CORRECTING BACK FIRING AND FUEL WASTE IN A LARGE PRODUCER GAS ENGINE PLANT.*

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A short time ago the writer, with some associates, had occasion to test a large producer-gas engine plant in order to determine whether or not the plant met guarantees as to average and maximum output and fuel efficiency, and every effort was made to put the machinery in the best of condition and to obtain the best possible performance. It is not the purpose of this paper to report the entire test, which occupied the greater part of a month, but rather to point out some specific items wherein it was possible to improve performance, and to briefly analyze the more important of these. Since, in spite of best endeavors, it was not possible to bring the apparatus up to guarantee I omit any specific references by which the plant would be readily identified.

The installation consisted of single tandem double-acting producer-gas engines with 33 x 48-inch cylinders, driving three-phase 25-cycle alternators at 107 revolutions per minute. The alternators operated in parallel and delivered power to an industrial plant furnishing a substantially steady load, and to some other minor uses.

Gas was furnished by producers of a well-known type. From their individual wet scrubbers the gas passed through a common dry scrubber to a 30,000 cubic foot holder and thence to the distributing main leading to the engines. The fuel was lignite of about 7,600 B.t.u., containing about 34 per cent. moisture and 8 per cent. ash. The gas averaged about 105 B.t.u., high thermal value. In making our tests the mill load was adjusted to suit the engine output and there was always available as much load as the engines could carry.

The plant had been installed by the manufacturers and shortly after its installation the designer of the engines had spent a great deal of time in bringing it up to the best possible performance. Subsequent to this, the operating engineer of the station had continued running the plant along the lines which had been fixed upon by the designer and he obtained slightly better results from the engines, and also somewhat improved producer performance. The results were still very far from satisfactory, however.

We found that the engines had given much trouble with back-firing and some with premature ignition. The back-firing had been so serious that it had been deemed necessary to put throttles in the air lines and cut down the air supply to a point below that at which the rate of propagation of the flame in the mixture was a maximum. As is well known, this expedient, though wasteful of gas, is usually effective in stopping back-firing and it was so in this case.

We were told that the designer of the engines directed that they should be adjusted to give "round-top" diagrams and indicator diagrams which we took showed that these instructions had been observed. This shape of diagram is obtained by timing the ignition so that it is not early enough to bring about substantially complete combustion during the period of very slight motion near the dead center. The exact timing of ignition to give this or any other shape of diagram naturally depends on many factors, the principal ones being compression; composition and homogenity of mixture; shape of combustion space and location of spark plugs; temperature [?] and character of spark. The ignition points of the different engine cylinders in the plant under discussion differed somewhat and had been determined empirically as giving the desired diagram with the rich mixture deemed necessary to prevent back-firing.

This practice led, as late ignition is likely to do, to a magnification of the unavoidable differences between successive diagrams, so that a "card" consisting of twenty successive diagrams with one unchanged governor and mixture setting showed a very large range of contours. We were assured by the attendants, however, that if the mixture giving best maximum diagram were employed, the back-firing would recommence and in time become prohibitive. Tentative experiments seemed to confirm this and it therefore became necessary to determine the reason for this back-firing.

Back-firing is most likely to occur from ignition of the incoming combustible mixture at the inlet valve. In a double-acting engine it may also be caused by leakage of hot gases from the explosion in one end past the rings and into the other end where the suction stroke has just been completed. It may also occur from a lingering flame in an indicator fitting or from red-hot carbon or extremely hot metal parts so placed as to pocket gas between two heated surfaces.

If the back-firing is due to escape of flame past the piston rings it can occur in only one of the ends of a given cylinder on a four-stroke double-acting engine. For instance, if the cam setting is such that combustion is occurring in the crank end just as suction is finished in the corresponding head end, there may be preignition from this source in that head end but, since the cycle is never reversed, it can never occur in that crank end. Since one of the most obstinate cases of back-firing of which the writer had known was due to this cause the matter was carefully investigated. It was found that preignition occurred in the crank ends and head ends indiscriminately, so that blowing through the rings was certainly not the only source even if it was an occasional one.

The indicator fittings not already so made were changed to a type which closed off practically flush with the inner surface of the cylinder wall and it was at first thought that this effected an improvement, but back-firing developed again, proving that it was merely chance which caused its diminution when the new fittings were put on. This led to the inevitable conclusion that the trouble was ignition of the incoming gas either by the outgoing exhaust or by heated parts of the cylinder, or both.

The design of the engine differed from that of most American tandem double-acting gas engines in that the valves occupied a valve chamber connected by a relatively narrow neck with the main clearance of the cylinder. The exhaust valve was in the bottom and the inlet valve in the top of this chamber and they were separated from each other by a distance of only about ten inches.

The valve setting was such that the inlet opened before the exhaust closed. The amount of lap was different on different cylinders, due to slight wear of the cams and rollers, and it could be controlled to some extent by adjusting the amount of clearance between the valve rocker-arms and the stems, but with no normal adjustment which did not entail serious shock was there a complete closure of the exhaust port before the inlet valve opened. This suggested the idea that the slight back pressure presumably existing in the cylinders might force a little of the hot exhaust gas past the slightly opened inlet valve and ignite the mixture. This seemed highly improbable, however, on account of the cooling action upon the gases which would result from intimate contact with the water-cooled inlet-valve seat and the valve which had just risen from it.

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