RELATIONS BETWEEN POWER AND VELOCITY IN SCREW PROPELLERS.

By JOHN LOWE, of the U. S. Naval Engineers.

It is something remarkable that, considering the numerous rules given to estimate the relations between the power and speed of steamships, there should be so very many examples afloat of disappointments and failures in these respects. It is even yet more remarkable that, of all these rules, no two give nearly the same results from the same premises. What wonder, therefore, if, in view of these facts, that perplexity and doubt should exist, and that a suspicion should arise that all were more or less faulty. Indeed, nearly all have a coefficient which reconciles the rule and the practice, and which coefficient may be taken either as a confession or as a concealment of the defects involved.

Take, for an example, the simplest rule of all :

$$P = \frac{S^3 X}{B} \quad W = \text{Horse-power; } S = \text{Speed, and, } B = \text{co-efficient; } X = \text{Midship section.}$$

Now B is found from known examples of vessels now or previously afloat—that is, we choose from our precedents a vessel having similar lines to our proposed vessel. But what if we have no precedent, as is very likely to be the case in a man-of-war, where traditional models must often necessarily be departed from. Suppose we desire a different type of engines, etc., and notably suppose we desire a better propeller than in the precedent.

Referring to our rule, we find that the coefficient, B , does not discriminate at all; but good and bad qualities of engine, propeller, and hull are lumped together in a mass, inextricable and misleading. Even under the best circumstances, our coefficient must be guessed at, and is it not easily seen that to guess at one quantity of a mathematical equation is as allowable as to guess at another, and so we might as well guess at the power as at the coefficient, and save an unnecessary calculation. So far, then, as this rule is concerned, it is not wonderful that engineers have been misled, and so many disappointments met with.

Mr. Froude's experiments conclusively settle the question regarding another rule, and we are only improved by knowing our errors, and therefore no longer trusting in delusions, though not positively knowing the correct method.

In the rule proposed by this paper, the direct issue is perhaps avoided, and the speed obtained indirectly; still it may not be without merit.

The power required to revolve a screw-propeller at a given rate, the vessel being fast to the dock, is the primary object sought for; because the writer has been enabled to verify his work with experiment. From this, by well-known rules found in Isherwood's works, the speed of the vessel may be found within a possible error of 5 per cent, this being the difference possible between our estimate of the slip and the slip actual.

A rule of this kind has the advantage of being able to tell us upon whom to fix the responsibility of failure, for if the propeller fails to revolve at a given rate at the dock, there would be no doubt as to whether it was the engineer or the constructor who was to blame.

It is to be distinctly understood, however, that this rule applies to propellers having a sufficient immersion; for, if the propeller throws off broken water from the surface, or if it displaces part water and part air, these conditions are difficult to estimate, and the power will vary with a lower function than the cube of the speed. In any case, however, the rule will give power enough, and, unless these noted exceptions are aggravated, will give a sufficiently correct result.

The figure represents a plane advancing against a fluid medium in the direction b to c , with the velocity v . It advances at an angle $\beta = acb$. The work done by this plane in displacing the fluid will be $dU = \frac{A v^3 \delta dx \gamma}{2g}$

dU = work performed; A = a coefficient depending upon the angle β ; δ = the width ab ; v = velocity in feet per second; dx = the thickness of the plane; $2g = 64.4$ = effect of gravity; γ = the weight of one cubic foot of fluid, which we will pronounce to be salt water, and therefore $\gamma = 64.125$.

A , however, is a constant or rather coefficient depending upon the angle β at which the plane advances against the water. Although various authors give formulas for this coefficient, yet the writer obtained it for himself—that is, the trials at the dock of a number of U. S. naval vessels were taken as experiments.

The angles of the blades were laid off, and the power calculated for each angle, using each circular function, sine, versed sine, etc., and the results for each were plotted. Integration was then performed by means of the planimeter. This was repeated in a number of examples until the conclusion was arrived at that the sine was the correct function.

We have then $dU = \frac{\sin \beta v^3 \delta dx \gamma}{2g}$ as a fundamental formula, or (1)

Our next step must be to so enlarge our formula that it may embrace all the planes situated in the radius of the screw-propeller. For this purpose,

Let n = number of blades.

x = radius of blade in feet.

R = revolutions of the screw in one minute.

Then $\frac{R}{60}$ = revolutions in one second.

$$v = \frac{Rx 2\pi}{60} \quad \text{and} \quad v^3 = \frac{R^3 x^3 8\pi^3}{60^3}$$

So that the work done by any plane situated x feet from the centre is

$$dU = \frac{\sin \beta R^3 x^3 dx 8\pi^3 \gamma n}{60^3 \times 2g} \quad (2)$$

Regarding P = pitch of the screw in feet, we have,

$$\sin \beta = \frac{P}{\sqrt{4\pi^2 x^2 + P^2}} = \frac{P}{2\pi \sqrt{x^2 + \frac{P^2}{4\pi^2}}}$$

For simplicity we will call this,

$$\sin \beta = \frac{P}{2\pi \sqrt{x^2 + a^2}} \quad \text{in which } a^2 = \frac{P^2}{4\pi^2}$$

Substituting and reducing in (2), we obtain,

$$dU = \left(\frac{x^3 dx}{\sqrt{x^2 + a^2}} \right) \frac{P R^3 2\pi^3 \gamma n}{g \times 60^3}$$

This is the complete formula for a plane whose thickness is dx , and whose position in radius is x feet from the centre of the screw.

Since the total work done is the sum of all the small elements of work done by each plane in radius, we may call this formula the differential formula, and proceed to find their sum by integration. In order to make criticism easy, we will perform this operation by calling $z^2 = x^2 + a^2$.

$$\text{Then } x^2 = (z^2 - a^2); \quad \frac{1}{z} = \frac{1}{\sqrt{a^2 + x^2}} \quad \text{and } z dz = x dx.$$

$$\begin{aligned} \text{Therefore } &= \int \frac{x^3 dx}{\sqrt{x^2 + a^2}} = \int (z^2 - a^2) \frac{1}{z} z dz \\ &= \int (z^2 - a^2) dz \\ &= \left(\frac{z^3}{3} - a^2 z \right) + C. \end{aligned}$$

Restoring the value of z , we have,

$$\begin{aligned} \int \frac{x^3 dx}{\sqrt{x^2 + a^2}} &= \left[\frac{(a^2 + x^2) - a^2}{3} \right] (\sqrt{a^2 + x^2}) + C \\ &= \left(\frac{x^2 - 2a^2}{3} \right) (\sqrt{a^2 + x^2}) + C. \end{aligned}$$

Reducing x to a we find that $C = \frac{2}{3} a^3$, and the complete formula for the screw is,

$$U = \left[\frac{(x^2 - 2a^2)}{3} (\sqrt{a^2 + x^2}) + \frac{2}{3} a^3 \right] \frac{P 2\pi^3 \gamma n R^3}{g \times 60^3}$$

In this, U is the work done in one second of time in foot-pounds. Sixty times this will be the work done in one minute, and this, divided by 33000, will give horse-power, which is the most usual mode of measurement.

$$\text{Therefore } W = \left[\frac{(x^2 - 2a^2)}{3} (\sqrt{a^2 + x^2}) + \frac{2}{3} a^3 \right] \frac{P 2\pi^3 \gamma n R^3}{g \times 60^3 \times 33000}$$

This rule is not a simple one; but, in the light of numerous examples, is a correct one. Relying upon its merits, the writer respectfully invites criticism, and a reduction to a simpler form, which he thinks possible. Knowing now the power required at the wharf, it is easy to find the speed at sea, as before indicated.

A rule, giving the speed directly, is contemplated by the writer; but, until it is subjected to critical experiment, will not be presented.

[Engineer.]

HYDRAULIC RAMS.

THE following useful information is given by a correspondent of the *Engineer*: The efficiency of a ram need not be less than 60 per cent, and not as illustrating the highest efficiency obtained. One that I erected at Churchfield House, West Bromwich, gives off an efficiency of 84 per cent. I must acknowledge that I have not yet been able to reach 90 per cent. These are the proportions asked for by Mr. Hett:

(1) Fall, 18in.; supply, 19 quarts per minute; height of delivery, 20ft.; quantity raised, 1 quart per minute; length of injection pipe, 13ft. 6in.; diameter of pipe, 1 1/4in. at leading end and 1 1/2in. at junction with ram; diameter of pulse valve, 2 1/2in.; number of beats per minute, 68; efficiency of ram, 70 per cent. (2) Fall, 50ft.; supply, 16 quarts per minute; height of delivery, 153ft.; quantity raised, 5 quarts per minute; length of injection pipe, 300ft., and 2in. diameter at leading end and 3in. diameter at junction with ram; diameter of pulse valve, 2in.; number of beats per minute, 120; efficiency of ram, 76 per cent. I believe I am the only maker of hydraulic rams that uses a taper injection pipe, but its advantages must be obvious to any one who will give a moment's thought thereto.

"R. E. D." has asked for, but not obtained, the proportions of a ram that will in his case yield an efficiency of 60 or 70 per cent. I herewith give him the particulars required. Height of fall being 9ft.; supply, 28 gallons per minute; height to be raised, 35ft.; and length of rising main, 250ft. Length of injection pipe should be 54ft.; diameter at leading end, 4in.; at junction with ram, 2 1/4in.; diameter of pulse valve, 4 1/4in.; number of beats, about 75 or 80 per minute; diameter of rising main, 1 1/2in. With a ram otherwise well proportioned, an efficiency of at least 72 per cent may be relied upon, or a yield of 31 quarts per minute. I will guarantee 20 quarts.

If I have not already trespassed too much upon your valuable space, perhaps you will allow me to give the rule I adopted some years back for determining the proper size of a ram and the injection pipe, the quantity of water available as supply, and the fall being given; I may say in passing it is the result of a great number of experiments, and of close observation, and I have never known a ram yield less than 60 per cent, since adopting it. Injection pipe at its junction with ram should be of the same diameter as a pipe which, being one yard long and having a head of six inches, will pass three times the quantity of water that is available as supply, because the water in an injection pipe only flows towards the ram about one-third of its time. Now, supposing we had a supply of 10 gallons per minute, a pipe one yard long, that will pass thirty gallons per minute with six inches of head, will require to be 1 1/4in. diameter, which is the size required. Having got the diameter of the small end, what size should the leading end be? Again, supposing we had a fall of 10ft., a 1 1/4in. pipe, one yard long with 10ft. of head, will pass 134 gallons per minute, and it will require a pipe 2 1/4in. diameter, one yard long with 6in. of head, to pass 134 gallons per minute; the large end should thus be 2 1/4in. diameter, and taper down to 1 1/4in. at ram to be of equal carrying capacity throughout its whole length. Length should be 9ft. long for each foot of fall, for 2ft. and under; 8ft. long for each foot of fall, for 3ft. and under; 7ft. for each foot, for 4ft. and under; and 6ft. for each foot of fall, for 5ft. and upwards, with taper injection pipes. Area of pulse valve should be equal to four times the area of injection pipe, at its junction with ram, thus: Area of 1 1/4in. injection pipe being 1.7671, which, multiplied by four, gives 7.0684 as the area of valve, or 3in. diameter. No double valves are required where these proportions are used; the valve being of so large an area, its stroke never exceeds five-sixteenths, which entirely does away with the usual long sledge-hammer stroke that destroys the valve. Rising main should be of such a size that it will not add more pressure on the ram that is due to a head of 2ft. or 3ft. Of course the longer it is the larger it should be; a 1in. pipe 200 yards long will convey 2 gallons per minute with a little more

than 2ft. 3in. of head; if it is 600 yards long, it will require a head of nearly 10ft. to pass the same quantity.

STAFFORD, ENG., Feb. 1876.

B. MASSEY.

[American Journal of Science and Arts.]

NEW TERTIARY LAKE BASIN.

By GEORGE B. GRINNELL and EDWARD S. DANA.

SEVERAL Lake Basins of Tertiary age have already been discovered in the Rocky Mountain region, and the more important of them have been carefully explored. Those of Eocene age have only been known since 1870, but the Miocene deposits of the White River have long been noted for their wonderful scenery, as well as for the number and variety of the mammalian remains found in them. Another Miocene basin is known in Oregon, and both the lake beds of this period are overlaid by deposits of Pliocene age.

During the explorations carried on last summer under the direction of Col. William Ludlow, Corps of Engineers, a series of Tertiary deposits were identified by the writers near Camp Baker, Montana. These deposits indicate the existence in this region of a Miocene lake basin, which was succeeded by another lake basin in Pliocene time. As these basins are quite distinct from those heretofore known, it is considered important to put the fact of their discovery on record.

Camp Baker is situated on Deep Creek, a stream which flows into the Missouri River above Sun River. It lies about fifty miles nearly due east of Helena. It is surrounded on all sides by mountains, of which the Big Belt Range, lying immediately to the south or southwest, is the highest and most conspicuous. The Little Belt Mountains lie to the North, and the Crazy Woman Mountains to the southeast, though at a greater distance.

The Tertiary beds found here consist for the most part of homogeneous cream-colored clays, so hard as to be with difficulty cut with a knife. The beds are horizontal, and rest unconformably upon the upturned yellow and red slates below. The clays of which they are formed resemble closely those found in the Miocene beds at Scott's Bluffs, near the North Platte River, in Wyoming. The deposits at Camp Baker have been extensively denuded, and nowhere reach any very great thickness. At a point about three miles southeast of the Post, some bluffs were noticed where the Miocene beds attained a thickness of 200 feet, and these were capped by fifty feet of Pliocene clays, both beds containing characteristic fossils. In the underlying Miocene beds were found a species of *Rhinoceros*, several species of *Oreodon* Leidy and *Epoecodon* Marsh, a canine tooth apparently of *Elotherium* Pomel, and remains of Turtles. In the Pliocene beds the principal fossils were a species apparently of *Merychyrus* Leidy, remains of an equine smaller than the modern horse, and Pliocene Turtles. These fossils have not yet been carefully studied, and for this reason their relations to the remains found in the other lake basins of similar age can not here be stated.

We saw the first exposures of these beds a few miles west of the Sulphur Springs, just after crossing a rather high ridge of trachyte through which Deep Creek flows in a narrow and picturesque cañon. This point is about six miles southeast of Camp Baker. From here the lake bed was traced continuously long Deep Creek for a distance of fifteen miles, extending quite up to the mountains on the eastern side at least. Beds of the same character containing similar fossils were found on White-Tailed Deer Creek, a branch of Deep Creek, about seven miles to the north of Camp Baker, as well as on Camas Creek to the southwest of the Post. Traces of this deposit, containing what appear to be remains of *Rhinoceros*, were also found two miles or more south of Moss Agate Springs, and at a considerable elevation above the creek-bed. With more time than we had at command they could no doubt have been traced much farther, although in many places the beds have been washed out, or have been covered by the later local drift.

These Tertiary beds were all laid down after the elevation of the mountains and the igneous eruptions. They are, as has been said, perfectly horizontal, and are often seen covering over ridges of trachyte. The line of separation between the Miocene and Pliocene beds is in some places well marked. It consists of about six feet of hard sands, interstratified with layers of very small water-worn pebbles soldered together into a hard mass, but easily picked out with a knife. Each of these layers is about six inches in thickness. Immediately above these strata the Pliocene fossils were found. In several places fragments of trachyte were noticed in the Pliocene beds.

Near Camp Baker are a series of upturned ridges of Potsdam sandstones and limestones at a level very little above that of the Tertiary beds, and doubtless in this region the lake was divided into many arms, which bent around and extended among these ridges.

It is known that in the neighborhood of Fort Shaw, and near Helena, Pliocene deposits exist, and at Fort Ellis and in the valley of the Yellowstone we saw, but were unable to examine, gray sands and marls, which Dr. Hayden refers to the same age.

No Miocene beds, however, have been identified at any of these localities. It seems probable that in Pliocene time at least, the Baker Lake may have extended north to the Missouri River, and perhaps up that stream to the Three Forks, thus connecting with the lake which existed near Fort Ellis. Indeed, it would seem that we just touched upon the northern edge of this basin, which may have extended far to the north and west.

An interesting point in connection with these deposits is the fact that they are at a much greater elevation than any other beds of the same age now known on the continent. The elevation of the White River and Colorado beds is about 3000 feet, and that of the Oregon basin somewhat less, while that of the deposits near Camp Baker is over 5000 feet.

In reference to the relations which this lake basin bears to the Oregon basin and to the White River deposits, nothing can be certainly known without a careful exploration of the whole region and a thorough study of its vertebrate remains. It is by no means impossible that the Baker Lake may have flowed into that at White River by some old river channel, but so little is known of the intervening country that no definite opinion can be pronounced on the subject.

THE COMBER ENGINE NOT NEW.

TO THE EDITOR OF THE SCIENTIFIC AMERICAN:

In number 11, page 165, of the SCIENTIFIC AMERICAN SUPPLEMENT, there is an illustration of a novel steam-engine invented by Mr. W. A. Comber, of Birmingham, England. The fact may have escaped your notice that the same thing in principle was invented twenty-five years ago by Mr. S. Furman, of Romulus, Seneca County, N. Y., and illustrated in the SCIENTIFIC AMERICAN in the year 1851, volume 6, page 361.

GEORGE STRINGER

ITHACA, N. Y.