an official trial, is not the highest speed ever attained, the "Turbinia" having steamed 35 knots, and the "Hai Lung," a torpedo boat built by Schichau for the Chinese government, 35·2 knots an hour in private trials, the last named standing as the fastest speed ever made by any type of vessel.

LIQUID AIR AS A NEW SOURCE OF POWER—ANOTHER ENGINEERING FALLACY.

BY PRESIDENT HENRY MORTON, PH.D., LL.D., SC.D.

During 1894–95 the present writer prepared two articles under the title of "Engineering Fallacies," which were published in the Stevens Institute Indicator, vol. xi., pp. 273–294, and vol. xii., p. 125.

Since that time, though several new forms of what might be termed in a general way "Perpetual Motion Schemes" have appeared, none of them has seemed of sufficient importance to warrant any special notice, but in the March number of McClure's Magazine there is published an article entitled "Liquid Air—a new substance that promises to do the work of coal and ice and gunpowder, at next to no cost," which is so eminently calculated to mislead the general reader and even to become the basis of financial frauds, like that of the Keely Motor, that it would seem a duty to draw attention to the fundamental errors in scientific principles and in statement of facts which this article contains.

This McClure article may be fairly considered as made up of two prominent elements or parts, one of which is the statement of certain things as facts which, as I shall presently show, cannot possibly exist and are inconsistent with other facts stated in the same article and known from other sources to exist as so stated; while the other main element consists of rather vague statements concerning general principles which, though in a general sense true, yet as here used are calculated to cover up or befog the too obvious inconsistencies of the statements of facts with the established principles of science.

As an example of the first element, we find on page 400 as follows: "I have actually made about ten gallons of liquid air in my liquefier by the use of three gallons in my engine." This I shall presently show is simply impossible and inconsistent with data given elsewhere in this article and known to be substantially correct.

A sample of the other element is found on page 399, in the following:

"That is perpetual motion, you object. 'No,' says Mr. Tripler sharply; 'no perpetual motion about it. The heat of the atmosphere is boiling the liquid air in my engine and producing power exactly as the heat of coal boils water and drives off steam. I simply use another form of heat. I get my power from the heat of the sun; so does every other producer of power.'"

This, while true as a general statement of what might be done on an impractical scale, is not correct as here used to imply that in his experiments Mr. Tripler actually derives or can derive any adequate amount of energy from the heat of the atmosphere or in that sense directly from the sun. This I shall show later, but will first take up the statement that three gallons of liquid air have supplied or can supply the power to liquefy ten gallons.

On pages 402 and 403 of the McClure article we are told that Mr. Tripler uses to make his liquid air a steam engine of 50 horse power and that with this he can make liquid air at the rate of 50 gallons a day. This I know, from other sources, is substantially correct, and means that each horse power in a day (say 10 hours) makes 1 gallon of liquid air. In other words, 1 gallon for 10 horse power hours.

It is again stated in this article on page 405 that a cubic foot of liquid air contains 800 cubic feet of air at ordinary atmospheric temperature and pressure, or, in other words, any volume of liquid air, if adequately heated, will expand 800 times in reaching atmospheric temperature and pressure. This also is substantially correct.

We may remark in passing that this is nothing wonderful; for water, when expanded into steam at atmospheric pressure, increases about 1,700 times in volume, or more than twice as much as liquid air.

Now if we apply to the above data the well known and universally accepted formula for the maximum work done by air when expanded at constant temperature,

$$W = p_2 v_2 \text{ hyp log} \frac{v_2}{v_1}$$

we find that a pound of liquid air in expanding 800 times would develop about 190,000 foot-pounds of work. As a gallon of liquid air weighs about 8 pounds, this would give eight times as many foot-pounds, or 1,520,000. If this work were accomplished in an hour, it would represent almost exactly three-fourths of a horse power, because one horse power means 1,980,000 foot-pounds of work per hour, and 1,520,000 is only a trifle over three-fourths of this.

From the above it follows as a matter of absolute certainty that the maximum power which liquid air could develop in an ideally perfect engine without any loss from friction or other cause would be three-fourths of a horse power for an hour for each gallon of liquid air expended.

We have seen, however, that with his 50 horse power plant, which on account of its size should operate with considerable efficiency, Mr. Tripler makes only 1 gallon of liquid air with 10 horse power hours. In other words, he requires to make a gallon of liquid air twelve times as much power as a gallon of liquid air could possibly develop in an ideally perfect engine.

In face of this, how supremely absurd is the statement that with a little engine such as the pictures and descriptions in the McClure article show, lacking all conditions for efficient working, Mr. Tripler can make 10 gallons of liquid air by the use of three.

Turning next to the statement about using the heat of the atmosphere to develop mechanical energy or work, let us put this to the test of a quantitative example.

Assume the temperature of Mr. Tripler's laboratory to be 70° F. and that he has an abundant supply of water at 50° F. These will be of necessity the limits of work he can get out of the atmosphere, because any lower temperature is only secured by doing work and so expending energy which will be at least equal to the power obtainable from the use of such lower temperature. All the work that can be obtained for nothing is that which nature will freely give in the warm air and cool water, supposing both to be supplied freely without charge.

The 20° F. which we may assume as being possibly taken out of the air by the cool water will represent the maximum gift of nature in this shape of "power costing nothing." Now, 42 British thermal units or pounds of water changed 1° F. per minute will represent one horse power, and as the specific heat of air is about one-quarter that of water, we should need four times as many pounds of air to produce the same effect. This would call for 168 pounds of air changed 1° F. If, however, the air is changed 20° F. in place of 1° F., we need but $\frac{1}{20}$ or 8·4 pounds of air parting with 20° F. each minute, to give us 1 horse power at 70° F. For "round numbers," let us say 8 pounds. Now, a pound of air has a volume of about 13·3 cubic feet. Call this also, for "round numbers," 13 cubic feet, then 8 pounds of air would be about 104 cubic feet, and this volume of air would have to part with its 20° F. heat each minute to the apparatus, in order to develop one horse power. For a 50 horse power engine fifty times as much air would be required, or 5,200 cubic feet each minute; this would be the contents of a room 26 × 20 feet on the floor and 10 feet high, which would have to be drawn through the apparatus each minute in such a way as to completely yield its 20° F. between 70° F. and 50° F. What sort of a boiler or heat-absorbing apparatus can we imagine which would absorb from air at 70° F., 20° F. of its temperature while the said air was passing through it at the rate of 5,200 cubic feet a minute?

It would surely need to be "as big as a house," to use a familiar phrase.

This also, be it remembered, makes no allowance for loss by friction, eddy currents, and the like, which would be enormous, nor for the power to put this air in motion.

Obviously, such a machine would be simply huge in size, and, indeed, the friction involved in it would probably use up a large part of the power it could develop.

Suppose, however, that it could be built and operated in place of Mr. Tripler's 50 horse power steam plant. Its entire output would be 50 gallons of liquid air a day, and this, as we have seen, could only develop in an ideally perfect engine ¾ horse power for an hour for each gallon or 3¾ horse power for a day of 10 hours.

This does not look as if heat obtained from the atmosphere and operating an engine by aid of liquid air is likely to become a dangerous rival to the coal mine.

On page 402 of the McClure article it is stated that Mr. Tripler makes his liquid air at a cost of twenty cents a gallon.

We have shown above that the maximum power obtainable from this liquid air, by heating it to ordinary atmospheric temperature, is ¾ of a horse power hour. This, at twenty cents, would be vastly more expensive than power derived from an ordinary steam engine, whose cost ranges from less than one cent per horse power hour under the best conditions to three or four cents, where a profit is included, or the conditions are less favorable.

The really difficult thing to explain in connection with this McClure article on Mr. Tripler and his liquid air, is how those concerned in its publication (being as I do not doubt honest men) can be deceived or have so deceived themselves as to make and repeat such obviously impossible statements.

In this connection, however, I will make a suggestion founded on experience.

Some years ago I was called upon to examine an engine operated with liquid carbonic acid, which was said to have ten times the efficiency of an ordinary steam engine.

I of course told the applicant that such a thing was physically impossible and did not deserve investigation, but, finding that a number of substantial people had been so impressed by what had been shown them that they would not be satisfied without an investigation, I consented to make one. This proved an easy piece of work. I found that the promoters and others were under the impression that a horse power was measured by the raising of 33,000 pounds one foot high irrespective of time, and in their demonstrations were contented with showing that their engine did this amount of work in ten minutes. As, however, a horse power involves the raising of 33,000 pounds one foot high in one minute, it was obvious that the power shown by the carbonic acid engine was $\frac{1}{10}$ of a horse power and not one horse power, as those exhibiting the engine claimed.

This, of course, explained the situation. An engine developing $\frac{1}{10}$ of a horse power might easily require only $\frac{1}{10}$ as much fuel as an ordinary steam engine developing 1 horse power, without violating any of the established laws bearing on this subject. The curious thing was that such people as were concerned in this matter should have been misled on such a simple and elementary subject; but if they were, as I personally know, so misled, why may not Mr. Tripler and his friends be in a similar case?

I could give from my own personal experience many like examples, but have said enough for the present to make it evident that what is claimed in this McClure article as a new source of "power which costs nothing" is not founded on fact, but is probably the result of some oversight in observation or calculation not inconsistent with honesty of intention.

THE NEW SATELLITE OF SATURN.

Prof. William H. Pickering, as the discoverer of the new satellite of Saturn, suggests that the name "Phœbe," a sister of Saturn, be given to the new satellite. Three of the satellites, Tethys, Dione, and Rhea, have already been named for Saturn's sisters, and two, Hyperion and Iapetus, for his brothers. The direction of the motion, which is toward Saturn, shows that the apparent orbit is a very elongated ellipse and that it lies nearly in the plane of the ecliptic. Prof. Asaph Hall has pointed out that this is to be expected in a body so distant from Saturn. The attraction of the latter only slightly exceeds that of the sun. Hyperion appears as a conspicuous object on the plates which have been taken by direction of Harvard College Observatory, and the new satellite appears about a magnitude and a half fainter on each. As seen from Saturn it would appear as a faint star of about the sixth magnitude. Assuming that its reflecting power is the same as that of Titan, its diameter may be about 200 miles. It will, therefore, be noticed that while it is probably the faintest body yet found in the solar system, it is also the latest discovered since the inner satellites of Uranus in 1851. Prof. James E. Keeler, director of the Lick Observatory, says: "Considering the extreme faintness of the satellite and its great distance from Saturn, it is not surprising that this discovery was not made by visual observation. With a great telescope directed to Saturn the satellites would be far beyond the limits of the field."

The last discovery of a satellite of Saturn was made in September, 1848, by Prof. W. C. Bond, then director of Harvard College Observatory, and his son, Prof. George P. Bond. The satellite Hyperion was seen by his son September 16 and 18, but its true character was first recognized on December 19, when its position was measured by both father and son. Soon after it was discovered independently by Laselle at Liverpool.

PROGRESS OF THE ZOOLOGICAL PARK.

Two new buildings are rapidly nearing completion in the grounds of the new Zoological Park. These are the reptile house and the winter house for birds. The Park Department is also constructing walks and roads and is laying sewer and water pipes. Much work has also been accomplished upon the various outdoor animal dens. In a hollow in the park is a body of water which will be utilized for aquatic rodents. The beaver pond is also ready, while up on the elevated portions among the rocks work on the bear dens is well under way. Owing to the configuration of the park, many of the outdoor inclosures need but little changing beyond fencing in. The work on the buffalo house is rapidly progressing.

THE English Society for Checking the Abuse of Public Advertising, or "Scapa" as it is called for short, has approached the Chancellor of the Exchequer with the suggestion that exposed advertisements should be taxed, contending that a moderate impost would tend to greatly reduce the volume of displayed advertisements without causing any real loss or hindrance to legitimate forms of advertising. The Chancellor replied that he could only regard the matter from the point of view for revenue, and he could not see on what ground the tax on advertisements could be defended unless newspaper advertisements were included.