level of which corresponds with that of the water in the receiving tank. Surplus steam, air, and gases are forced out through a check valve in the top of the upper cylinder by the momentum or hammer of the water, obviating the necessity of air pumps, siphons, or similar contrivances, and making a very cheap and direct-acting device for raising water. For draining mines, wrecking purposes, pumping for railroads, elevating water for supplying cities, towns, and villages, and for producing a water power by creating a head, this machine is believed to be applicable and efficient. Forty-five barrels of water can be raised twenty-five feet high per minute with this machine and a ten-horse power boiler carrying twenty-five pounds of steam.

Patented Oct. 27, 1868, by A. J. Reynolds, who may be addressed at the Detroit Locomotive Works, Detroit, Mich., or Reynolds & Newell, 17 Maiden Lane, New York city.

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 342.*)

The anthracite, as a rule, contains much more refuse than the other varieties. The English coals probably average 10 per cent of waste: the West Pennsylvania and Ohio coals have only 5 per cent, and the maximum of our bituminous coals rarely exceeds 13 per cent. On the contrary, the refuse from anthracite rarely falls as low as 10 per cent and often reaches to 24 per cent, so that, on the average, its waste is double that of the bituminous varieties. It will therefore be interesting for us to examine the results produced by the combustible portions of the different kinds of coal The part consumed is called the "combustible," and is found by deducting from the weight of the coal the weight of the ashes, clinkers, soot, etc., which can be collected after the trial. Referring again to the Navy Experiments, we find that the mean evaporative efficiency of thirteen varieties of American anthracite combustible was equal to the evaporation of 10·69 pounds of water, from a temperature of 212°, and, for the three varieties of bituminous combustible, the corresponding effect was 10·84 pounds. The results are practically identical. By throwing out of the comparison some of the varieties of anthracite, which justly have a poor reputation in the market, the preponderance would be upon the other side. If, then, we take it for granted that the average foreign and American and bituminous coals are substantially equal in value, the value of the combustible of the foreign coal will equal that of American bituminous and American anthracite, and we may assume that the combustible of the coal, burned in any case, is a tolerably accurate comparative measure of the economy of a steam engine. All these restrictive qualifications are necessary, for, if selected coal of the best quality, be used in a trial, the results will be above the average in any case. We wish simply to indicate that the greatest difference in the results given by different coals is due to the difference in the quantity of non-combustible matter, so that, if this be thrown out, the weight of the combustible remaining gives the nearest approach possible, without absolute trial, to the comparative heat-producing powers of different specimens. The best standard to show the comparative economy of the steam engine, other than that of the steam used, is therefore "The number of pounds of combustible used per horse power per hour."

We cannot fairly, however, compare the combustible per horse power per hour, used in experiments here, with other experiments when only the coal was noted. This necessitates us to correct the amount of coal used by a common standard, founded on the combustible. Good bituminous coals, here and in England, leave about 10 per cent refuse; hence, to make our experiments compare with those abroad, as well as for convenience, we suggest that in every case, the coal burned in determining the economy of a steam engine be reduced to a common standard of 10 per cent refuse. Let us see the effect of this. The true comparative test for engines is the amount of heat they receive; we have shown that the heat-producing power of the coal is proportioned to the weight of the combustible; hence, if the weight of the coal be also proportioned to that of the combustible, it also expresses the relative economy. The coal is so proportioned when it leaves the same percentage of refuse, so by our plan of correcting the weight of the coal by its combustible, so as to give 10 per cent refuse in each case, the weight of the coal is a true comparative test of the relative economy of the engine. For instance, 100 pounds of coal leaving 20 per cent refuse will evaporate no more water that 88·9 pounds leaving 10 per cent refuse, for both contain only 80 pounds of combustible. If to the combustible we add one ninth of its weight, the quantity added is one tenth, or 10 per cent of the sum, which represents the weight of the coal, corrected to the uniform standard of 10 per cent refuse. Suppose a horse power in a certain foreign steamship costs 2·8 pounds of bituminous coal per hour, and in an American vessel it costs 3 pounds of coal, using anthracite, are we to say our engines are inferior? Let us see. We first deduct the refuse from the anthracite—for instance, 20 per cent, which leaves 2·4 pounds of combustible. This, then, is nine tenths of the weight of coal having ten per cent of refuse; so multiply 2·4 by $\frac{10}{9}$, gives 2·67 pounds as the true cost of the power in the American engine, to compare with 2·8 pounds used by the foreigner, when both are compared by the same standard.

We have been thus explicit because the fuel is so generally used in the comparison of the performance of steam engines. The coal bills of course show the absolute cost of the power in any particular case, no matter what quality of coal was used; but, under such circumstances, the weight of coal consumed, even when corrected as above pointed out, is, as must be seen, but an imperfect comparative measure. To make comparisons sufficiently correct to answer the demands of science, we must measure the steam used in each case—in other words, compare engines by the Number of Pounds of Steam used per Horse Power per Hour.

The calculations are usually made from the pressure shown at the termination of the stroke; the assumption being that the engine uses, at every stroke, one full cylinder of steam at that pressure. In other cases, however, the initial pressure, and the portion of the cylinder filled at the point of cut off, are used in the calculation. These methods of determination pre-suppose that dry or saturated steam enters the cylinder, which may be true, and that the steam continues in this state, through at least part of the stroke, without condensation, which is never the case. Steam is necessarily condensed to set free the heat transmuted into the work done; and the temperature of the metal of the cylinder is a mean of the temperature to which it is subjected, and therefore forms a condenser with respect to the initial steam. The consequence is, that there is always more steam taken from the boiler than is shown by the indicator; the discrepancy increasing with the degree of expansion and amount of external refrigeration. Clarke, in his work on the locomotive, points out great differences between the amount of steam calculated from the initial and terminal pressures shown by the indicator; and yet uses the first in all his calculations. Later experiments, where the steam has been actually measured, show that in small engines twenty to thirty per cent of the steam is unaccounted for by the indicator at full stroke; and as high as sixty to eighty per cent when the steam is expanded considerably. Large engines show a small discrepancy at full stroke, which rises to thirty, and often fifty per cent, with shorter admissions. The best examples of the English double cylinder pumping engines use thirty-three per cent more steam than is shown by the indicator or the cylinders. This method of determination is therefore absolutely worthless for our purpose, as it furnishes no basis for reliable comparative tests. To these discrepancies must be attributed the losses which are known to arise in the steam engine. They have been ascertained, in practice, by indicating the engine and measuring the water pumped into the boiler, and evaporated there, to furnish steam. In other cases, the exhaust steam of the engine has, by surface condensation, been reduced to water, and its quantity determined by measuring or weighing it. The weight of feed water, or, what is the same thing, of steam used in any case, to produce a given power, may, by either of these plans, be ascertained with scrupulous accuracy; and if the coal be weighed at the same time, the evaporative efficiency of the boiler can also be determined, and the excellence of both engine and boiler be detected and credited aright.

In addition to the standards above given, expressing the economy of the engine, others of special application are used, which give the cost in terms of that which costs money everyday; namely, the coal, and the result in that which returns the money. For instance, the miller speaks of the number of pounds of coal it requires to grind a barrel of flour—a thing, by the way, which may depend as much upon the condition of the mill as of the steam machinery. Locomotives are rated by the number of pounds of coal or coke burned per tun, per mile. So, also, what is known as the "duty" of a pumping engine, is the number of foot pounds of work derived from the consumption of a certain quantity of coal.

Having discussed the various measures and means that may be employed for our purpose, we desire next to select such as will be useful in particular cases, and show their practical application, which leads us to

THE METHOD OF CONDUCTING EXPERIMENTS.—I. TESTING BOILERS.

The power of an engine can never exceed that of the boiler which furnishes it with steam; hence, it is eminently proper that we should first select measures to ascertain, in a given instance, whether the steam is economically generated. As has been said, the heat producing power, or evaporating efficiency of a boiler, is measured by the number of pounds of water evaporated per pound of coal from a given temperature, say 212° Fah. We have therefore to weigh the water evaporated, and the coal producing the evaporation—a very simple thing apparently, but one about which there is much misapprehension, resulting in statements grossly erroneous and ridiculous. The water may be measured in a tank or barrel, the contents of which have been ascertained by careful measurement, or by weighing water into it of a given temperature. When experimenting, the water in the tank should be pumped out dry if possible, or at least to a given mark; the pump then stopped, the tank re-filled to the proper hight (the easiest way is to overflow it), when the supply can be shut off and the operation repeated. The supply pipe should be arranged so that the water can be seen entering the tank, and leakage detected while the pump is working. The better way is to have a hose to throw in and out of the measuring tank. Before making even experiment, it should be ascertained if the boiler foams or raises water; if so, it must be remedied before proceeding farther. All leaks about the tank, pump, and boiler, should be stopped; and all extra pipes leading water in or out of the boiler be disconnected, or frequently examined. The steam generator may be worked off in the engine, blown off through the safety valve, or otherwise disposed of, so long as no water is lifted with it. The latter is less liable to happen when the evaporation takes place under considerable pressure. The greatest care is necessary in commencing and ending experiments. There are two methods of doing this. The first is to measure the temperature and hight of the water in the boiler, and, immediately upon starting the fire, to keep an account of the fuel consumed, until the close of the experiment; then to weigh the coal and ashes hauled out of the furnace. This involves a calculation to ascertain the heating effect of the fuel used in generating steam. It is of little value for the purpose of comparison, for the shell of the boiler and its surroundings (often a heavy mass of brick work) has also to be heated; and of this no estimate can be formed. The better plan is to get every thing in average working condition before starting the experiment. The steam should have the proper pressure, the fire be clean, and of a certain thickness, judging by marks on the sides of the furnace, the ash pit clean, and the water at a certain known hight. The experiment may then proceed, weighing all the coal afterward used, and measuring the water pumped into the boiler, till near the desired time to stop, when the fire should be thoroughly cleaned and filled up with coal to the same marks as at the beginning; and should be maintained at that point, with the steam at the starting pressure, till after pumping in the last tank of water, when, as soon as the water level reaches the same hight as at starting, the experiment may be terminated. The ashes in the pit should then be weighed, as well as those previously collected. The fire should be equally bright, and the steam pressure the same at the beginning and end of the experiment, so that the water level will be disturbed in like manner. At stopping or starting a certain feed should be kept on; or the water should be pumped too high, and time noted when, by evaporation, the level falls to the mark. No experiment should be less than eight hours in length; and a trial of forty-eight to seventy-two hours' duration can better be depended upon. During the experiment a log should be kept, upon which should be recorded the time, the weight of the coal and ashes, the number of tanks of feed water, and the temperature of each. The temperature of the escaping products of combustion, and of the fire room, may also be noted; as well as any evident remarks about the kind of coal, and the circumstances of the trial. After the experiment, the following calculations are necessary: First, in an evident manner, ascertain the total amount of coal and ashes, subtract one from the other, which gives the total weight of the combustible. Then find the average temperature of the feed water, and the average pressure of steam. Then calculate the weight of the whole quantity of water evaporated, making allowance for its temperature.

(To be continued.)

Correspondence.

The Editors are not responsible for the opinions expressed by their correspondents.

Steam Engine Indicator.

MESSRS. EDITORS:—I have read with surprise the criticisms on the indicator as a means of ascertaining the power exerted by steam engines, contained in the paper by Mr. Emery, published in your last two numbers. The writer says that its indications have been shown to be of a most unreliable and deceitful character, even in those respects in which they had heretofore been considered practically perfect; and that although the Richards Indicator is undoubtedly a great improvement upon the old style, still the best of these instruments give, at fifty revolutions of an engine per minute, when cutting off at an early point of the stroke, diagrams which have been demonstrated to be erroneous by from ten to twenty-five per cent. He describes an experiment by which he states that any one may prove the existence of these errors, and then attempts to show that they are unavoidable.

The connection leaves it to be inferred that this startling discovery has been made in the course of the experiments on steam expansion, which have for several years been carried on by the Navy Department. This show of authority, together with the candor and evident sincerity of the writer, is likely to carry some weight; and the charge might, if permitted to pass unchallenged, be regarded by many as confessed.

Now, nothing can be more certain than that the defects here attributed to the indicator have no existence. The action of this instrument has been investigated too thoroughly, by too many able engineers, and under too many varied conditions, to permit confidence in it to be shaken by any statements inconsistent with the general experience. I cordially unite in recommending experiments of the character suggested by Mr. Emery to be generally made; and whenever these are properly conducted, it will be found that all the diagrams taken from an engine when exerting the same power, however they may differ in their outlines, instead of presenting the discrepancies stated, will contain the same area exactly.

Mr. Emery accounts for these imagined errors by supposing that the inertia of the moving parts of the instrument compels the indications to be tardy. Let it be assumed that such tardiness of action exists, in a degree sufficient to account for the least amount of error stated; namely, ten per cent at fifty revolutions of the engine per minute. Then, if the speed of the engine is increased, this error also must increase in the same ratio in which the power required to overcome the inertia of the moving parts increases; or as the square of the speed, and at four hundred revolutions of the engine per minute will amount to six hundred and forty per cent, and we find ourselves far beyond the limit of speed at which the indicator can give any diagram at all. But I have taken diagrams with the Richards indicator at four hundred revolutions and over per minute, which were demonstrably perfect, although the entire figure was completed in less than the one seventh part of a second. I have also taken diagrams from locomotive cylinders at two hundred and sixty revolutions per minute, in which the admission line was carried by the momentum of the moving parts, much above the point which