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No. 861.*

THE GAS-ENGINE HOT TUBE AS AN IGNITION-TIMING DEVICE.

BY WM. T. MAGRUDER, COLUMBUS, OHIO.

(Member of the Society.)

THE series of tests of a gas engine, the data and results of which it is here desired to record, was made as part of the regular post-graduate laboratory work in gas enginery, given by the writer at the Ohio State University at Columbus, Ohio, during the college year 1898–9, by Mr. F. J. Hale, M.E., class of '98, and Mr. Horace Judd, M.E., class of '97, as part of their elected work for their post-graduate degrees. Mr. Hale had previously assisted in making over fifty tests of gas engines under eighty horse-power in size; while Mr. Judd had been for more than a year an assistant in the mechanical-engineering laboratory. Both young men were unusually painstaking and careful observers, and it is therefore thought that the data and results are trustworthy. Most of the indicator diagrams here presented were taken by the writer. The results have been worked up chiefly by Mr. Hale, and have been checked by the writer and one of his students.

The engine tested was rated at 9 indicated horse-power and at 7 brake horse-power when using natural gas and running at 280 revolutions per minute. It may be classified as a 4-cycle, scavenging, horizontal gas engine having a single cylinder of 6-inch diameter and 12-inch stroke. The lay shaft was driven by spiral gears from the crank shaft at one-half the latter's number of revolutions per minute. Cams on the lay shaft caused the inlet and exhaust valves to open once in every two revolutions of the crank shaft. The governor was the usual type of hit-or-miss inertia pendulum governor, actuated by a cam on the lay shaft and propelled by a spring; and hitting or

* Presented at the Cincinnati, Ohio, meeting (May, 1900) of the American Society of Mechanical Engineers, and forming part of Volume XXI. of the *Transactions*.

missing, as the work and the speed of the engine demanded, a tappet on the end of the gas inlet-valve spindle, whereby gas was admitted to the mixing chamber, whence the mixture of gas and air, or the air alone, passed through the inlet valve into the ignition chamber, and so into the combustion chamber, or cartridge space, of the engine cylinder.

About 25 tests of this engine had been made during the preceding college year, so that it is thought that the newness of the engine had been worked off, and that both valves and journals had become adjusted in their bearings.

The method of testing was the usual method employed in this laboratory for testing gas engines. A full description of the gas-engine testing plant may be found in Vol. VII., page 122, of the *Proceedings* of the Society for the Promotion of Engineering Education, in a paper presented to that society by the writer at its Columbus meeting, in 1899, on "The Hydrocarbon-engine Testing Plant of the Ohio State University." For the purposes of this paper, however, it should be stated that the power gas for a test is collected in a gasometer of 225 cubic feet capacity, which is graduated into cubic feet, and so that readings may be easily estimated to one-tenth of a cubic foot. From the gasometer, the power gas is forced by city water pressure to the engine through an ordinary tin gas meter, whose readings are used solely for the purpose of checking. The pressure of the power gas is measured by a water manometer connected to the gasometer, and is regulated by the observer who is stationed at the water-inlet valve. By this means almost any desired pressure may be obtained. The power-gas pipe leading to the engine is 1¼ inches in diameter, while the engine's gas cock was ¾ inch. The air inlet of the engine was tapped for 1½-inch pipe, into which was connected a 1½-inch close nipple, a 1½-inch by 2-inch reducer, a 2-inch close nipple, and then a 2-inch malleable-iron pipe union, so that the air of the room entered the engine through these fittings in the reverse order to that here given. In order to regulate or throttle the air supply, circular orifices made with sharp edges in thin planished iron were inserted between the two halves of the 2-inch pipe union.

The gas for the Bunsen burner of the hot tube was taken from the main and measured by a separate 5-light tin meter, and had no relation to the power gas except that it came from the same street main.

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The exhaust gases passed by a 2½-inch pipe through the usual exhaust pot, and so by a 2½-inch pipe to the atmosphere.

The jacket water entered the cylinder jacket below the combustion chamber, and passed out above at the front end of the cylinder. Its temperatures were measured by chemical thermometers whose bulbs were immersed in cylinder oil in thin-walled brass thermometer cups inserted in pipe fittings through which the jacket water was passing. The engine was so piped that the jacket water could be weighed either before or after it had passed through the cylinder of the engine.

No attempt was made in this series of tests to measure the quantity of air consumed, although ample facilities were at hand, as a previous series of 25 tests had been made on this point, and tests made with the engine receiving air at from 4 inches of pressure to 19 inches of suction. Neither were the exhaust gases analyzed. The gas used was ordinary Columbus coal gas. Its composition is accepted as reported below by the analysis of a sample made by Mr. Frank Haas, C.E., E.M., of the department of metallurgy of the university, and under the direction of Prof. N. W. Lord, E.M.

Analysis of Gas.

Illuminants (C_2H_4)	7.7	per cent.
CO_2	.4	"
O	2.4	"
CO	5.3	"
H	50.5	"
N	9.0	"
CH_4	24.7	"
	100.0	"

Its calorific value, as determined from this analysis, is 584 British thermal units per cubic foot of the gas at 32 degrees Fahr., and at standard barometric pressure (29.92 inches of mercury). Its calorific value, as determined by these chemists in the Mahler bomb calorimeter of the department of metallurgy, is 564 British thermal units per cubic foot of gas under the same conditions.

The indicated horse-power was obtained by means of a new Crosby gas-engine indicator and an "Ideal" reducing motion, which received its motion from a stout iron arm rigidly secured to the piston of the engine. The straight indicator cock was screwed directly into the top wall of the combustion chamber. The brake horse-power was obtained by a rope brake resting on a pair of double-beam platform scales, and whose rope encircled a water-cooled brake pulley. The revolutions of the lay shaft and the admissions of gas per minute were obtained by electric counters, either or both of which could be thrown into or out of action by the observer at the gasometer, and also at a place nearer to the engine.

In the accompanying illustrations, Figs. 275 and 276 represent longitudinal and cross-sectional elevations of the mixing and ignition chambers. Referring to the figures, the gas enters the engine through a $\frac{3}{4}$-inch stop cock, whose pointer handle *W* rotates over a dial *P* graduated from zero to 10. When the hand is at zero the cock is closed, and when at 10 it is wide open. When the load is increased and the speed is decreased, the inertia pendulum governor strikes the tappet on the right-hand end of the gas-inlet valve *U*, causing it to open to an extent that can be regulated by the thimble *V*. The gas thus enters the space *G*, and passing through the holes as shown, mixes with atmospheric air, which has come in by way of the $1\frac{1}{2}$-inch air pipe into the air chamber *A*, whence it, too, passes through numerous small holes so as to cause an intimate commingling of the gas and air in the mixing chamber *M*.

Once in each two revolutions, a cam on the lay shaft actuates the lever *Q*, and, through the "inlet-valve lever set screw" *S*, causes the valve *T* to rise and so permit the mixture of gas and air, or of air alone, to enter the ignition space *B*. Here the fresh gases mix with the burnt gases of the preceding stroke, and fill the ignition chamber *B*, the inlet *C*, and the combustion chamber and cylinder volume, during the suction stroke of the piston. The passageway *D* to the hot tube, being, as it were, a dead end, remains filled with the burnt gases of the preceding stroke.

The ignition chamber *B* is formed in a casting *N*, bolted to the end of the engine cylinder, so as to have direct communication with it through the rectangular inlet *C*. On the outside of the ignition-chamber casting *N* is bolted the casting *O*, in which is fastened by set screw *L* the hot-tube tee *E*, which is connected to the passageway *D* by a hole $\frac{1}{4}$ inch in diameter. Into the tee *E* is screwed the hot tube proper *X*, having a solid end, and also the lower hot tube *H*, made of $\frac{1}{4}$-inch gas pipe, and having on the end a $\frac{1}{4}$-inch by $\frac{1}{8}$-inch reducer, and the "lower hot-tube pet cock" *I*. This pet cock *I* originally contained a hole $\frac{1}{64}$ inch

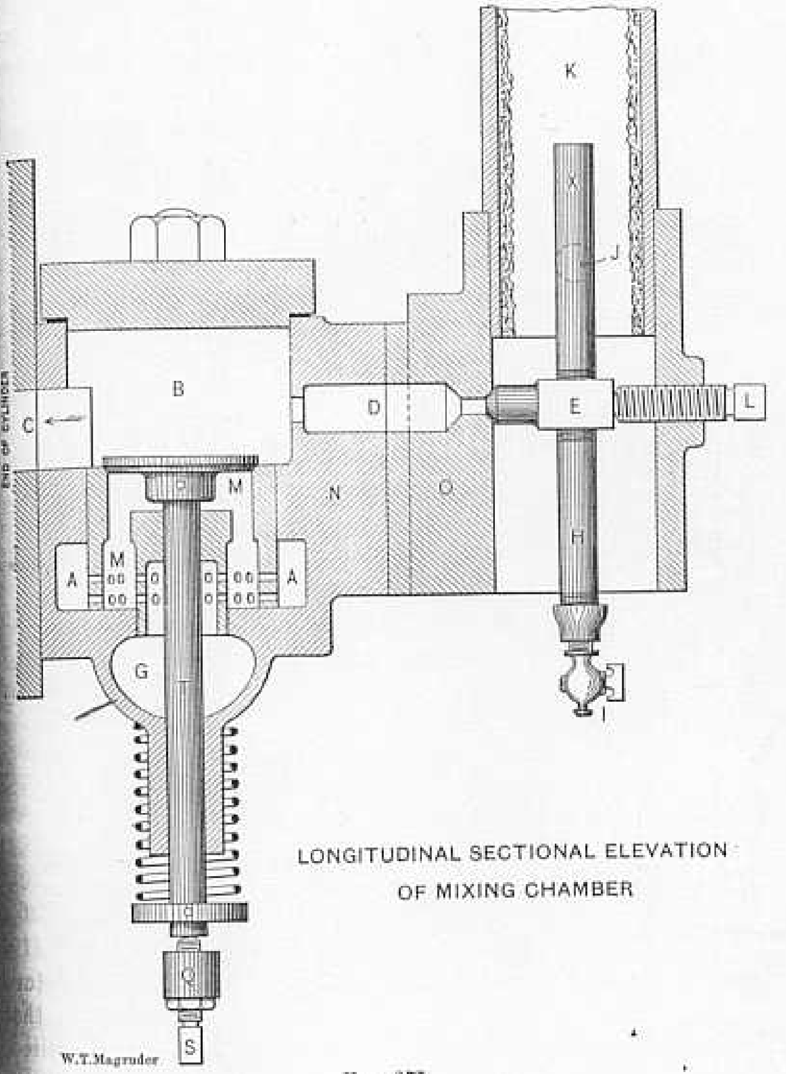

FIG. 275.

in diameter, but was replaced in certain of the experiments by an ordinary $\frac{1}{8}$-inch pet cock. The upper hot tube *X* was surrounded by an asbestos-lined cast-iron chimney *K*, through