in some way as by a vote for supplies. At present it has neither treasurer nor funds.

The study of soils under identical conditions, as illustrated and described in the SCIENTIFIC AMERICAN for December 3, 1898, has been carried on, and the results may be regarded as important. By far the greater part of the force of the division during the past fiscal year has been employed in the investigation of food products. The particular subject of food study which has been investigated is the preservation of meat by sterilization, otherwise known to commerce as "canned corn beef" and "canned roast beef." The scope of the investigation has been twofold. In the first place, the chemical composition and nutritive value of the meats have been determined. The results of this investigation has been to supply us with a definite idea of the food value of all the various products which have been examined carefully, and systematic research has been made for preservatives of all kinds which may have been used in or on these meats. Investigations have been also carried on in the culture of sugar beets and the production of beet sugar. Many thousands of samples have been received and careful analyses have been made, the results of which work were valuable in defining with greater accuracy the lines of the most successful beet culture in the country.

FACTS VERSUS CLAIMS FOR LIQUID AIR.

BY HUDSON MAXIM.

Liquid air is such a strange substance and so readily lends itself as a plaything for the imagination as well as for the hands, that many have been ready to believe the most absurd things concerning it. When it was first discovered that air could be liquefied, it was so very expensive as to preclude any serious considerations of its usefulness except as a scientific curiosity. But when Tripler showed that it could be produced by the gallon, and at low expense when compared with its cost by earlier methods, the question naturally arose concerning its commercial value.

So extraordinary are some of the claims which have been made for liquid air as a motive fluid, that the public eye is beginning to look askance at its mere mention in connection with any commercial application. This is unfortunate, both for the public and for the promoters.

Ignoring propositions for the production of perpetual motion by liquid air, which have been made and exploded, let us consider claims which are now being made by advertisers in the public press, from which I quote the following:

> "The use of liquid air in the generation of power on land and sea will reduce the cost to one-half of that now paid for steam power. This statement carries its own argument, and needs no elaboration."

> "In the production of motive power, liquid air has a wonderful future as a fuel saver. Liquid air, after a short exposure, loses most of its nitrogen (the chief obstacle to combustion), and the resultant oxygen used in connection with carbon (coal, coke, etc.) produces perfect smokeless combustion, avoiding the large percentage of loss now incurred in the use of fuel."

Liquid air is not a magic wand by which miracles may be wrought, and yet it is hard to see how, without the enlistment of the miraculous, such results can be accomplished.

Examining the first of these claims, let us compare liquid air with steam as a motive fluid, under like conditions, in a triple expansion marine engine. It is common for such an engine, with 250 pounds steam, to produce a horse power hour for every 1½ pounds of coal consumed. Now, suppose we were to substitute liquid air for the water. We should still require boilers for its evaporation, and to make it as economical as possible, let us assume that we heat it to the temperature of steam at 250 pounds pressure; in other words, to 406° F. It must be assumed that the air is to be expanded 4½ times, which is the average ratio of expansion in compound triple expansion engines at the present time. To determine the weight of any motive fluid required for 1-horse power hour, we have the following formula:

$$W = 183{\cdot}45\ T\left(1-\left(\frac{T''}{T'}\times\frac{T'}{T}\right)\right),$$

in which W is the work in foot-pounds, T is the initial temperature, T' is the temperature after expanding to do work, and T'' is the temperature after expanding from the last temperature to atmospheric pressure. (Clarke's Manual of Rules, Tables, and Data, page 909.)

Solving the above formula, the result obtained is 78,607·6 foot-pounds, as the energy in 1 pound of air at 250·3 pounds pressure, and 406·2° F. temperature.

Therefore, 1-horse power hour would consume 1,980,000 ÷ 78,607·6 (foot-pounds in 1 pound of air) = 25·19 pounds of liquid air. It would take 0·7 of a pound of coal to evaporate this amount of air and superheat it to the temperature of saturated steam at 250·3 pounds pressure (406° F.). Hence, we should need nearly half as much coal per horse-power hour for the air as for water. By any means now known which could be employed on shipboard, the amount of heat which could be absorbed from the air and water and utilized would in practice be a negligible quantity. As air could not be re-condensed like water, we should be obliged to load up with enough liquid air to last the whole voyage without re-condensation.

The engines of the "Teutonic" develop about 20,000 horse power. This would require 242 tons of liquid air per hour, 5,829 tons per day, and 40,807 tons for a seven-days' voyage, considerably more than enough to float the vessel.

Some have made the claim that liquid air can be made as cheap as 2 cents per gallon. Let us assume, for argument sake, that such be the cost. This would be $4.28 per ton, and liquid air enough to take the "Teutonic" across the ocean would cost $174,560. In other words, it would cost this sum to save about half the coal bill.

This is, of course, without taking into account the additional horse power which would be required to carry the enormous cargo of liquid air necessary.

Referring to the second of the claims above quoted, it requires about 2⅔ pounds of oxygen to burn 1 pound of carbon. Air contains 22·92 per cent, or, roughly, 23 per cent of oxygen. A gallon of liquid air weighs about 9·351 pounds, 2·143 pounds of which is oxygen. If the nitrogen were separated so that all of the oxygen were saved, and if this could be done without expense, and if liquid air could be produced for 2 cents a gallon, then the oxygen would cost 0·9333 cents per pound, or $18.67 per ton. Now, let us assume that the coal costs $3 per ton. It would, therefore, cost $49·80 to save $3 worth of coal.

In regard to the value of liquid air for refrigerating purposes, of course much will depend upon the cost of its production. The latent heat of liquid air as calculated from data given by Sloane is 140 heat-units. As the specific heat of air is 0·2377, it would require 81·91 heat-units to raise 1 pound of air from its boiling point to the freezing point of water, or to the temperature of melting ice: 81·91 heat-units added to 140 heat-units = 221·91 heat-units. As the latent heat of ice is 144 heat-units, liquid air has a frigorific value above ice of 77·91 heat-units per pound. Yet, ice has many advantages above liquid air, not the least of which is its power to maintain adjacent bodies at the freezing point without actually freezing them.

For the preservation in transportation of substances which would not be injured by freezing, and by reduction to an exceedingly low temperature, liquid air might have an especial value in the saving of freight on ice, particularly when such substances contain a very high percentage of water. This is a proposition which I have never seen discussed, and it may, perhaps, be worthy of consideration. Let us take, for example, beef, which contains such a high percentage of water that we may consider its specific heat when frozen, as that of ice. The meat could be placed in a bath of liquid air before packing for shipment, and its temperature reduced to 313° below zero Fah. The specific heat of ice being 0·504, and the temperature of liquid air below zero Centigrade being 344·6° F., we have 344·6 × 0·504 = 174 heat-units. It would, therefore, require about 20 per cent more heat to raise the temperature of a pound of beef up to the melting point of ice than would be required for melting a pound of ice. Hence, the beef could be made to carry its own cold, as it were, and without the use of additional ice. This might be a means of saving considerable freight, as I have said. Yet, we must take into account that the rapidity with which heat is radiated or lost is as the square of the difference in temperature of bodies, and it would be necessary to carefully insulate articles so refrigerated for shipment.

With regard to the use of liquid air for internal combustion engines or explosion motors, it is estimated that in the Diesel motor, which is one of the most economical, both for the fuel and air consumed, it requires about 10 pounds of air to produce 1-horse power hour. This would require about 1 gallon of liquid air per horse-power hour; and if liquid air can be produced at 2 cents a gallon, then it would cost, in addition to the fuel, 2 cents per horse-power hour.

The contingent loss of liquid air by evaporation in transportation and handling, and while motors in which it is employed are standing idle, would certainly counterbalance any advantages which might exist from having the air in concentrated or liquid form.

Liquid air will be chiefly valuable as a source of oxygen for other purposes than the production of motive power.

If liquid air can be produced cheaply enough, even at, say, 5 cents per gallon, it may be destined to find its most useful application as an ingredient of blasting agents, especially for mining purposes.

I am aware of the many difficulties which would attend such use of it, yet I believe that if it can be produced at the above price most of the difficulties in the way of its practical application in blasting agents may be overcome. I have given this matter considerable thought, and have ascertained from calculations and experiments that explosives may be made from liquid oxygen and combustibles which will rank among the most powerful known to science. Liquid air, slightly enriched in oxygen by letting a portion of the nitrogen distill off, would produce, with a suitable combustible element, a high explosive comparable with dynamite.

It must be borne in mind that liquid air as a blasting agent, especially in mines, possesses some great advantages to offset its disadvantages. For instance, there would be no thawing out required in cold weather, with attendant inconvenience and danger, and the products of combustion would be smokeless. There would be no nitrous fumes, and the gases would be far less noxious than those produced by other explosives.

It has occurred to me that some of the difficulties which lie in the way of its practical application in the manufacture of explosives might be surmounted in the following manner:

In many mining districts very cheap water power, and in others very cheap coal may be obtained. If, by these means, liquid air can be produced at the prices I have suggested, then we might, perhaps, by a specially constructed centrifugal machine separate the oxygen from the nitrogen without much additional cost. We could then use the oxygen in making explosive cartridges, and these could be packed and immersed in a bath of liquid nitrogen. As the nitrogen is more volatile than the oxygen, there would be practically no loss of oxygen from the cartridges. In this way the cartridges could be shipped for a considerable distance, or kept for a considerable time before use; but, as the material could be put up at the mine, or in the mining district, it would not be necessary that many hours intervene between its production and its use. In charging holes, they could first be chilled by a jet of liquid nitrogen, and their temperature so lowered that the oxygen would not be very rapidly driven off for some time after loading. To further protect the cartridges, they could be covered with a combustible non-conductor of heat, which would form part of the explosive.

The explosive would be so quick in its action that the holes would need only to be tamped by simply filling them with water, or by pouring sand into them, instead of ramming them in the usual way, and, in many cases, no tamping at all would be required.

To prevent tamping being blown out by the evaporating oxygen, a small and very thin copper tube could be inserted into each hole when loading, which would serve both to vent the hole and to conduct electricity to an exploder to fire the charge.

In order to allow for some evaporation, we might use 3 pounds of oxygen to a pound of carbonaceous matter in producing explosives. Three-quarters of a pound of oxygen, and a quarter of a pound of carbonaceous matter would, therefore, produce 1 pound of explosive. Oxygen, at 20 cents per gallon, would cost about 2 cents per pound. The carbonaceous matter would not cost more than half a cent per pound. We would need, therefore, 1½ cents worth of oxygen, and ½ cent worth of combustible matter. Hence, our explosive would cost 2 cents per pound. Now, if we double this cost to make allowance for incidentals, labor and interest on capital, and add another cent per pound for loss in weight by evaporation, we would still have a powerful explosive at a cost of 5 cents per pound, and one which would have some obvious advantages above dynamite, at less than half its cost.

At any rate, if liquid air can be made at a sufficiently low cost the question of its application in the manufacture of explosives for mining purposes is worthy of consideration.

A BILLION DOLLAR COUNTRY.

Every year's developments seem to justify the assertion that this is a "Billion Dollar Country." The year 1899 brought our foreign commerce for the first time past the $2,000,000,000 line, and the month of February, 1900, shows our money in circulation for the first time as more than $2,000,000,000. Thus, by a peculiar coincidence, the announcement of $2,000,000,000 of foreign commerce and the $2,000,000,000 of money in circulation are made within a single month, the totals indicating that the $2,000,000,000 line had been crossed in our commerce for 1899, the figures being official, having been compiled by the Treasury Bureau Statistics, and the Treasury Bureau of Loans and Currency. The total foreign commerce for the year 1899 was $2,074,345,242, while the total money in circulation on February 1 was $2,003,149,355. The use of figures carried out to ten places with which to show the business conditions of the country is indeed becoming surprisingly frequent. For example, the total resources of the national banks is $4,475,343,924. The latest report of the Comptroller of the Currency shows that the deposit in savings banks amount to $2,230,366,954. The total resources of all banks in the United States are given as $5,196,177,381. The amount of money for each individual is greater to-day than ever before. The actuary's estimate that the population shows that on February 1, 1900, it amounted to 77,116,000, the money in circulation being $2,003,149,355, the circulation per capita is $25.98. This gives a larger per capita than in any previous month in the history of the country.