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An INVESTIGATION of the TURBULENT MOTION of the GASES in an ordinary 4-CYCLE GAS ENGINE.

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The diameter of the Inlet Valve of an average poppet-valved gas engine is of the order of one-fourth the piston diameter, which means that the velocity of the admission gas must be at least 16 times that of the piston, and it is quite probable that the velocity of the gas is considerably higher, due to the design of the cam profiles, which, in many cases, allow for a very small period of maximum valve opening. This high initial gas velocity causes the cylinder to be filled with a charge in a highly turbulent condition.

Under ideal conditions of admission of the charge to the cylinder there would be a certain gas velocity ranging from zero to a velocity equal to that which the piston had at any point in the cycle.

The author has therefore defined turbulence as the excess velocity of the gas at any point in the cycle over that due to the piston motion at the same point of reference.

The object of the experiments described in this paper was to obtain an estimate of the amount of the turbulence at various engine speeds, and to consider its bearing on the question of the heat losses in the cylinder.

The method of experiment has been to measure the variation in the heat losses from a fine platinum wire .001″ diameter, situated in the centre of the combustion space of a gas engine which was motored round at various constant speeds, using air only as the working fluid.

Further experiments have been made, using similar platinum wire, in which different disturbing factors were removed, as for example:—

(a) The engine was motored round at same speeds, but with the valves out of action, the object being to eliminate turbulence.

(b) Heat losses measured from a similar platinum wire situated in the centre of a covered iron vessel, resembling the combustion chamber of the engine, under the following conditions:—

(i) Pressure varied over the range met with in the engine cylinder, and the temperature kept constant.

(ii) Temperature varied over the range met with in the engine cylinder and at atmospheric pressure.

The object being to separate the effects due to temperature and pressure without any piston interference.

(c) Heat losses measured from a similar platinum wire placed in a stream of air of known velocity, the object being to get some idea of what the actual gas velocities are in the cylinder by comparing the heat losses so obtained with those observed in the engine cylinder.

An important practical aspect of the effects of turbulence is the question of valve design, and with it the relative merits of the poppet and sleeve valved engines. Ordinarily the poppet valve of a gas engine is designed to operate in more or less a pocket of the cylinder, and when the valve is opened the head of it is in such a position that the flow is restricted. The design of the sleeve valve is such that the maximum port opening occurs much sooner, and remains at its maximum opening for a much longer period, than is possible with the quiet running of the poppet valves. During the period in which the sleeve valve is open there is no obstacle to impede the direct flow into the cylinder, consequently the turbulence of the mixture should be less. It was possible that most of the increased efficiency of the sleeve-valved over the poppet-valved engine is due to this diminution of turbulence.

Description of Apparatus.

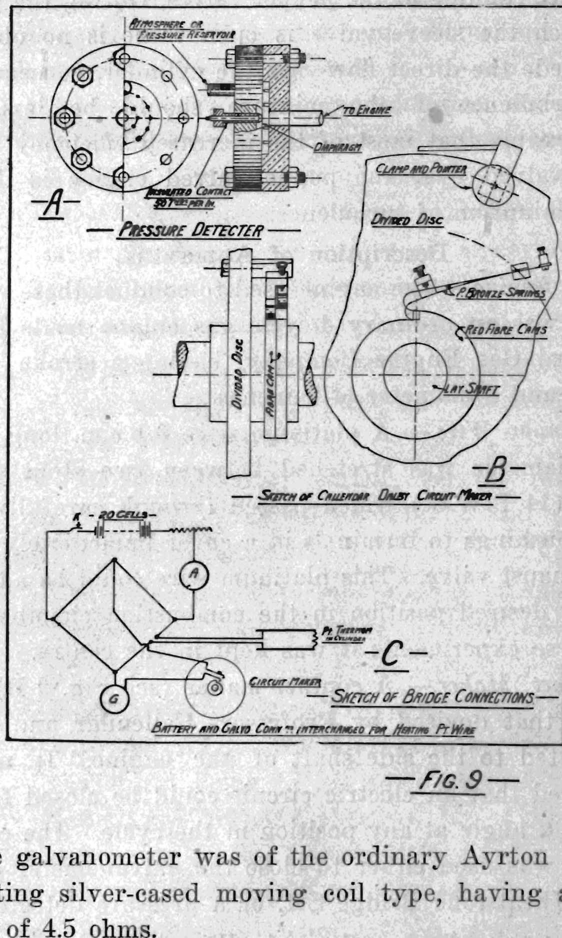
The Engine.—The engine used to conduct these experiments was an ordinary 4-cycle gas engine made by the Forward Gas Engine Company, having a stroke of 15 inches and a diameter of 7 inches.

Platinum Wire.— A platinum wire 5.1 c.m. long and 1 mil. diameter was stretched between two stout copper wires (14 B.W.G.) which passed through carefully insulated bushings to terminals in a cover immediately above the exhaust valve. This platinum wire could be adjusted to any desired position in the combustion chamber, and for these experiments it was kept in the centre.

Contact Maker.— A contact maker (see Fig. 9 B) similar to that devised by Professors Callendar and Dalby was fitted to the side shaft of the engine. It was so arranged that an electric circuit could be closed for 10° of crank angle at any position in the cycle. The contact maker was used either to close the galvanometer circuit of a Wheatstone Bridge Set, or a pressure detector.

Wheatstone Bridge Set.— A Wheatstone Bridge Set was used to measure the resistance of the platinum wire in the cylinder at any position in the cycle, as determined by adjustment of the contact maker which completed the galvanometer circuit.

The battery consisted of 25 to 30 secondary cells used in series, with a particularly high resistance, so that the change in resistance of the platinum wire was too small to materially affect the constancy of the current. A Siemen's milliammeter was used to measure the current.

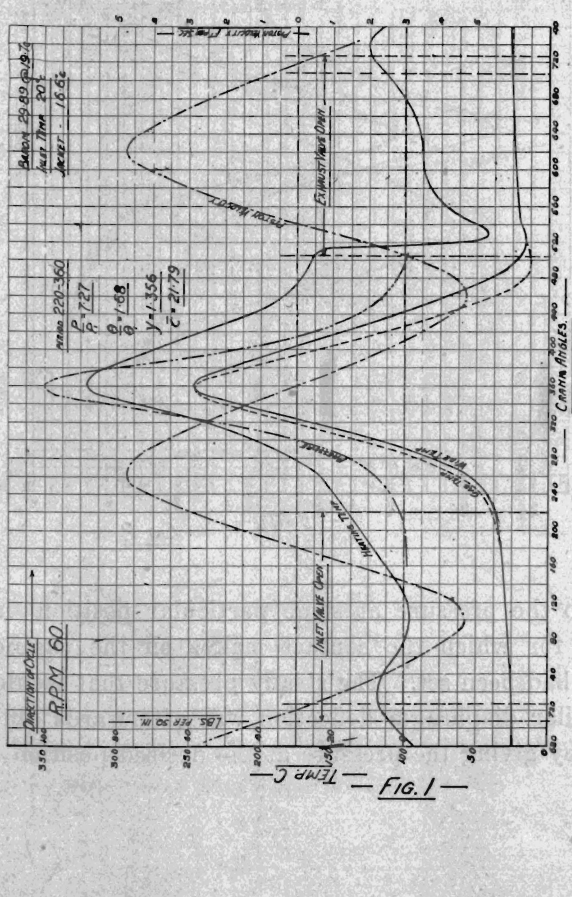


— FIG. 9 —

The galvanometer was of the ordinary Ayrton Mather reflecting silver-cased moving coil type, having a resistance of 4.5 ohms.

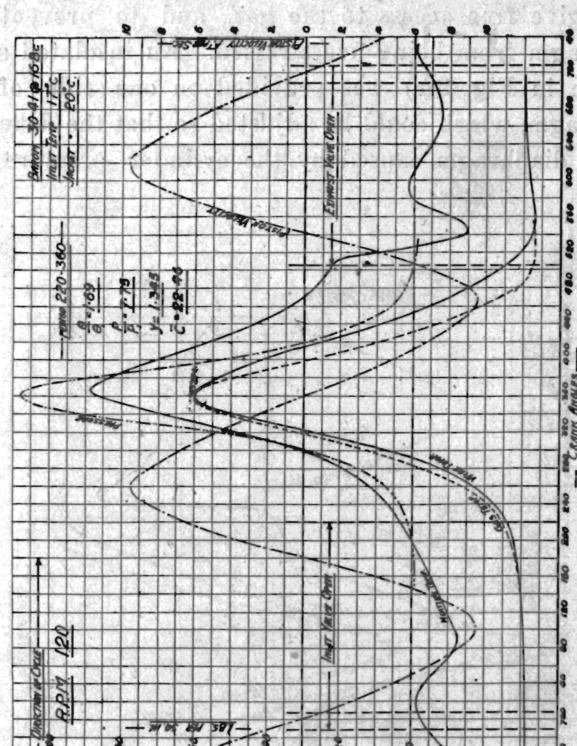
Indicator.— The indicator used for determining the pressure readings during the cycle was one of Professor Hopkinson's Photo-optical instruments.

Pressure Detector.— The pressure detector shewn in Fig. 9A was used to determine the pressures, checking the indicator, and also for locating the position at which the pressure in the cylinder was atmospheric. A thin steel diaphragm (15-1000th of one inch in thickness) was firmly clamped between two gunmetal boxes, forming a chamber on either side of it. One chamber communicated with the interior of the cylinder through a cock, and the other chamber with either the atmosphere or a closed vessel in which the pressure could be accurately determined. The interior of the chambers was so arranged as to give free access to the gas, and to prevent the diaphragm from being overstressed. An insulated screw (shewn in Fig. 9A) was provided on one side of the diaphragm, which could be adjusted so that the deflection of the diaphragm caused by the cylinder pressure was



— FIG. 1 —

sufficient to complete an electric circuit. The diaphragm and insulated screw were included in the circuit with a portable galvanometer, a battery, and the contact maker previously mentioned. An adjustment could then be made giving the deflection of the diaphragm correspond-

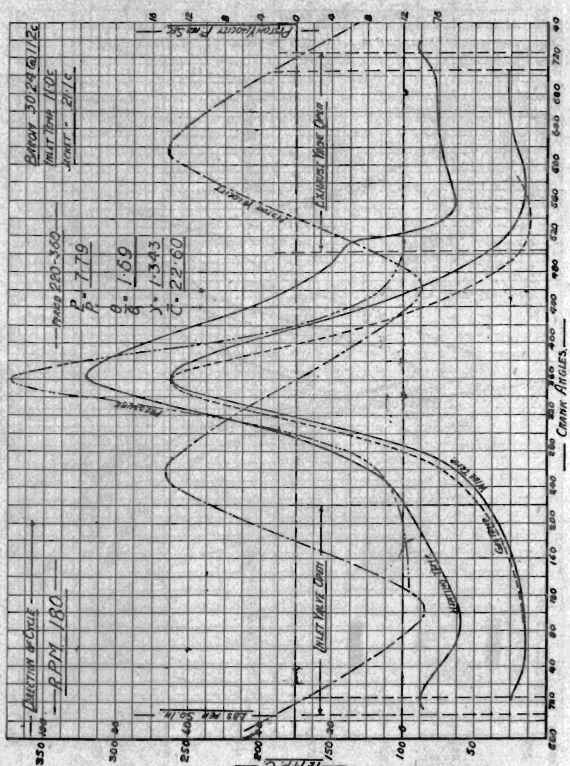


—FIG. 2—

ing to the pressure at some particular position in the cycle for which the contact maker on the engine side shaft had been set. The steady pressure that would give a similar diaphragm deflection was afterwards obtained, thereby giving the pressure at the desired position in the cycle.

Details of Experimental Work.

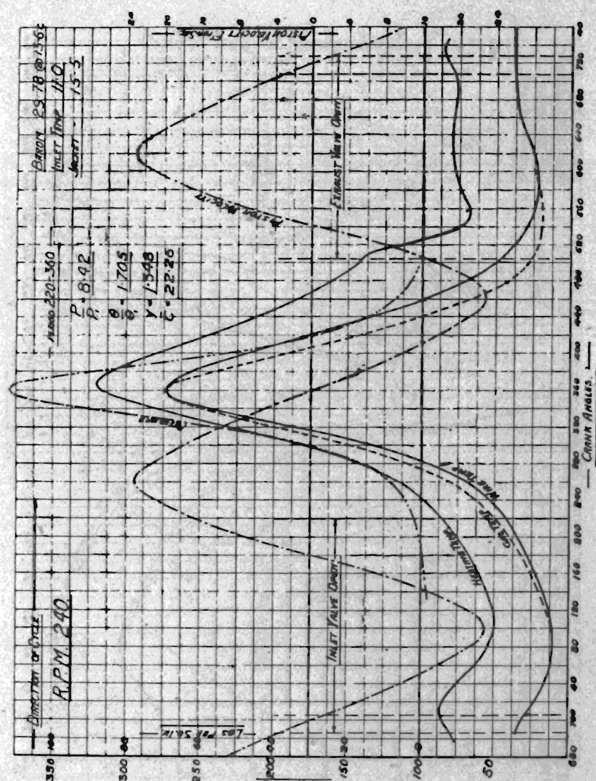
Engine Experiments.— The engine was motored round by belted connection to a steam engine, and maintained at constant speeds of 60, 120, 180 and 240 revs. per minute, 240 R.P.M. being the normal working speed of



—FIG. 3.—

the engine. Air only being used as the working substance in the gas engine during all the experiments. At each speed pressure readings were taken with the indicator and detector to determine the maximum pressure, and also the position of the crank for which the pressure in the cylinder was atmospheric.

The resistance of the platinum wire in the cylinder was also measured at these speeds at various positions in the cycle: *Firstly,* when a small current, .003 amperes, was used, which was quite insufficient to heat the wire; and *secondly,* when a current of .2 amperes was used, which was sufficient to heat the wire considerably. When



—FIG. 4.—

measuring the resistances in the *first case,* the battery was connected across the ratio arms of the W. Bridge in the ordinary way, but in the *second case* the galvanometer and battery connections were interchanged so that the galvanometer was joined across the ratio arms; this prevented any injury to the low resistance coils of the W. Bridge through overheating.

The temperatures calculated from the resistance measurements are shewn plotted in Fig. (1—4), in which series the valves were working normally, and the cylinder water-jacketed, whilst in Figs. (10—13) the valves were out of action and the cylinder steam-jacketed.

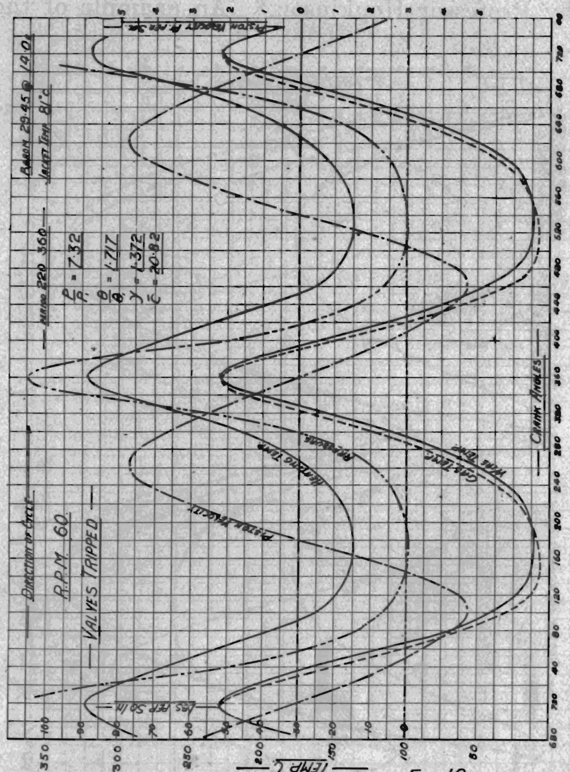


FIG 10.

In Figs. (1 to 4 and 10 to 13) the curves marked Heating Temperature indicate the temperatures of the platinum wire when a current of 2 amperes was used, and those marked Wire Temperature indicate the temperatures of the wire when a current of .003 amperes was used.

The variation of the wire temperature is, of course, due to the gas becoming heated with the compression.

This wire temperature lags behind the gas temperature, due to the platinum wire having a certain capacity for heat.

The temperature of the gas may be calculated from these curves Figs. (1 to 4, 10 to 13) by the method devised by Professor Hopkinson.* An example of the cal-

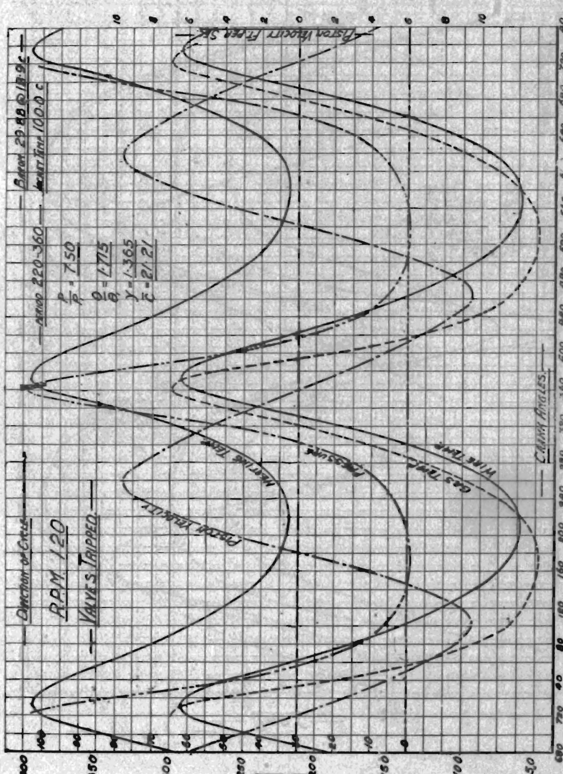


FIG. 11

culation of this gas temperature is given in Appendix I, and requires no further explanation here, except to explain one of the symbols used in the analysis, which will be frequently used later in this paper. The term

* Phil. Magazine, January, 1907.