ICE MACHINES.

II.—MACHINES ACTING BY THE PREVIOUS APPLICATION OF HEAT.

To understand the working of this apparatus it is necessary previously to explain a few peculiar properties of ammoniacal gas, chemically simply called ammonia. A solution of this gas in water is universally known as spirits of hartshorn or liquid ammonia; the gas is produced by heating an intimate mixture of chloride of ammonium (sal ammoniac) with slaked lime; the chlorine combines with the lime, the ammonia is set free, and being a gaseous substance escapes; when this gas passes through cold water it is readily absorbed, as the affinity of water for ammonia is so very great that it will dissolve of this gas 1,000 times its own volume. It is absorbed with such rapidity that when a bottle, filled with ammoniacal gas, is with its neck plunged in cold water, the water will rush in the bottle as suddenly as if previously a vacuum had been made in it; this demonstration of the rapid solution of the gas by the water, constitutes a common but striking lecture-room experiment. On the contrary, when the water is hot it will not only absorb no gas, but by heating water previously charged with it, the gas absorbed at a low temperature will be almost entirely expelled.

Another property of this gas is, that it also may be liquefied without the intervention of water. When at the common temperature of 70° Fah., a pressure of nine atmospheres, or 135 pounds to the square inch is applied to it, it will take the liquid form, and by relieving the pressure, return at once to the gaseous state. The liquefied gas is thus not to be confounded with its solution in water, having quite different properties.

Now a principle comes into play here, which has been alluded to before, and which is also at the base of the working of different machines operated by ether, water and sulphuric acid, carbonic acid, chymogene or petroleum gas, etc.; namely, when a liquid substance, by removal of pressure, is forced to assume a gaseous condition, it will absorb heat; as a general rule it is necessary to communicate heat to liquids when we wish to change them into a gaseous condition, and the greater portion of the heat will become latent, which means that no thermometer will indicate it, it is, as it were, hidden in the gas or vapor; but when we force liquids to become gaseous without giving them the heat absolutely required to assume the gaseous condition, they will take the heat from the surrounding bodies, and from themselves, that is, from the liquid remaining, from the vessel containing it, and from the sensible heat of the escaping gas,which then, by the thermometer, will indicate a very low temperature, and communicate this to all bodies they come in contact with, or in other words, absorb their heat after the laws of caloric equilibrium. The more so, when in case of a liquid which owes its condition to pressure, by removal of this pressure, we allow the liquid to resume its natural gaseous condition, it will absorb still more heat than in the previous case, and consequently the degree of cold produced will be in exact proportion to the pressure previously required to keep it in the liquid state.

As a matter of course there are practical limits; where the immense power required to liquefy certain gases would not be compensated for by the greater degree of cold produced, and on the other hand, where the volatile power of the liquid employed is small and consequently affects only a slight degree of cooling, the results cannot be of the most favorable kind.

These are the properties of which use is made in the machine now to be described. It appears to have been first practically applied to the making of ice by Carré, of Paris, who, in 1862, had such a machine on exhibition in London; its construction is so simple that it may be easily understood without figures. It consists of two vertical cylindrical vessels, of different size, at their upper ends connected by a tube; they are made of strong sheet iron; the largest of them has double sides, the space between them being hermetically closed, and at its upper part connected by means of a strong tube, with the upper part of the second smaller vessel, which is a simple upright cylinder and also hermetically closed; the vessel is filled with a strong solution of ammonia in water, or the so called *aqua ammonia fortior*. By the heating of this vessel the ammoniacal gas is driven out of the water, according to the properties explained above, and if the double-sided vessel, at the same time, is placed in cold water, the pressure of the developed gas, will be sufficient to liquefy the gas itself between the double walls of the large vessel. As soon as this is accomplished, the apparatus is ready to commence the freezing operation, the water to be frozen is placed in a proper vessel of a thin well-conducting metal closely fitting in the open space inside the double-walled larger cylinder, between the walls of which the ammoniacal gas has now been liquefied by the pressure produced by heating the smaller vessel. This smaller vessel being hot, is now suddenly plunged in cold water, the water confined inside which first had its ammonia expelled by heat, regains at once by means of the cold applied to it, its most intense affinity for this gas, it will absorb it with great rapidity, the liquefied gas in the larger vessel will be relieved from the pressure which brought and kept it in the liquid state, and it will consequently re-adopt the gaseous form, distil over as it were, to be condensed in the water of the smaller vessel, and this forced evaporation in the larger vessel, will be productive of such an absorption of heat from this vessel and the water contained in its center, that this water will rapidly be frozen to a very hard solid cylinder of ice.

Experience has taught the following rules in the manipulation of his apparatus: The heating of the smaller vessel containing the solution of ammonia in water, must be done slowly, till a thermometer connected with it shows a temperature of 260° Fah. above the larger vessel placed in the cold water, which must be kept agitated, or, better, continually renewed by a small stream, in order to keep it cool, much heat being developed or set free during the liquefaction of the gas inside. It is this same heat which is absorbed by the evaporation of the liquefied gas during the consecutive absorption of this gas by the water in the smaller vessel, which produces the freezing temperature; this heat (abstracted from the water to be frozen), will be set free again, and is thus carried to the cooling water into which the smaller vessel is placed. The operation thus amounts to the abstraction of heat from a small portion of water (to be frozen) and the carrying of it to a larger portion of water, by means of the peculiar properties of ammonia, as explained.

It is clear that after this freezing the apparatus is at once ready for another operation, the only precaution being to turn the vessel for a few seconds in such a position that any water carried over accidentally into the double-walled vessel may run back into the smaller one, so as to be sure that the double-walled vessel is entirely empty, when commencing the operation: the heating of the smaller vessel containing the solution of ammonia in water.

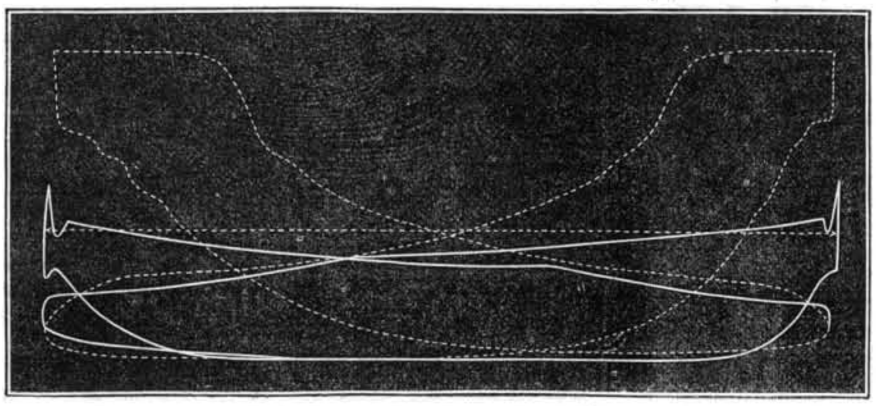
THE BEST MODES OF TESTING THE POWER AND ECONOMY OF STEAM ENGINES.

BY CHARLES E. EMERY, LATE OF THE U. S NAVY AND U. S. STEAM EXPANSION EXPERIMENTS.

Read before the Polytechnic branch of the American Institute, Oct. 22, 1868.

(Continued from page 323.)

Note.—Mr. Emery, when reading that portion of his paper which was published on page 322, exhibited the diagrams above shown in support of his position. "These," he said, "were selected from a number taken in the manner described, for the purpose of testing the accuracy of the indicator when used under different circumstances. The engine was provided with a link motion, which was adjusted first to give a certain speed with a wide throttle, and afterward shifted to full gear, and the throttle closed to give the same speed, without altering the load. The two sets of diagrams should therefore bear the same area. On the contrary, the difference can be seen with the eye. The light diagram shows a mean effective pressure of 8·6 lbs., while that of the dotted diagram is 11·06 lbs., or 28·6 per cent larger. The engine was making fifty-one revolutions per minute, and the scale of the indicator was 16 lbs. to the inch. (N. B.—The diagrams have been reduced to suit our columns.—Eds.) In this case the tardy action of the pencil of the instrument showed itself both on the steam and cushion lines, so the difference is enormous. With an independent exhaust valve, the difference in proportion would have been only about twelve per cent, and by using a stiffer spring would have been still up." Mr. Emery requested others to try the experiment themselves before expressing their views too strenuously, and then proceeded with the reading of his paper.



When the indicated power alone is used, it is important to know the probable friction of the engine, so that the net power, or that portion available for useful work, may be estimated. A favorite method is to take an indicator friction diagram from the engine, when disconnected from its load, and running at its working speed. The mean friction pressure thus obtained is supposed to be constant at all loads. Hence it is usual to deduct from the indicated working pressure the indicated friction pressure previously obtained, when the remainder represents the force available to produce motion. From this, however, is deducted the friction of the load, usually called seven and a half per cent; and the net power is calculated from the second remainder. For instance, if the mean working pressure be 42 lbs., and the friction pressure 2 lbs., 40 lbs. is available to produce motion without a load; and seven and one half per cent of this, or 3 lbs., represents the friction of the load; so that 5 lbs. pressure is lost in friction, or about twelve per cent of the whole. This mode of calculation cannot always be depended upon. We have known a case where the mean indicated working pressure in the cylinder was only 8 lbs., and the friction pressure two pounds. Consequently, by the above method, about thirty per cent of the power was absorbed by friction; but the dynamometer showed that less than ten per cent was lost in that way. Similar cases, differing only in extent, will be found quite frequent. The reason is that engines are packed for the working, and not for the friction pressure. If the steam pressure be 100 lbs., the packing must embrace the piston and valve rods with sufficient force to prevent leakage, or say 105 lbs. for every square inch of surface packed; and nearly the whole of this will produce friction, when a low pressure is used, but the full pressure will work in between the surfaces, and force back the packing, so that the friction from that source will be least when the engine is doing its regular duty. Spring packed pistons modify the friction in the same way. In very large engines the state of the packing would have little influence on the friction, though it certainly would seem proper to loosen the stuffing boxes before taking friction diagrams. In some cases engines are so weakly constructed, that, though the indicator may show little friction, without a load, there will really be a great loss when the work is being done, due to parts springing out of line, etc. The dynamometer furnishes, therefore, the only true means of obtaining the net power. In well constructed engines we should be able to calculate the friction by regarding the weight of the moving parts as part of the load,which is moving with a certain velocity in bearings of a given material, and having therefore a certain co-efficient of friction, say seven to eight per cent. For ordinary purposes, when trial is not convenient, we may assume the friction of small engines, of bad design, or of any engine with weak framing, as being from twenty to twenty-five per cent of the indicated power; while in good engines, of ordinary shape and proportions, it is sufficient to allow fifteen per cent for medium size, and as low as ten per cent, or even eight per cent, in exceptional cases, in large engines of solid construction and good workmanship.

Having described the instruments used in determining the power of the steam engine, we propose to postpone future remarks upon the proper methods of their application and use, until the closing general discussions; and we will now proceed with the next branch of inquiry; namely,

II. THE ECONOMY OR COST OF THE POWER.

Money is the standard unit of value. Hence everything which costs money, that is required in order to obtain the steam power in any case, is a proper charge to the cost of the power. Therefore, strictly speaking, the cost of the fuel, of the oil, and of needed repairs, together with the wages of the attendants, and also, perhaps, a sinking fund for prospective renewals, should all form part of the aggregate cost. Nor should either of these items be neglected. It would be poor economy for a person to purchase an engine designed to save fuel, which, for any reason, was liable to frequent derangement; for it is not alone the cost of the repairs which are to be considered, but the losses which occur from stopping work in the mill or factory. We cannot, however, in our present inquiry, discuss matters of design (though they should always be considered by a purchaser), but must confine ourselves to the methods and means employed to ascertain the economy of fuel.

The combustion of the fuel evolves heat, which uses water as a vehicle, and is carried with it to the engine, and there produces the power. The true measure of the cost, then, is the quantity of heat required toperform a certain quantity of work. Heat being imponderable, can be measured only by its effects on other bodies. The standard unit of heat, or "heat unit," is the heat required to raise the temperature of one pound of distilled water at 39° one degree Fahrenheit. The mechanical equivalent of a unit of heat is 772 foot pounds of work; but the best steam engines obtain only about one tenth of that quantity. Such a result has often been regretted by scientific minds, and many have spoken of it as mysterious. We consider the steam engine of to-day very defective. Some of the defects are inherent; they can be pointed out, but cannot be remedied without changing the general principles of construction. The majority of the practical loss has, however, never been satisfactorily explained. The writer, like others, has his own theories on the subject, but he has no desire to present them publicly till they have been tested; for if they be correct, the principal difficulties can be removed. Few appreciate the extent of the losses in the steam engine. It is only the best examplesthat utilize even one tenth of the heat. In such cases one tenth is condensed for the work, and about four tenths is wasted in the clearances and the exhausting steam, even when expansion is carried on, until the terminal equals the back pressure. The remaining five tenths are imperfectly accounted for. Cases are not unfrequent where only three to five per cent of the heat taken from the boiler is utilized in work! The discrepancies occur chiefly at the higher grades of expansion. Without expansion, it is easy to understand that most of the heat must go away with the exhaust.

When steam is generated by the application of heat in the boiler, to water only, the water, in becoming steam, always takes up a certain fixed quantity of heat; in other words, becomes saturated with it, and forms saturated steam. Hence, if we can measure the water evaporated, to produce the power of an engine, we can easily estimate the quantity of heat used. The feed water is therefore a perfect measure of the comparative cost of the power, when evaporated in a good boiler, having no superheating surface. The economy of steam machinery is, however, generally measured by the amount of coal or other fuel consumed to perform a certain quantity of work. The conventional standard of comparison between all kinds of engines is, The Number of Pounds of Coal Burned per Indicated Horse Power per Hour. The indicated power can be obtained with comparative ease, as has been explained; so also can the coal per hour. Hence the above standard has the merit of great simplicity, and consequently is used by all nations. We must therefore adopt it, or at least use it, in order to be able to compare our rsults with those of others; still the method is liable to very considerable errors, which we will examine with the view of correcting them.