which the tip J of the Bunsen burner projected, so that the flame could play upon the upper hot tube at a point about 1½ inches above the tee E. It will thus be seen that ignition was effected in this mechanism by compressing the burnt gases which were left in the passageway D, the tee E, and the upper and lower hot tubes X and H, into the lower hot tube H, and

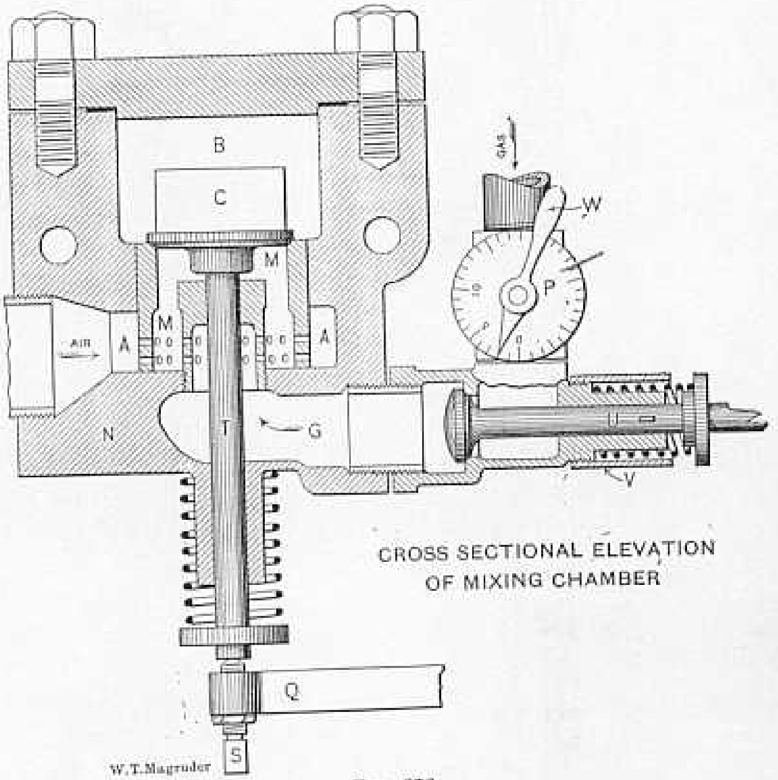

FIG. 276.

the upper portion of the upper hot tube X, so that the mixture of fresh gas and air followed and came into contact with that part of the upper hot tube which was red hot, became ignited, and, striking back through tee E, passageway D, ignition chamber B, and inlet C, caused the ignition of the large volume of the compressed gas and air in the combustion chamber of the engine, and so caused the piston to make a power stroke.

The exhaust valve was opened by a lever operated through

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a roller actuated by a cam on the lay shaft. The roller was journaled on an eccentric stud in the lever, and so arranged that it could be rotated so as to cause the exhaust valve to always remain open a small amount, and, by thus creating a leak at the exhaust valve, decrease the compression and so make the starting of the engine easier. When the tee-handled end of the eccentric was vertical, the exhaust valve was closed and kept closed by its spring; but when the handle was horizontal, the exhaust valve could not close and therefore leaked.

Early in the experimenting with this engine, under the unusual conditions imposed, it was discovered that the time of ignition was a variable depending upon quite a number of different conditions, and that before any accurate and scientific data could be collected or any satisfactory results could be obtained, these conditions must be individually and systematically studied. To do this intelligently, the following schedule of conditions was assigned, and tests made in which, as far as possible, only one condition at a time was allowed to vary.

The variable conditions upon which the time of ignition was assumed to depend were :

1. The length and diameter of the upper hot tube.
2. The length and diameter of the lower hot tube.
3. The volume of the passageway *D*.
4. The amount of compression due to the percentage of piston displacement in clearance volume.
5. A leak at the lower hot-tube pet cock *I*.
6. A leak by the piston rings.
7. The position of the inlet-valve lever set screw.
8. Whether the exhaust valve leaked or not; that is, whether the starting cam handle was vertical or horizontal.
9. The temperature of the jacket-water outlet.
10. The temperature of the mixing and ignition chambers.
11. The speed of the engine at constant jacket-water outlet temperature.
12. The temperature of the hot tube.
13. Whether the previous stroke had been missed or not.
14. The pressure of the gas.
15. The position of the gas-cock handle.
16. The size of the air-inlet diaphragm.
17. The pressure, or suction, at which the air was delivered to the engine.

1. *The Length of the Upper Hot Tube*

From what has previously been said, it is evident that the greater the volumes of the spaces in the upper and lower hot tubes, either or both, the greater will be the amounts of the burnt gases which they will contain, and therefore the sooner will the fresh gases reach the red-hot part of the upper hot tube. Consequently, the longer the upper hot tube, the earlier will be the ignition. Fig. 278, Card No. 8 of Run 136, and Fig. 277, Card No. 20 of Run 139*A*, show this for an upper hot tube 5½ inches long. Fig. 279, Card No. 8 of Run 129, and Fig. 280, Card No. 3 of Run 135, show this for an upper hot tube 4 inches long. Figs. 281 and 282, Cards Nos. 4 and 6 of Run 140, show this for a 3½-inch upper hot tube. Figs. 283 and 284, Cards Nos. 4 and 9 of Run 139*A*, show this for a 2¾-inch hot tube. Figs. 285, 286, and 287, Cards Nos. 2, 7, and 8 of Run 139, show this for a 2-inch hot tube, and also the variation in the time of ignition due to so short a hot tube.

2. *The Length and Diameter of the Lower Hot Tube.*

From what has been said under the first condition, it will be quite apparent that the greater the volume of the lower hot tube (that is, the greater its length for a given diameter, or the greater its diameter for a given length, or both), the earlier will be the time of ignition. This, it is thought, is clearly shown by the diagrams from Run 139*A*, where the length of this tube was changed from 1¼ inches with Fig. 288, Card No. 1, to 2½ inches with Fig. 289, Card No. 2, to 2¾ inches with Figs. 283 and 284, Cards Nos. 4 and 9, and to 8¼ inches with Figs. 290 and 291, Cards Nos. 17 and 18, while the upper hot tube remained constantly 2¾ inches long. Therefore the longer or larger the lower hot tube, the earlier will be the ignition.

3. *The Volume of the Passageway D.*

No means were available to prove this condition, but it would seem quite evident that the larger the volume of the passageway *D* the larger would be the volume of burnt gases for which room would have to be found in the upper or lower hot tubes

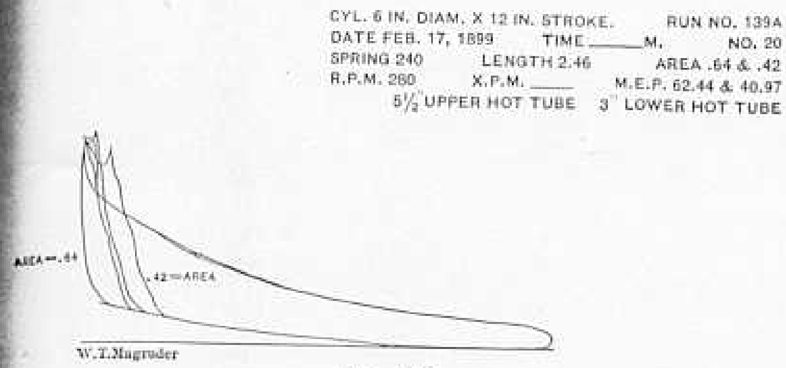

FIG. 277.

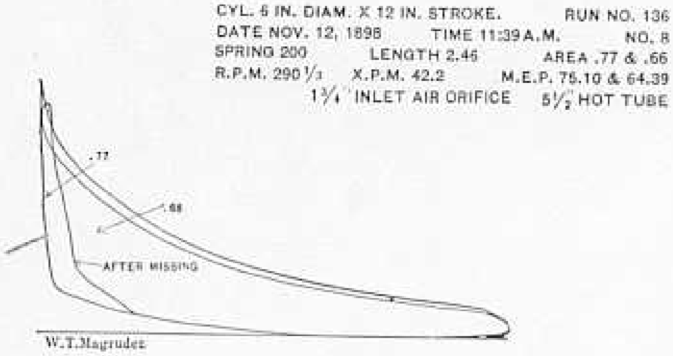

FIG. 278.

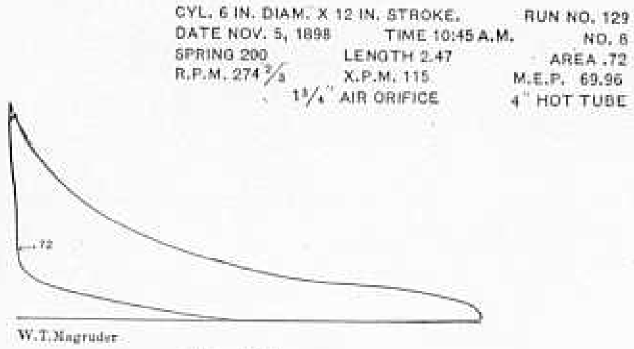

FIG. 279.

before the fresh gases could become ignited. The logical conclusion would therefore seem to be that the larger the passageway *D*, the later would be the ignition.

4. *The Amount of Compression Due to the Percentage of Piston Displacement in Clearance Volume.*

With this engine no facilities were available for either increasing or decreasing the volume of the combustion chamber, and thereby changing the percentage of clearance volume, which was 33.99 per cent. of the piston displacement. But it is evident that with a larger combustion chamber the compression will be lower, and the volume into which the burnt gases of the passageway *D*, etc., will be compressed will be larger, and, therefore, the greater the clearance volume and the lower the compression, the later will be the ignition, and *vice versa.*

5. *A Leak at the Lower Hot-tube Pet Cock I.*

From Figs. 292, 293, 294, 295, 296, and 297, Cards Nos. 3, 6, 14, 18, 22, and 27 of Run 156, it is evident that a leak at the lower hot-tube pet cock (or at where the tubes *H* and *X* are screwed into the tee *E*) will allow the burnt gases in the passageway *D* to be exhausted into the air, and thereby cause a very early ignition.

6. *A Leak by the Piston Rings.*

Run 159 was made to determine the result of running without the four piston rings being in their usual places. The leak of burnt gases from the front end of the cylinder was very perceptible. The compression was reduced from the usual 60 pounds to about 48 pounds, and the average mean effective pressure was reduced from 75 or 80 pounds to 48 pounds, except after missing a stroke. Figs. 298, 299, and 300, Cards Nos. 2, 3, and 5 of Run 159, show that ignition took place exactly on the dead centre with a hot tube $3\frac{1}{2}$ inches long. It would therefore seem that the omission or breakage of one or more piston rings, while effecting the compression, mean effective pressure, and the indicated horse-power, will have practically but little effect upon the time of ignition.