0.0352''$$

$$\text{Algebraically Def. at Middle} = 0.0379''$$

Fig. 6

is known. Having found R the correct moment diagram may be calculated and plotted. This is done in the lower part of Fig. 5 and the deflection curve is then obtained in the usual way. The correct moment diagram may also be obtained by plotting the moment diagram due to R_1 and the moment diagram due to the loads on the beam, on the same side of a common base line, and then taking the difference between the ordinates.

In a built-in beam,* the effect of the fixed ends is to produce moments M_a and M_b as is shown in Fig. 6. These moments are in general negative and tend to make the beam convex upward thruout its length. It can also be shown that the value of these moments is as follows:

$$M_a = \frac{6\,A\,x}{L^2} - \frac{4\,A}{L_1} \text{ or } 2\,\frac{A}{L_1}\left(\frac{3\,x}{L_1} - 2\right)$$

$$M_b = \frac{2A}{L_1} - \frac{6\,A\,x}{{L_1}^2} \text{ or } \frac{2A}{L_1}\left(\frac{3x}{L_1} - 2\right)$$

Where A = moment area due only to loads on beam,
x = distance from left support to centroid of the area.
L_1 = length of beam between walls.

In a numerical case the moment for every foot due to the loads may be easily calculated, and then the moment diagram drawn. The moment of the area, A x, may then be found graphically or, taking the load diagram, a funicular polygon may be drawn, the ordinates of which will be proportional to the moments at different points in the beam. This funicular polygon treated as the moment area A may be used to determine A x graphically. This second method is used in Fig. 6. The area A is easily found from the average ordinate by taking the mid-ordinate of each strip in the moment diagram and dividing the sum of the ordinates by the number of strips.

When M_a and M_b have been determined as shown in Fig. 6, the true moment diagram for the beam is easily calculated and plotted. Or, as was done in the figure, the moment area due to the loads only is plotted from a base line and then M_a and M_b are plotted to the same scale from the same base line. Since the first moment area is plus and the second minus, the

*Morley's Strength of Materials.

difference in the ordinates gives the correct moment diagram, shown shaded in the figure. A funicular and force polygon drawn for this area will give the deflection curve in the usual way. If the work in Fig. 6 had been absolutely correct the points A″ and K″ in the last force polygon would have coincided; and then of course the corresponding strings would have been colinear. In this problem more nearly correct answers would have been obtained if the linear scale had been twice as large as the one used.

THE SELECTION OF A PAVEMENT

Louis C. Rockett, c '15

"There are three things which make a country great and prosperous —a fertile soil, busy workshops, and easy conveyances for men and things from one place to another."

Roads indicate the degree of progress made in the development of a country. At first roads were constructed for military purposes to facilitate the movement of troops and the munitions of war. In Europe this is brought out in a remarkable manner by the present bloody conflict. For a secondary reason roads are laid out to further commerce. This has been enhanced by the tremendous strides made in the great industrial world in the last four or five decades. The demand for the distribution of produce to the channels of consumption must be supplied by adequate thoroughfares, reaching, like arteries, into the most remote districts, ministering to the wants of cities, towns, and hamlets. A third reason for good roads is becoming more and more prominent with the development of the automobile, which requires comfortable and pleasant routes. Country highways in particular must now be constructed in large measure in a manner suitable to this class of traffic. Thus it is seen that the reasons for the existence of a road may be three-fold: it must annihilate distance for the captains of war, industry, and pleasure.

In conformance with these reasons for highways a certain type will be chosen. The ideal pavement will possess the following qualities:—it must be durable to resist the punishment of traffic; it must be noiseless so as not to disturb thinking people; it must be suitable to the class of traffic so as to furnish the best wear and satisfaction; it must be clean to protect the public health; it must be non-slippery so as to prevent accidents; it must have low tractive resistence so as not to prohibit traffic; it should be aesthetic so as to be pleasing; and finally, it must be economical. Such are the requisites for the ideal pavement. No single actual pavement has yet been designed and constructed but that it has failed in at least one of these attributes. Hence in the selection of a pavement these peculiarities must be weighed and balanced so as to furnish the best pavement under the given conditions.

The prime requisite in a pavement is durability. How long can a certain roadway be maintained before reconstruction will be the more economical course to pursue? There are two ways in which to determine the life of a pavement: first, the number of years during which a certain class of road will last, based on the results of past experience with such roads, and secondly, the total number of tons per unit width of street surface that can be transported before reconstruction will be necessary.

The former method, advocated by George W. Tillson, allots a certain number of years as the average life of a pavement; for example, a sheet asphalt should last about eighteen years, a stone block twenty-five years and so on. The latter method supported by John A. Brodie considers that a pavement will be subject to a certain tonnage per yard of width of street surface; for example, he estimates that before replacement a small stone block pavement ought to be capable of sustaining during its life seven and a half million tons of traffic for each yard of its width. This second view conveys more information because it goes into the chief cause of the destruction, and takes into account the real factors which accomplish the ruin of pavements. It is the more scientific course.

A second requisite in a pavement is noiselessness. Nothing so much disturbs the mental activities of brain workers as the incessant rumbling, clanging, and clamorous din that rises from a noisy street. This is the deciding element in a pavement in special localities such as the vicinities of hospitals, schools and similar places where it is absolutely necessary that the strictest quietness prevail. In residential districts it is also desirable to have a street which will not magnify and reverberate each hoof-fall. People desire a little quiet and in many cases have gone to great expense to secure it.

The third quality essential in a highway is that it must be suited to the kind of traffic to which it is subjected. The road of yesterday is now inadequate. Traffic conditions are changing, motor-drawn vehicles are increasing at a tremendous rate, drawn loads are growing to greater proportions, and slow moving conveyances are being supplanted by high speed automobiles. Some streets will have heavy commercial traffic, others will have a heterogeneous traffic, and still others will have light and speedy traffic. The construction suitable to one condition may not be suitable to another. A water-bound macadam cannot economically replace a stone block pavement. The type to be chosen depends upon the character of traffic. "The traffic census should be considered one of the most important variable factors in the solution of that important problem, the selection of that type of road or pavement best suited to local conditions considered from both the standpoints of economy and efficiency. In connection with the census returns on any road, should be considered the traffic on cross and parallel highways and the effect of improvement of these highways on the traffic of the highways under consideration. It should not be taken for granted that the bald return of a traffic census should be the sole basis of the selection of the type of road or pavement; but it should be considered a guide in estimating the value of the type of construction adopted." *

A fourth characteristic which ought to be indigenous to a pavement is cleanliness. To be clean a street should possess an impervious and smooth surface and should be composed of non-dust-producing materials. Dirt and dust upon a road are unsanitary and, moreover, act in the destruction of the road by serving as an abrasive to wear away the surface.

A fifth requirement is non-slipperiness. This point is not confined simply to horses but it is also of special importance to the motor-driven traffic. A skidding automobile will and does occasion a great amount of damage to human life and property. Some types of construction become altogether unsafe when built steeper than a certain grade, so that quite frequently grade is a determining factor in the selection of a pavement. However, slipperiness may also result from a dirty street; but, of course, such a fault is more a matter of maintenance than a question of type.

A sixth quality is that the pavement should offer low resistance to traffic. This characteristic depends on the kind of

(1912 Report of the Special Committee on "Bituminous Materials for Road Construction" of the American Society of Civil Engineers.)

traffic and the grade of the street. In the case of horse drawn vehicles the low resistance will be given by a very smooth and glass-like pavement, while motor-drawn vehicles on the other hand require a slight roughness so as to prevent the driving wheels from slipping. Indeed, there is considerable difficulty in securing a pavement which will be ideal for all kinds of traffic under all sorts of conditions.

A seventh requirement is that a pavement ought to be aesthetic. It is a deplorable fact that the average American municipality neglects to beautify its highways. In Europe and even South America this feature receives considerable attention. Roads are bordered with trees and parkings and the entire arrangement is such as will give the most restful, harmonious and peaceful impressions. Here, on the other hand, these details quite frequently fail to receive any care whatever. Hence a little forethought on this score will be well spent.

An eighth factor in the selection of a pavement is its economy. The highway which, under the particular conditions peculiar to it, has the smallest annual cost ought to be the best pavement to construct. This does not mean that the roadway having the lowest first cost will have the lowest annual cost. Under some conditions it may be the most expensive. The pavement having the lowest annual cost may be impossible of selection because the financial condition of the community will not permit of a high first cost. The annual cost is a function of three variables: the interest on the first cost, the annual expenditure for maintenance, and the annuity or fund which is set aside each year and which will be sufficient at the end of the life of the pavement to replace it. The table on page 60 gives the comparative costs of several pavements under conditions obtaining at Cambridge, Massachusetts.

In comparing the annual costs of these several types, the conditions in each individual case must be considered. One pavement is not cheaper than another because its annual cost is less; it is cheapest under its peculiar conditions of durability, suitability, and other factors. Thus a water bound macadam substituted for a granite block pavement would have a much higher annual cost because its life would be shorter under the punishment of heavy traffic, its maintenance costs would be excessive, and the inconvenience and loss of time to the users of the street occasioned by tearing up and making repairs would pay two-fold the construction of the granite block in the first place.

The selection of a pavement, therefore, depends on several factors which are more or less interrelated. A type of construction selected merely for one excellent quality will very likely give poor satisfaction. The pavement to be desired is that one in which the various excellencies are dove-tailed one into another so as to give the best possible service.

*Estimated Life and Cost of Various Pavements.**

Kind of Pavement	Estimated Life in years	First cost per sq. yd.	Annual cost per sq. yd.
Macadam	10	1.00	.1790
Granite blocks grouted with P. cement..	20	3.25	.2003
Brick grouted with Portland cement....	15	3.00	.2435
Bithulitic on concrete base	10	2.65	.2840
Wood block grouted with P. cement	15	3.75	.2920
Tar Macadam	10	1.25	.2960

Bonds run for a term of 10 years. To make all calculations on the same basis.

Now that the qualities of the ideal pavement have been discussed, it would be well to see how the various pavements in general use approach this ideal. Among the many surfaced pavements may be mentioned the following: Stone block, wood block, water-bound macadam, concrete, brick, sheet asphalt, bituminous macadam and bituminous concrete.

A stone block pavement laid on a sand cushion and concrete foundation with a grout filler is about the most durable type. If properly constructed it is capable of sustaining the severest kind of punishment. Hence from this point of view it is especially adapted to streets whereon heavy trucking is predominant. Its chief defects are its noisy surface and high first cost. Much depends upon the selection of the stone. The granular structure of the stone should be rather coarse so that

*Considerations affecting the selection of types of Pavement adapted for use upon a given street. "Engineering & Contracting," Dec. 11, 1911.

the surface will wear to a sand paper finish. The use of a filler is also an important item. Unless the filler protects the edges of the block, these edges are likely to chip off, causing a rounded top or turtle-back wear on the blocks. When such a condition obtains, a very irregular surface is formed which affords places for the deposition of all kinds of dirt and filth.

The wood block pavement laid upon a sand or mortar cushion and a concrete foundation with a suitable grout filler constitutes a street surface as durable as the stone block. Extreme care must be exercised in the selection of the wood and the preservative treatment thereof. This type has the advantage of being the most noiseless. Its surface is very clean as long as the blocks do not bleed. However, this oozing of the preservative is prevented by the proper treatment of the block in the first place. The chief defects of the wood block pavement are slipperiness in wet weather and high first cost. It makes a good pavement in business districts, often supplanting the stone block because it is a quieter pavement.

A water-bound macadam makes a good pavement for light and medium horse-drawn traffic. It is fairly noiseless and as a general rule the cheapest pavement in first cost. However it has a very dusty surface, and under automobile traffic will readily ravel and go to pieces. It is especially adapted to country roads which carry only horse-drawn traffic. The deficiencies can be somewhat overcome by the application of a dust preventative.

Concrete pavement is suitable to all kinds of automobile and medium-heavy horse-drawn traffic. It has a smooth surface which is easy to clean, is not very noisy, and has a good appearance. Its chief defects are slipperiness, especially in wet weather, and the difficulties of good construction.

A brick pavement laid on a sand cushion and a concrete foundation with a suitable bituminous or grout filler is most suitable for medium-heavy traffic and is well adapted to automobiles. It presents a smooth surface, can be easily cleaned, presents only a low resistance to traffic and is dustless. On grades of five per cent or greater the grout filled pavement becomes too slippery but in this case a specially designed block may be used with a suitable bituminous filler. The cost of brick is rather high depending on the distance of the point of delivery from the centers of production.

A sheet asphalt pavement is excellent for all kinds of medium heavy traffic. It is comparatively noiseless, it has the cleanest and most sanitary surface and offers the least resistance to traffic. A great disadvantage is its slipperiness, especially when it is wet.. A poor asphalt pavement is almost always the result of poor selection of material or improper incorporation, or a combination of the two. By scientific manipulation and adequate inspection, sheet asphalt will make an exceptionally serviceable pavement. With proper aesthetic design of the street, it gives an artistic finish such as is secured by very few pavements.

A bituminous macadam highway is suited to light traffic and especially to motor-driven traffic. Its advantages over the water-bound macadam are several,—it is less noisy, it is dustless, it has an impervious surface and is cheaper to maintain. Its chief disadvantages are that it may be slippery, particularly upon grades, that it does not always adapt itself to the changes of the climate, and that the surface does not possess homogenity owing to the non-uniform penetration of the bitumen.

A bituminous concrete pavement is suitable for medium-heavy horse-drawn traffic and is best adapted to all kinds of automobiles. It possesses all the advantages of the asphalt in a lesser degree without the marked disadvantages. It is noiseless, clean, non-slippery and offers light resistance to traffic. Its first cost is greater than that of the bituminous macadam and less than that of asphalt. Its aesthetic qualities are almost equal to those of asphalt, and are particularly suitable for parks, boulevards, and pleasure driveways.

To determine which pavement to build requires a scientific investigation into the past, present and future traffic. It is evident that in wharving and heavy freight districts the stone block pavement must be chosen. In a business district where less noise is desirable, a wood block may be the choice. In most other types first cost, appearance and other factors will decide whether the pavement shall be asphalt, brick concrete or bituminous. Under all circumstances the traffic condition is the principal determinant and that type of pavement will be the best which will render the best satisfaction in service, durability and economy.

RACING, ITS ADVANTAGES, AND ITS INFLUENCE ON AUTOMOBILE DESIGN

Robert Bruce White, m '18

Automobile racing is not only the most costly but it is also the most sensational of all sports. As a spectacle and in its demands upon the sportsmanship of the contestants it surpasses even aviation. This is proved most conclusively by the rapidity with which the racing craze has swept over the country in recent years and by the enormous crowds which attend speedway contests. Unfortunately there has been much loss of life in connection with racing, and this has led to numerous agitations to prohibit the sport. Its opponents claim that it is not a sport, but rather a slaughter, a commercialized murder comparable in many respects to bull fighting. Nevertheless racing, in spite of its toll of human life, has been largely instrumental in bringing about the wonderful advancement in motor car design. The adversaries of automobile racing apparently fail to realize that the freedom of their own cars from annoying troubles and frequent breakdowns arises from the fact that the extremely severe conditions of racing have made possible the detection of weak parts and have thus led to improvements in design which are reflected even in the cars intended for less strenuous service.

Following the London-Brighton non-stop run in 1896 a race the entry list of which contained the best efforts of the pioneer designers, Leon Bolleé, Daimler, and Levassour, the necessity for increased power output and limitation of weight became very apparent. Further, since the purchasers of automobiles of that period were necessarily wealthy men and true lovers of the sport, it was natural that the racing machine was developed much more rapidly than was the pleasure car. In fact, there is little question that racing, and racing enthusiasm alone, developed the automobile industry up to 1903 or 1904. Throughout this period the principal object of the designer was to develop the power of the motor; and since practically all interest had been centralized in the advancement of the four-cycle engine, many different designs for greater power were introduced, and considerable effort was expended on the development of detail.

To one who has studied the early history of the automobile, it is apparent that in the period between 1903 and 1907 the aim of the designer was principally to develop the speed car, the touring car being substantially an adaptation of high speed design to the less strenuous conditions of touring. Inasmuch as practically all important investigations or modifications in design demanded tests beyond the ability of the touring car tester, the field of high speed testing in races was introduced as a side issue. Then, since the most rigorous experimental investigations of racing strength had met with success, the results of such experiments on racing machines were applied to the earlier designs of pleasure vehicles. During the last decade, although considerably more attention than before has been given to luxury, accessibility, ease of riding, and grace of exterior design, some of the greatest engineering minds, Harounn, Vincent, Porter, and Stutz, have continued to work on speed creations, developing them to the highest degree of the art. Since the manufacturer has not continued his former policy of concentrating effort on high speed production, racing has not received due credit for modern advances in designing, but the fact that racing has been very intimately related to these advances may be shown beyond question of doubt.

Racing, it cannot be denied, has promoted the sales of many makes of automobiles, and many companies now doing a thriving business would long since have declared bankruptcy had it not been for the wonderful advertising medium a victorious racing car became. The many victories of Stutz alone gave this car its start and sudden popularity. In one day it had proved, its stamina, its sturdiness, its speed, and its power—and had provided a free advertising medium for itself in every part of the country. The names of National and Mercer invariably reflect their victories at Santa Monica, at Indianapolis, at Savannah, or at Elgin. Simplex gained its initial fame from racing in the pioneer days, as did Alco, Fiat, Locomobile, Marmon, Peerless, and Lozier. In further retrospection of the early days of the industry, the names of Packard and Panhard are instantly brought to mind. The name of Panhard especially was known as one of the leading makes to everyone with the most remote knowledge of automobiles. The finest speed creation the world has ever known, the Peugeot, a masterpiece in design, was brought into public light by its wonderful consistency and enduring speed service in France and América. Indeed, Henry Ford's first step toward his present position, his very first financial backing, was a result of the victory of his car over the famous product of Alexander Winton.

The introduction of light weight reciprocating parts and high compression ratios, the investigation of proper exhaust discharge and manifold design, the proper selection of the bore-stroke ratio, in fact, the entire design of the modern automobile engine has been most potently influenced by the results obtained from racing practice. In racing, light weight reciprocating parts were the essential outcome of practice and experiment. Since long connecting rods became a necessity in order to minimize angularity and consequent power losses in cylinder side thrust, laboratory investigations were conducted with high grade alloy steels stressed to 60,000 pounds per square inch which proved entirely satisfactory in service. Although it had been recognized for years that the use of steel in cylinders and pistons would be ideal if they could be manufactured properly, steel had received but very little attention until comparatively recent times. Indeed the Mercédes engineers in their most exacting investigations in preparation for the French Grand Prix of 1914 proved that steel could be used in cylinder construction by adapting it to the motors which gave such wonderful service in this classic race. Experimental researches for weight diminution by the use of different materials conducted in the laboratories of a racing manufacturer developed to a large extent the aluminum cylinder and piston, testimony for the successful use of which was first shown by the Maxwell racing cars. The wide adaption of alumnium to pleasure car usage of today hardly needs mentioning.

The high compression ratios employed in the modern high speed engine are a direct result of racing practice. Compression ratios on the Grand Prix Mercers of 1914 were carried as low as 19 per cent. of the total volume with a mean effective pressure of 100 pounds per square inch, and no pre-ignition resulted. The employment of large valve passages and port areas became necessary in these engines and forthwith demanded considerable research as to proper proportioning of the valve and cylinder diameters. Valve-timing, another most influential factor in speed and power development, constitutes a field in which experimentation, although comparatively easy to conduct, can be thoroughly carried out only in racing engines. To quote from Finley Robertson Porter, designer of the 1914 Mercer and the F. R. P. engines:

> "Placing the opening of the exhaust as early as 70° ahead of center and closing as late as 63° past lower center, with practically no attention paid to the closing of the exhaust and the opening of the intake within reasonable limits, have proved thoroughly practical and efficient in stock car production, as well as in racing; and to racing alone is this due."
>
> S. A. E. Transactions, 336, 9, 2, 1914.

The predominance of overhead valves in the modern racing engine has proved beyond question their supremacy in high speed, high powered efficient design, and in fact it has been due to racing alone that the overhead valve has come to its high state of perfection. The disadvantages of exceedingly noisy operation and poor lubrication so manifest in the first overhead valves were eliminated as a result of racing tests. In the investigations for proper scavenging and proper formation of the combustion chamber or other conditions affected by the valve unit, such innovations as the overhead camshaft, the four-valve cylinder and proper exhaust port design have been evolved. Proper lubrication, which is of fundamental importance to victorious racing, has been a subject of much research in the production of many a new speed creation, and the results of these experiments have long since been incorporated in pleasure car design. In the construction of racing engines and the remainder of the chassis as well, pump shafts, lay shafts, gears, and many other important parts frequently rupture with no apparent cause and in spite of the fact that the mathematical stress lies well within the limits of safety. Similar difficulties are of course encountered in pleasure car manufacture, or develop when the car is in the hands of the owner; but as these failures occur at infrequent intervals and generally do not come to the attention of the designer, they are not investigated. Obviously these failures do not lead to any proper improvement in design.

It can not be denied that owing to the advent of the automobile, accompanied by ever increasing demands for steel of utmost strength, the metallurgical development of the world has made almost incomparable progress. The study of the metallurgy of such steels or the consideration of the microscopical metallography, heat treatment, and the relationships between chemical composition and physical characteristics involves unlimited investigation and endless work which deserves far more credit that will ever be established. Not only improved metallurgy but also improved thermal treatment and a considerable increase in the number of industrial alloys are credited to the automobile in its relations with the steel industry. To what extent racing has influenced this development is difficult to state, but it is an indisputable fact that racing has fundamentally influenced the development of light weight construction of the chassis as well as the engine. And were it not for the modern alloy steels, light weight design would indeed be difficult.

Another development rarely attributed to racing but essentially a direct influence of racing, is ease of riding. The fundamental requirement for this property, although generally neglected in racing design, was revealed in endeavoring to keep the wheels of the racing vehicle on the ground. The facts that sprung and unsprung weight must of necessity bear a given ratio to one another and that keeping the wheels on the ground is a factor not to be considered by itself were well brought forth by the laboratory investigations conducted by F. R. Porter for the Mercer racing cars. In fact, these experiments in conjunction with a vast amount of detailed research directed toward the accomplishment of these ends led to very gratifying conclusions which are well evidenced by the extensive application of cantilever and semi-elliptic spring construction in present day practice. The form which was decided upon as being most satisfactory in high speed service and which has later proved very successful in touring cars is the semi-elliptic spring, shackled at the fore end and fast at the rear end. This form, it may be observed, is fast superceding the old three quarter elliptic and the full elliptic suspensions.

The conception of the stream line body and the wire wheel is due entirely to high speed construction. The former development, decreasing wind resistance to such a large extent and providing at the same time a body extremely more graceful and far more harmonious to the eye, is the product of the French racing designers. The wire wheel with its advantages of light weight, decreased wind resistance, easy riding properties, and most important, added strength, owes its American popularity to the unrestricted use of wire wheels in racing. These factors and such indirect influences as the introduction of the multiple cylinder engine, developed principally for greater power and high speeds in aviation work, or the advancement of the Knight engine for greater power and silence as well, are all important indirect influences of racing practice.

The efforts put forth by the chief engineer and his staff of research engineers in their efforts to produce a victorious car are enormous. The innumerable adjustments in the final preparations, the changes needed to meet new road and atmospheric conditions, and the replacing of different parts constitute the lesser portion of the real efforts of the laboratory and factory engineers. Were it possible for the racing antagonist to note how carburetors, magnetos, and entire lubricating systems, are tried out for weeks, even months preceding the speed trial, for the purpose of accumulating data on the respective qualities of each, a conception of the value of racing to the motor car production and efficiency of today might more fully be realized. Were it possible to see the concentrated efforts of the designer to produce a lighter yet stronger and more efficient part, a part which later would be incorporated in the stock production after its racing test, the value of racing would be unquestioned.

THE FIGURE OF THE EARTH

R. D. Hughes, c '13

The figure of the earth is *per se* of universal interest. In astronomy, moreover, it is a matter of highest importance, since the diameter of the earth is the unit to which all celestial distances are, and must be, referred. It is natural, therefore, that from very early times men have given much thought to this subject. And, singularly enough, every determination that has ever been made, from the time of the soothsayers up to the present day, has been based on the same fundamental principle. This is the principle of measuring a line on the earth's surface and finding the corresponding arc of the heavens, from which the value of the total circumference may be computed.

Contrary to the present popular opinion, the earliest astronomers regarded the earth, not as a flat body, but as a sphere. Their conclusions were based upon the varying altitude of the stars, and upon the appearance of ships at sea. Probably the first of these men to attempt the actual measurement of our globe was Eratosthenes, an Alexandrian. He observed that at Syene (in Egypt), on the day of the summer solstice, the sun was exactly vertical, while at Alexandria, at a corresponding season of the year, its zenith distance was 7° 12′. He assumed these places to be on the same meridian, and calculating their distance apart to be 5,000 stadia, he inferred that the circumference of the earth was 250,000 stadia. His result was probably far from correct, or if correct, was accidental. At present, however, we have no means of checking his value, or those of several other early astronomers, as the length of the stadium has not been handed down to us by history. The Arabs, as early as 814 A. D., made similar measurements, but it is probable that their results likewise were incorrect.

No other determinations were made until several hundred years later, when Fernel, a Frenchman, attempted to solve the problem. He measured the distance along a meridian by counting the number of revolutions of the wheel of his carriage. His astronomical observations were made with a triangle, used as a quadrant. By a happy chance, his resulting length of a degree was very near the truth. As his determination of the earth's size was made on the assumption that our planet is a spheroid, his value for the diameter was, of course, erroneous.

The next person to improve the method of the determination was Willebrord Snell. He used a chain of triangles for his measurements. In 1637 Richard Norwood made a still more accurate determination. He observed the sun's meridian altitude in London on June 11, 1633, as 62° 1′, and on June 6, 1635, the meridian altitude in York as 59° 33′. The distance between these places he measured along the public road, partly by chaining and partly by pacing.

The application of the telescope to circular instruments was the last improvement of a fundamental nature. This was made in 1669 by Picard. After his invention calculations were made with increasing frequency and accuracy. Governmental bureaus were established in most of the prominent nations of Europe. In the middle of the last century an international congress was established for the purpose of discussing new methods of increased accuracy and for comparing the completed determinations. In short, the foremost scientists of Europe entered into this international competition, the goal of which was the most accurate determination of the size and figure of our earth.

During all this time the United States government continued as a spectator. Not a single attempt was made toward measuring the globe. In 1898, however, the United States Coast and Geodetic Survey started what proved to be the most comprehensive and accurate measurement of all. To the pluck and ingenuity of the men on this Survey, the scientists of the Old World, with all their years of experience, have been forced to acknowledge defeat.

Up to 1898 the best computation was that of Clark. His work was based upon six arcs scattered over Europe, Asia and South America. The longest of these, the one in India, subtended a celestial arc of 24°. The flattening of the earth at the poles Clark computed by comparing the curvature of his

Indian arc with that of an arc measured in Russia. His results are as follows:

Equatorial radius	6,378,206
Polar radius	6,356,584
Flattening	$\frac{1}{295}$

This value of the earth's diameter we now know to be about 400 meters too small, while the value for the flattening is several per cent too large.

The United States authorities, realizing the inadequacy of the arc method determined to use a plan which, because of the enormous amount of work connected with it had never before been attempted. This method, known as the area method, consists of taking observations of many stations covering large areas in all parts of our country, and tying these together by triangulation. The superiority of this over the arc system is apparent. Suppose, for example, that a molder was given six pieces of bent wire and told to shape a globe with a diameter ten times that of the longest wire which would most nearly fit the wires. Would he not have an infinitely more difficult task than if he had been given a large area of the surface, which in fact included in itself innumerable arcs running in all directions.

The greatness of the task performed by our United States Coast and Geodetic Survey may best be appreciated by a consideration of the following facts: (1) The area treated covers 18° 50′ in latitude and 57° 7′ in longitude. (2) Five hundred and seven astronomic determinations were made. (3) All astronomic determinations are connected by primary triangulation. (4) The effects of all topographical irregularities within 4,126 kilometers of each astronomical station have been taken into account. (5) The effect of possible distribution of densities beneath the surface of the earth corresponding to the condition called isostasy has been taken into account, and the existence of isostasy established.

Space forbids that, in this discussion, the work of the United States Coast and Geodetic Survey be described in detail. Suffice it to say, that the area mentioned above is tied up by a triangulation from New Jersey to California, an oblique arc extending three-fourths of the length of California, another oblique arc from Maine to Louisiana, a triangulation of the Great Lakes, and several minor arcs. All the triangulation has been reduced to the United States Standard Datum, which gives to Meade's Ranch, in Kansas, a latitude of 39° 13′ 26″.686 N. and a longitude of 98° 32′ 30.″506 W.

As stated, 507 astronomic determinations have been made. The difference between these astronomic values and the corresponding geodetic values is a measure of the deflection of the plumb line from the vertical, and hence, of the deflection of the actual surface of the geoid, or sea level globe, from the theoretical ellipsoid of revolution.

In order to make a more comprehensive determination of the minor irregularities of the geoid in our own country, it was deemed advisable to compute, if possible, the deflection from the vertical at stations where the actual deflection was not determined. The principle of this computation is very simple, being based upon Newton's law of universal gravitation:

$$g = k \frac{M' M^2}{d^2}$$

When g = force of gravity.
M' and M^2 = the masses of the attracting bodies.
d = the distance between them.
k = the universal constant.

In calculating the deflection, the attraction of all topographical deflections within 4,126 kilometers of the station was taken into account. The formula most used in this work is one derived by Clark, and is as follows:*

$$D = 12.''44 \frac{\delta}{\triangle} h (\sin \alpha' - \sin \alpha,) \log e \frac{r'}{r_1}$$

In order to test the accuracy of these so-called topographical deflections, two independent experiments were made. In the first place, the contour lines of a part of the geoid were drawn from the data compiled above. These contour lines, be it remembered, are lines of equal elevation on the surface of the

*For explanation and proof see *Geodesy*, by A. R. Clark, Oxford, 1880; pages 294–296.

geoid referred to the hypothetical spheroid, and they show, therefore, the departure of the geoid from the true spheroidal form. When this work had been completed, it was found that the contours followed the topography to a remarkable degree.

The second experiment was the comparison of observed deflections of a number of stars with the computed, or topographic, deflections. It was found that the computed declinations were in every case far too great.

These facts lead to but one conclusion. This is perhaps best summed up in Prof. Hayford's *Figure of the Earth and Isostasy:* "The logical conclusion from the study of the geoid contours, taken in connection with the fact already noted that the computed topographic deflections are much larger than observed deflections, is that some influence must be in operation which produces an incomplete counterbalancing of the deflections produced by the topography, leaving much smaller deflections in the same direction."

What is this "influence?" Before answering this question let us consider a few all-important fundamental facts. If the earth were of homogeneous material, its figure of equilibrium would be an ellipsoid of revolution. But, as a matter of fact, it is heterogeneous matter, and, moreover, obeys the laws of fluids. Now, since it is in equilibrium, the irregularities in densities must be compensated by irregularities in the surface; that is to say, above each region of deficient density there will be a bulge on the ellipsoid and above each region of excessive density there will be a hollow. These "bulges" and "hollows" are the mountain ranges and ocean beds, and the "counterbalancing influence" has been given the name of "isostasy."

Perhaps this isostatic condition of the earth can best be explained by the homely example of the ant hill. Imagine a huge ant hill upon a level plain. The material for the hill has largely been brought up from the ground directly below it, so that the amount of matter is no greater per unit area at the hill than at other points, and its density is less. Now a plumb bob hanging near the ant hill is deflected towards it. A distant bob is, however, attracted no more when the material is heaped up than when it was below the ground.

This effect is exactly what has been observed in practice.

Plumb lines are deflected by near irregularities of topography, and very little by distant ones. This fact was of highest importance in proving the existence of isostasy.

The final step necessary before making the principle of isostasy of practical value was to determine the depth of the so-called compensated density. By experiment, this was found to be in most cases approximately 70 kilometers.

The work of computation was now a simple matter. All topographic deflections were calculated with isostasy corrections. The accuracy of such calculations is easily shown from the following table:

Station	Observed deflection	Topographic deflection	Topographic deflection with isostacy
	″	″	″
Santa Barbara, Cal.	—18.38	—64.97	—14.91
Point Arena, Cal.	+16.98	+104.63	+16.45
Waddoup, Utah	+24.84	+54.71	+22.11
Patmos Head, U.	—13.52	—27.20	—9.42
Chewer, N. Y.	—14.77	—37.46	—10.32
Maximum error as shown by obs. def.	......	87.65	4.45
Average error	......	40.08	3.05

With all the data now at hand, there remained the work of computing from it the correct size of the globe. The details of this computation are not within the scope of this article. It is sufficient to say that five calculations were made, each by a different method. The final results of these calculations are as follows:

Latitude of Meade's Ranch....................	39° 13′ 26′.47 N
Longitude of Meade's Ranch	98° 32′ 30′.64 W
Equatorial radius	6,378,283 meters
Semipolar axis	6,356,868 meters
Flattening, $\frac{a-b}{a}$	$\frac{1}{297.8}$

The above values of the earth's radii are, with reasonable certainty, known to be within 34 meters, or about 120 feet of their actual lengths, and the flattening is known to be between $\frac{1}{298.7}$ and $\frac{1}{296.8}$ with $\frac{1}{297.8}$ as the most probable value.

The irregularities of the sea level surface can, of course, be shown only by a contour map. It will be impossible, therefore, to do more in this article than merely to mention the fact that the work of the United States Coast and Geodetic Survey confirmed the presence of these irregularities, but found them to be less than had been formerly supposed, owing to the isostatic condition of the earth's outer crust.

The people of this country cannot give too great praise to the men connected with the United States Coast and Geodetic Survey. In the short space of thirteen years they have arrived at a determination of the size of the earth which is much more accurate than any ever made. They have compelled the scientists of Europe, with all their past knowledge and experience, to admit the superiority of American methods. They have set a record which, it is safe to predict, will not be equalled in many years.

* * *

For the first time in the history of the University of Colorado a woman has become president of the Combined Engieers, an organization composed of engineering students. Miss Elsie Eaves having been awarded the honor.

* * *

In the December issue an interesting account of the Senior Chemical, Senior Civil and Senior Mechanical Engineers' trip will be published.

LEARNING TO FLY AT CHANUTE FIELD

Asher E. Kelty, m '17

Editor's Note: The following letter was received by Professor Callan last September. Since then Asher Kelty has graduated from the Rantoul Aviation School and is now awaiting his call for active service.

RESERVE DETACHMENT,
CHANUTE FIELD,
RANTOUL, ILLINOIS.

My dear Professor Callan:—I may now consider myself a real aviator, for I have been flying alone for almost three weeks. I was given a real calm joy ride when I first started because my instructor, Victor Vernon, did not believe in doing stunts with a raw recruit as many of the instructors do. The second time up, however, he gave me the controls at 700 feet and told me to keep her straight and level. This time up he made the turns, but the next time I was required to make the turns 90 degrees at a time, keeping lined up with the sections and roads on the straightaways. They are very easy to follow on account of the different crops in the fields. This preliminary work was done in the front seat, the instructor reaching over and touching me on the head when I was to take the controls and on the shoulder when I was to make a turn.

The next trip up I was given the back seat, and the instructor motioned the different turns I was to take from the front. This time we did left and right spirals and figure-eights. My air work, as this is called, was satisfactory, so we next started on ground work—landing, taking off, etc. This went somewhat slower. The air work depends considerably upon instinct, because it is just a question of banking the right amount for a given amount of rudder. The general tendency is to overbank, which results in a side slip, which is not serious with the Curtiss JX14 because these machines have so much vertical surface that the tail swings around on its own account very quickly. In fact it is quite difficult to keep the plane in a side slip.

As I mentioned, the landings came more slowly. It requires a certain amount of practice for each individual and thus the greater part of the instructional time is spent in this work. One must glide in at a good speed and slowly level off, starting at about 25 feet and finally flattening out at about two feet. Then just holding the machine off the ground, one must pull up on the elevators until the machine just starts to sink. The tail is then pulled quickly down so that the tail skid and wheels touch at the same time. The tendency here is a "tail high" landing, or if the ground is the least bit soft or rough, this results in a "noze over" or a "noze up." The "noze over" may break the machine up considerably, but it is not fatal. A "noze up" merely breaks the propeller. After staying on landings until I had had 276 minutes of instruction altogether, I then made my first "solo." I went up to about 1,000 feet over Rantoul, making figure-eights, and had a wonderful time for 16 minutes. It was quite windy (about 10 m. p. h.) and rough. On the way down I had judged my distance a little short so that it was necessary to cut in the motor for a few seconds, and then I made a poor landing on account of the puffs. Mr. Vernon, however, said that it was all right, so that from that time on I have been a real flier.

On my second solo ride, I was forced down because my motor cut out on one side (four cylinders), the jet on one side having plugged up with sediment. I was only up about 200 feet and going with the wind. I shut the motor down and banked for a left turn steeper than I had ever done before. I had just straightened out into the wind when I was practically on the ground, so I pulled the tail down and made a good landing. I afterwards learned that an experienced man would have taken a chance at landing with the wind rather than having tried such a steep bank near the ground.

I have had one spill and therefore think that I shall be a real flier, because the saying is that no one really learns to fly until they have had one accident at least. About my fourth solo ride I was practising landings and had decided to try a landing in the southeast corner of the section. I cut off about three-quarters of a mile away at 500 feet and came in over a farm house just outside the field. I looked down at a farm house to see how high I was, for the aneroid is of no value for altitudes less than 300 feet; I noticed that I was fairly low, but I thought that I had plenty of room to clear the telephone wires at the side of the road. Then I looked up just in time to see my left wing crash into a large elm tree. I spun around 180 degrees and dropped into the road with my tail hung up on the telephone wires. I did not know that the tree was there. Well, the top of it no longer is,—1,880 pounds at 70 miles an hour mean quite a lot of power. Needless to say, the machine was ruined and is in the repair shop yet. I did not get one scratch, but of course I did not fall more than 60 feet.

Oh, yes! I thought that the wind was strong the first day I went up alone, but since then I have been up in much stronger winds. One Monday I went up in a wind that was about 35 miles an hour on the ground. (It increases with altitude as we learned at ground school.) It was very rough the first 1,100 feet on account of the houses, clumps of trees, etc., on the ground, and thus I had to watch her every minute. I went up to about 2,000 feet, and although the wind was still stronger it was very smooth. I seemed barely to creep on the up turns or against the wind, and then down I went like the wind. I passed over a farm house, nozed her up slightly and stayed there hardly moving for nearly seven minutes. Then I veered off to the right and nozed down with the motor shut off to a successful landing. A landing is very difficult in a high wind because the distance one glides is much shorter and one has to dive much steeper than usual. If you bounce the least bit the wind may catch you and lift you eight or ten feet. Then you must "shoot the gun" or put on the motor and make another turn of the field, because if you allow the 1,800 pounds' weight of the machine to drop that distance, the landing gear would be ruined. In putting the motor on and off, the switch is never turned off, but the throttle is pulled back so that the motor turns over about 275 or 300 r. p. m., a speed which is insufficient for pulling purposes. Normal speed is about 1,400 r. p. m.

Straight flying is getting to be a good deal of a bore and I'll be glad when I am able to learn some of the tricks that save men's lives over on the front.

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PUBLIC SPEAKING

The ability to express oneself clearly and concisely is almost indispensable to any professional man, but it is an absolute necessity to the successful engineer. An engineer must not only be able to do things, but in order to be of the maximum service to the world he must be able to tell others how things should be done. He must not only have a wide knowledge, but he must be able to impart this knowledge to others. These two things demand, therefore, that a man have the ability to get up on his feet, at a moment's notice, if need be, and convey his own thoughts and conclusions to a group of people. In order to make what he says count, he must be able to organize his material well and to present it forcibly. The ability to do this requires practice and experience; and can be acquired in no other way.

There are three means by which the undergraduate can obtain this training here at the University: first, through the courses offered by the Public Speaking Department, second, by joining one of the Engineering Clubs, and third, by becoming a member of one of the three Debating Societies. Each of these methods has its advantages and a good many engineers are availing themselves of the opportunities offered, but there are still not enough men out into these activities from the Engineering College. We of the Engineering School must take more interest in these activities so that when our opportunity for leadership comes we will not be found lacking in the ability to grasp it.

-Warren

* * *

RECOPYING DATA

Many hours of valuable time spent in tedious and utterly useless recopying of experimental data are required in several of the laboratory courses of the Engineering School. Data, regardless of the neatness of the recorder, are not acceptable in original form, and thus columns and columns of data must be transcribed to a form data-sheet in order that we may, presumably, become familiar with commercial report writing. This is a decidedly inefficient procedure, wasteful of time, wasteful of energy, wasteful of paper. True, it is good practice in lettering, but what more? The present engineering curriculum in conjunction with the proper amount of student activities and the outside reading which one certainly should not neglect in these times of all times, permits of very few leisure hours. This is a year of overloads and overloads requiring utmost efficiency, and requirements of this kind are loops on the indicator card. In some courses it has been found possible to avoid this waste of time and effort; is it not possible to devise means to the same end?

White

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SCHUSTEDT, FREDERICK N., c '17, Sargeant, Camp Grant, Rockford, Ill.

TRAYOR, GEORGE W., c '12, Company B, 362nd Infantry, Camp Lewis, Washington.

VIGNERON, EUGENE M., e '17, Ft. Newcastle, New Hampshire.

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A COMMUNICATION

The study of valve gears and valve diagrams, as presented to the sophomore mechanical engineers in Machine Design 12, should be deferred until their junior year when the teachings of this course may be experimentally verified in the Steam and Gas laboratories and when the student has gained from Steam and Gas 1 his first true understanding of the principles of the steam engine. At the time the course is now given, many students of valve gears are unfamiliar with anything but the cross-sectional projection of the D-valve, are wholly ignorant of practical indicator cards, and do their work principally by following what his neighbor has done. Many of those who take Steam and Gas their junior year enter the class with the idea that indicator cards from the steam engine are like the cards from a steam pump. They know the Zeuner and the Bilgram diagrams quite thoroughly, but they are totally unfamiliar with the practical study of valve action. The terms "cutoff," "lead," or "lap" have a certain significance to them when applied to a drawing but not elsewhere. This is *not* because of an incompetent instructional staff by any means. It is because the course is given too early and is too brief. Even were the study of valve diagrams deferred to the completion of Thermodynamics and junior laboratory testing, one credit does not allow sufficient time to handle adequately a subject of this scope. Modern valve gears, such as the Walschaert or the Baker-Pilliod, poppet valves and valves with riding cutoff are hardly mentioned. There is very little time to study anything but the Zeuner and the Bilgram diagrams, a Corliss layout, and possibly a problem on the Meyer valve. It is interesting to note that the chemical engineers become practically as familiar with these diagrams and their theory as do the mechanical engineers, although the former study the subject only incidentally as a part of their three credit course in Thermodynamics. They are able to grasp the subject more readily because they have completed several experiments in the laboratory.

The trouble lies in the fact that the study of valve gears comes too early in the curriculum. To obviate this difficulty the following plan is suggested: The courses in Machine Design 11 and 12, testing machines and machine elements, could be incorporated into one course without overworking the student in the least. By this substitution Valve Gears would take the place of Machine Design 12 and would be studied simultaneously with the theory of the design and the thermodynamics of the steam engine. An expansion of the course to include many fundamental features of steam engine practice would thus be possible. This would result in a material improvement of the course. —Robert Bruce White.

ALUMNI NOTES

Howard Buck, c '17, famous tackle and captain of the varsity team in 1915, is now Director of Athletics of Carleton College, Minnesota.

John Wise, e '16, former editor of the Wisconsin Engineer, is still with the Engineering Dept. of the Westinghouse Co. He writes that Gus Andrae, also of the class of '16, is in the Sales Department of the same company, that Phil Jamieson is in the Works Department and that Eddie Andrews, e '16, editor of the Engineer '14–'15 and manager '15–'16, has recently been transferred to Cincinnati with the Publicity Department.

Samuel Eby, c '17, is a computer in the office of the Government Engineer at Milwaukee.

Grover C. Almon, m '17, is employed by the Gisholt Machine Company in Madison.

H. Z. Baebler, e '17, is working for the Western Union Telegraph Co., in New York City.

Roy H. Davis, c '17, is in the employ of D. W. Meade in Madison.

C. C. Dodge, e '17, and J. E. Mackowski, e '17, are employed by the T. M. E. R. & L. Co. of Milwaukee.

Arthur B. Foeste, e '17, is connected with the Denver Gas and Electric Company in Denver, Colorado.

Dwight S. Fowler, c '17, is Assistant Engineer for the city of Green Bay, Wisconsin.

Jerome H. Gefke, e '17, is employed by the Wisconsin Telephone and Telegraph Co., in Milwaukee.

Walter F. Grubb, c '17, and K. C. Spayde, e '16, are employed by the McClintock-Marshall Co. in Pittsburg, Pennsylvania.

Gordon G. Johnson, m '17, is now working for the Chicago, Rock Island & Pacific Railroad in Moline, Illinois.

A. E. Henry, e '17, is connected with the American Telephone & Telegraph Co. in Detroit, Michigan.

Leslie V. Nelson, e '17, is working for the Minnesota Steel Co. in Duluth, Minnesota.

Gilbert F. Roddewig, m '17, is draughting for the Stone & Webster Company, Consulting Engineers, of Boston, Massachusetts.

Frederick L. ReQua, m '17, is in the Research Department of the Cutler-Hammer Co., in Milwaukee.

August E. Kringel, c '10, was married to Miss Norma Paeske of Milwaukee, on April 16, 1917.

Charles A. Rau, e '17, is working for the Corn Products Co., in Pekin, Illinois.

Charles R. Poe, e '17, is in the employ of the American Telephone and Telegraph Co. in Chicago.

Warren Weaver, C. E. '17, is Assistant Professor of Mathematics at Throop Institute of Technology in Pasadena, California.

Louis Slichter is working on submarine detectors in New London, Connecticut.

Newton D. Whipple, ch '17, is working as a chemist for the American Steel & Wire Co. in Waukegan, Illinois.

Everett H. Van Patten, Jr., m '17, is with the Curtis Aeroplane Co. in Buffalo, New York.

Edwin J. Paulus, C. E. '11, was married to Miss Blanche McClelland of Chicago, on June 27 of this year.

E. R. Brandt, m '17, is acting as Standards Engineer of the Fairbanks-Morse Company.

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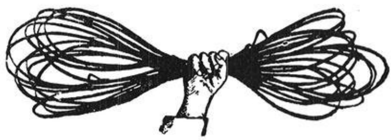

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