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PETROLEUM:

PETROLEUM *vs.* COAL FOR GENERATING STEAM

BY PROF. R. A. FISHER.

Gentlemen,—I herewith submit a report of a series of experiments, made at your request, with the apparatus of Mr. G. Hill, No. 606 Ninth avenue, New York, to determine the value of petroleum as a fuel, when its vapor is burned in presence of steam, by the method devised by Mr. Hill.

The value of any fuel, liquid or solid, depends upon its heat-giving power—the quantity of heat it evolves during the act of burning. This can be determined by three methods: 1. By the system of Lavoisier and La Place, in which the substance is burned in the centre of a vessel, the walls of which are lined with ice—the quantity of ice melted measuring the heat disengaged 2. By the "Calorimeter" of Watts and Rumford, in which the degree of heat communicated to a given quantity of water indicate the amount of heat produced. 3. By the quantity of water *evaporated* at a given temperature by a given weight of fuel.

It is now the usual custom, in making experiments upon the calorific power of different fuels, to follow the second or third method, or a combination of the two, *i. e.*, with a given weight of fuel, to heat in a boiler to 212° F., or a higher temperature, a known quantity of water, and afterward to convert as much of this hot water as possible into steam.

The amount of heat required to raise a gallon of water from 60° to 212° F. (its boiling point,) or to convert an equal quantity of boiling water into steam at the same temperature, has been accurately determined. Experiment proves that the heat requisite to raise 6.36 gallons of water from 60° to 212°, is sufficient to convert only one gallon of boiling water into steam; but if water be heated in a closed vessel from 60° to 268° (until a pressure of 40 pounds to the square inch be produced), the heat required to raise 4.38 gallons to 268° will convert one gallon of this water into steam of the same temperature.*

With these figures it is an easy matter to calculate the amount of heat produced by the burning of any fuel, whether the heat be employed to warm a given quantity of cold water, to convert boiling water into steam, or, combining these operations, to elevate cold water to the boiling point, and afterward convert a portion or all of it into vapor.

In former years, the effect of a given quantity of coal or other fuel, was estimated by the performance of an engine supplied by the steam produced. But this method complicates the question of the *production* of steam with its *application*. The practical question of the comparative value of any fuel, is answered most simply and satisfactorily by ascertaining the quantity of water that can be evaporated by a given amount of such fuel, when burned to the best advantage.

This was the object in view when undertaking the experiments now to be described, made in a locomotive boiler of the following dimensions:

Inside length	46	inches.
" diameter	24	"
Dome	10 " high. 12 " diameter.	
Fire box	16 x 24	inches.
Diameter of flues	1¾	inches.
Length of "	24	"
Number of "	20	

Evaporating surface at 1st cock, 19 x 16—974 sq. inch.
" " 2d " 21 x 46—966 " "
" " with 2 gallons of water above 1st cock, 922 " "

Capacity of the boiler to 1st cock .....40.5 galls.
" " " 2d " .....50.75 "

The apparatus of Mr. Hill, employed in the experiment of burning the vapor of crude petroleum with steam, consists essentially of a copper "retort," connected with two "feeding pipes" and a series of seven iron tubes, each furnished with three bat-wing burners. The whole arrangement is fitted into the fire-box of the boiler. The "feeding pipes" are of wrought iron (1 inch in diameter and about 50 inches long,) bent in an S form, and connected with the "retort" in a horizontal position. One pipe communicates with the "petroleum can," the other with the boiler. These feeding pipes are furnished with rotary valves, by means of which the quantity of petroleum or steam let into the "retort" can be regulated at pleasure. The "retort" is a box, made of ¼ inch thick copper, 17 inches long, 2¼ inches deep, 5¼ inches wide, outside measurement. When about to operate with this machine, the "retort" is heated to a greater or less degree, by wood or other material, and petroleum is allowed to flow into it. Here this substance loses the liquid form, and mixing with steam, (let in simultaneously by the "steam feeding pipe,") passes into the seven wrought iron tubes, (1 inch diameter and 16¾ inches long, arranged in a gridiron form,) and thence to the twenty-one burners, at the points of which the combustible material is inflamed.

The experiments with this apparatus were thus conducted. Water was let into the boiler up to the "first cock"; this was then closed, and two gallons more of water added. With these 42.5 gallons in the boiler, a fire was kindled by wood moistened with petroleum. As soon as the "retort" was thought to be sufficiently hot, the petroleum was permitted to flow into it, and here the vapor, as fast as produced, was mixed with air supplied by a "blower." When a sufficient "head of steam" had been raised, the blowing was discontinued, and steam introduced into the "retort" instead of air. The evaporation of the water in the boiler was then allowed to proceed (under pressure of 40 pounds to the square inch,) carefully noting the quantity of petroleum run into the retort during every thirty minutes, and the time required to evaporate two gallons of water, as determined by the period between pumping this quantity into the boiler, and the falling of the contents of the same down to the first cock.

After continuing the observations for several hours, the supply of petroleum was cut off, the steam-valve opened, and fifteen hours afterward, when the contents of the boiler had cooled to the ordinary temperature, water was pumped into it from the tank, and the quantity required to bring the level to the first cock carefully noted. By this means was accurately ascertained the total quantity of water evaporated, as well as the amount of petroleum consumed.* But, as the material used for heating the tubes and retort before the steam was "up" was not weighed, as the petroleum did not burn quite as advantageously during the early stages of the experiment as afterward, and as no correct estimate can be made of the effect of the blower, nor, (owing to expansion,) of the amount of water evaporated before the contents of the boiler first fell to the lower cock, the figures thus obtained give but an approximative result. The exact amount of water evaporated by a given quantity of the petroleum, is, however, indicated by the following figures, obtained an hour after the consumption of petroleum and evaporation of the water were proceeding very regularly.

1st—2 gallons	evaporated in	19	minutes.
2d—2 "	"	21	"
3d—2 "	"	20	"
4th—2 "	"	20	"
5th—2 "	"	21	"
Total, 10 "	"	101 min.—1.683 of an hour.	

In 105 minutes (1.75 of an hour) the quantity of petroleum run into the retort was 1.68 of a gallon, the flow being kept up as regularly as possible, and varying only a few hundredths of a gallon during every thirty minutes.

From these figures we obtain the following:

Quantity of water evaporated per hour, 5.95 gallons.
" of petroleum consumed " " .96 "
Hence, 1 gallon of petroleum evaporated 6.197 "

The petroleum used in the experiments was the "crude" article, of specific gravity 0.787 (48° Baum.,) and weighs 6.296 lbs. (6 lbs. 5 oz.) per gallon. Hence, 6.296 lbs. of the petroleum employed, evaporated 49.576 lbs. (6.197 gallons,) or 1 lb. of petroleum evaporated 7.81 pounds of water.

It now remained to determine the cost of generating steam with *coal*, in the same boiler, and at the same pressure. For this purpose, the apparatus of Mr. Hill was removed, and in its stead a grate (composed of fifteen rods, nineteen inches long, of five-eighths inch round iron, placed at the distance of three-eighths of an inch apart) was fitted into the fire-box.

The boiler was charged, as in the preceding experiment, with two gallons of water above the first cock, and the water-tank with 24 gallons. The fire was kindled with—

6 lbs. wood,
4 " charcoal,
40 " anthracite coal ("egg size.")

Depth of fire, 3—4 inches. An hour and forty minutes after "lighting up," steam commenced to "blow off," at a pressure of forty pounds to the inch, and during the next hundred minutes the water in the boiler was evaporated down to the first cock. The experiment was continued during four hours and thirty-five minutes, pumping in water as required (two gallons at a time, as in the petroleum trial) with charges, at first, of four pounds, and afterwards six pounds of coal, till a total of eighty-four pounds of anthracite had been put into the furnace. The fire was "drawn" thirty minutes after putting in the last charge, the "coals" quenched with water, screened,

* This calculation is based upon the figures given by Regnault (967.5 degrees F.), for the "latent heat" of steam, and assuming the sum of the latent and sensible heat of steam to be the same (1179.5 degrees) at all temperatures; though Regnault has proved that this rule is not absolutely correct, the variation from it is too small to be here taken account of.

* The petroleum was run into the retort, through the feeding tube, from a tin can, 18¾ inches high and 4¾ inches in diameter, the quantity consumed from time to time being measured by a gauge, graduated to read to the one hundredth part of a gallon. The water was supplied to the boiler by a force pump worked by hand, from a tank, accurately gauged, which, at the beginning of each experiment, was filled with 24 gallons of water.