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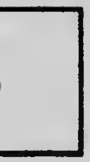

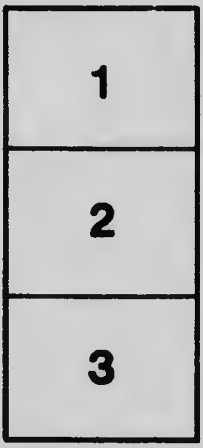

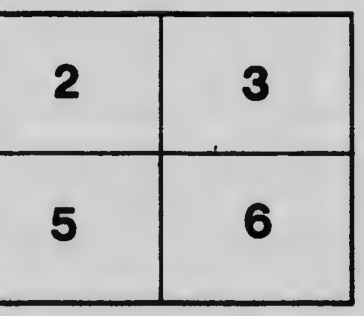

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THE ECONOMIC ADMISSION OF STEAM TO WATER-GAS PRODUCERS OF THE LOWE TYPE.

BY G. W. MCKEE.

It is the general practice of water-gas operators to vary the quantity of steam admitted according to the conditions of the producer, these conditions being:—(1) Temperature in the generator judged by the length of the preceding "blow." (2) Depth of the fuel bed. (3) The question as to whether an up or down run is being made. (4) The length of time that has expired since clinkering. The amount of steam admitted is judged by the number of turns given to the valve, sometimes checking the working of the steam line by an observation of the nozzle pressure, taken from a Bourdon's gauge placed on the wall. The important point to which it is desired to call attention is that in every case the steam valve is left open the same amount during the whole run.

If we consider the reaction for the formation of water-gas, *viz.*—

$$\underset{1\ \text{vol.}}{C + H_2O} = \underset{1\ \text{vol.}}{CO} + \underset{1\ \text{vol.}}{H_2}$$

we have one volume of steam yielding two volumes of gas. Of course, above 1200° C. the reaction is complicated by the fact that hydrogen acts directly on carbon, forming CH_4, C_2H_6, C_2H_2, &c.; but, since the percentages of these gases in water are small, we may, for the purposes of the following argument, leave them out of consideration. Of two things we are sure, *viz.*: (1) the volume of steam used should, at corrected temperature and pressure, be approximately one half that of the gas produced; (2) if any undecomposed steam gets through the machine we are not running up to the highest efficiency; for (*a*) it is costly to produce the steam in the boiler room; (*b*) the surplus steam passing through the generator has to be raised to the heat of the coke, and this heat is abstracted from the machine; (*c*) this steam must again be condensed in the condensers, thus necessitating the pumping of extra condenser water; (*d*) furthermore, the following reaction, $H_2O + CO = CO_2 + H_2$, is liable to be set up in the space above the coke, and in the carburetter and superheater settings. This reaction begins at 625° C., and comes to an equilibrium which is in accordance with the temperature prevailing in the machine.

The experiments which follow were conducted in three water-gas machines, two of them being those of the United

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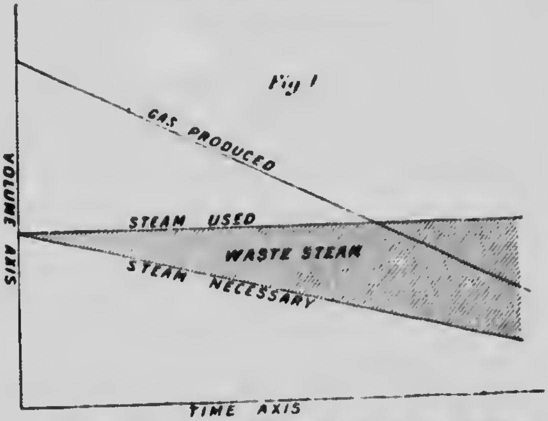


Gas Improvement Company, and the third of the Western Gas Construction Company of Indiana. The length of blow was six minutes, and the length of run eight minutes. In the first place it was observed from the scale-board in the operating room that by far the greater portion of the gas made during the run was obtained in the first three or four minutes. A ¼-in. pet-cock was then attached to the superheater of one of the machines, and a "dry run" was made. A thin-walled glass Leibig condenser was attached to the pet-cock, and it was found possible to co... water out of the gas at the latter part of the eight-minute period. Comparing, then, the gas produced and the quantity of steam employed, Fig. 1 may be expected to represent the condition of affairs.

In order to accurately determine the amount of gas produced at short intervals, and to establish a curve on the lines indicated above, various devices were tried, including Pictet's meter, but the best results were obtained by a direct measurement of the rate from the relief holder. A long rod, A (Fig. 1), was suspended from the railing that went up and down with the relief holder by means of a strap iron hook. At intervals of about 30 c.m., gimlet holes were made in this rod. A second rod, B, of the same dimensions as the above was made, and pointed at one end. The other end was secured to a heavy wooden block placed on the stone coping of the gasometer, and held in place by weights. A third strip, C, was prepared, with a thumb-screw in one end, and strips of heavy paper secured to it by means of tacks. In this way the rod C could be quickly fastened to A in such a way that the upper part of the strip of paper on C would be level with the bevelled

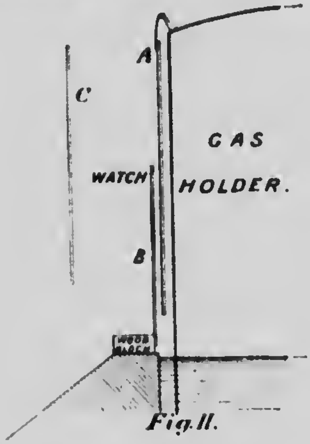
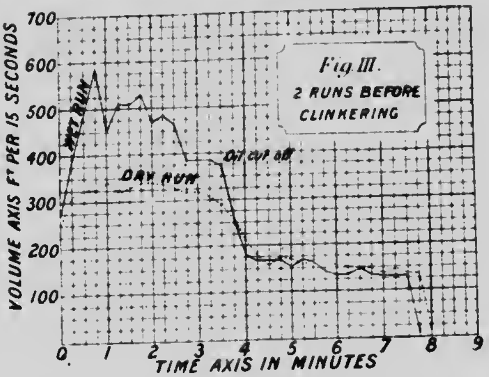
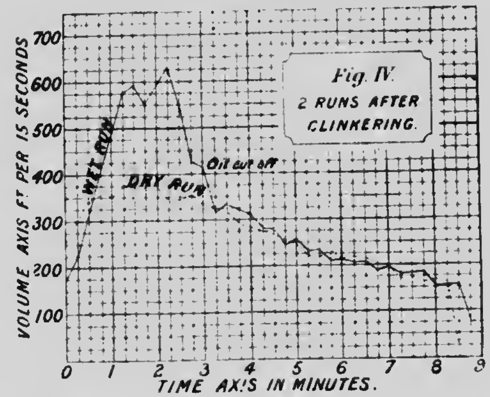


Fig. II.

point of B. A small hook was screwed in B at the point indicated, and a watch hung on it. All the water-gas machines except one were stopped, and the exhauster pumping from the holder was also stopped. When the machine began "the run" the holder would begin to rise, and, every 15 minutes, marks were made on the strip of paper opposite the point of B. The strips of wood were sufficiently thin to permit of them all being grasped in the left hand at once, and so the above markings could be quickly and accurately made. These measurements were continued over several days with both "dry" and "wet" runs. The best curves were obtained on calm days, as the slight movements of the holder caused by wind showed in the curves which were subsequently plotted. It was also found possible to obtain fairly good curves with the exhauster running by having the engineer maintain it at a constant rate, and by noting the rate from a slip of paper both before and after "the run." Very accurate measurements were taken of the capacity of the holders, and a table prepared for convenience in calculation. The distances between the marks on the strip of paper were transferred to a finely-divided rule with dividers, thus giving the number of inches between the markings, and by consulting the table this was readily transferred to cubic feet of gas produced per 15 seconds. In the curves produced we have nearly one minute consumed in reaching the maximum rate of output. This is accounted for by the following facts:—(1) The initial fraction is cooled below its average temperature on entering the condenser. (2) In the case of a wet run a certain amount of time is used up in admitting the oil, the inflow of





which gradually rises to a maximum. (3) The mains and the gas already in the holder is further removed from the temperature of the first fraction of the gas than from that formed in the succeeding part of the run. For these reasons the true curve of make conditioned by the internal state of the generator should, without doubt, be parallel to the time axis. This fact would tend to increase the output of the first three minutes above that shown in the curves actually obtained, and, *ipsa causa*, decrease the output of the latter part of the run. This would be an added argument for the method of operating proposed later on.

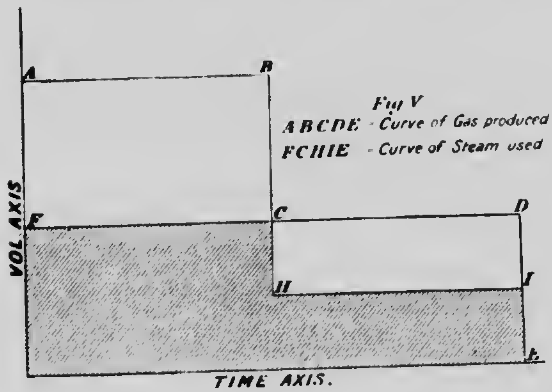
From the curves shown it is apparent that the curve falls off enormously between the third and fifth minute in every case, which is about the time that the oil is cut off iu the production of a gas of from 18 to 25 c.p. It would seem to be well, then, to cut the steam supply down to ono half directly after cutting off the oil supply. This would be in accord with the convenience of the men in operating the machines. Furthermore, it would be approximately correct, and would allow the machine to havo its full capacity during the beginning of the run, thus securing the maxlmnm daily output. This being settled upon, it becomes of importance to know just how much steam passes the inlet valve, and how much it is necessary to close the valve to cut that supply down to one half. A series of experiments were done on globe valves to determine the above, and it was established beyond a doubt that no simple relation exists between the number of turns a globe valve is opened and the amonnt of steam which passes in a given time. Some better control of the steam is evidently necessary. This is to be fonnd in the nozzle pressure appliances which are attached to most water-gas machines. Rankin, after a consideration of Napier's work on the subject, gives the following empirical formula for the amount of saturated steam escaping from a chamber where the pressure is p, through a short pipe and nozzle into a space where the pressure is p_a :—

(1) Where $p =$ or $> \frac{5}{3} p_a,\ w = \frac{ap}{70}$.

(2) Where $p < \frac{5}{3} p_a,\ w = \frac{a p_a}{42} \left(3 \frac{(p-p_a)}{2 p_a}\right)^{\frac{1}{2}}$.

In the above formula $w =$ the number of pouuds of steam delivered per second, and a is the area of the orifice in square inches. In water-gas practice conditions are somewhat different from the experiments on which the above formulæ were established, insomnch as we have a long steam line, and take the nozzle pressure, not from the boiler, but between the steam valve and the nozzle, at a point past which the steam is moving rapidly. If we apply the above formula, taking p as the indicated nozzle pressure, then $p = 30$ to 40 lb. per sqnare inch, while p_a is measured in a few inches water pressure, and the first formula applies; from which it follows that the amount of steam delivered in a given time varies directly with the nozzle pressure, and also directly with tho area of the orifice. A series of experiments testiug the accuracy of the above formula under water-gas conditions would be interesting.

Conclusions.—From actual experiments carried out, extending over more than a month, in which the nozzle pressure was cut down by one half after the fourth minute, a considerable saving in coke was effected, and the composition of the gas was in a measure modified also, its carbodioxide contents being lowered. Under this system of working the gas aud steam curves would resemble Fig. 5, though a curve of this kind was not actually taken from the machines. The above remarks apply where gas coke



is used in the generators; modifications may be expected in the case where anthracite coal is employed. From the curves just after clinkering, it is apparent that the machine's capacity could be increased by dividing the blow into three periods, and cutting the steam down to one-third each time. It being possible, therefore, to approximately regulate the amount of steam admitted during the run in accordance with the curves obtained, the yield of gas is increased, and the machine can be run up to its highest efficiency owing to the fact that the conditions causing imperfect working, indicated under (*a*), (*b*), &c., no longer exist.

The author wishes to acknowledge his indebtedness to Prof. W. R. Lang, of the University of Toronto, for the advice and assistance rendered in collating his experimental results.