which shows that the valves are sufficiently large to allow for the increased speed. When the engine speed is increased to 180 R.P.M., the gas velocity has increased four times that at 60 R.P.M., whilst at 240 R.P.M. the gas velocity has increased about 10 times that at 60 R.P.M.

Curve for 360° Crank Position.—The reason why gas velocities are obtained at all the speeds is due to the method of measuring the resistance of the wire in the engine. It will be remembered that the galvanometer circuit of the Wheatstone Bridge made contact for 10° of crank angle; the resistance measured is then the mean of this range. It is clear then that with this method it is impossible to obtain a reading at 360° devoid of piston influences. An estimate of the piston influence may be obtained by taking into account the relative positions of the wire and the piston (.9 to 1) from the back end of the cylinder. Such an estimate would infer a gas velocity of 30 c.m. per second at 60 R.P.M. for that position. The gas velocity for 360°, plotted in Fig. 8, shows a fair agreement with this estimate for 60 and 120 R.P.M., but at 180 and 240 R.P.M. the velocities are much higher. It is therefore evident that at 360° crank position there is no turbulence at 60 R.P.M. and 120 R.P.M., and that the turbulence at 180 R.P.M. is small; but at 240 R.P.M. the turbulence is considerable.

Curve for 480° Crank Position.—The gas velocities for 480° crank position show a straight line relationship for the different engine speeds.

If the relative position of the platinum wire and the piston are again taken into consideration, it will be found that the ratio of the distance of the wire and the piston from the back end of the cylinder where the gas is always stationary, is 4:18, so that the velocity of the air in the neighbourhood of the wire would be 120 c.m. per second at 240 R.P.M. The value given by the curve (Fig. 8) is 115 c.m. per second. From this check it is clear that there is no turbulence at any speed at 480° crank position, i.e., just before the exhaust valve opens.

Were there no turbulence at 240° crank position the gas velocities would be the same as at 480°, being positions of similar piston displacements, it follows then that the amount of turbulence of the gas at 240° is the difference between the two curves.

These results then show that when the engine is working normally:—

(1) There is turbulence at all speeds immediately after the closure of the inlet valve.

(2) There is no turbulence just before the exhaust valve opened.

(3) There is turbulence at the normal running speed of the engine, viz., 240 R.P.M., at the top of compression.

Calculations have been made for each set of experiments (Fig. 1 to 4 and 10 to 13) to determine how nearly the compression of the gas is adiabatic. The results for each experiment are given in the curves, and also in Table 3. The following symbols are used:—

P = Maximum pressure, absolute.

P_1 = Minimum pressure, absolute.

θ = Maximum temperature, absolute.

θ_1 = Minimum temperature, absolute.

(Gamma) γ = Ratio of the Specific Heats.

$\bar{c}$ = Volumetric Heat in foot lbs.

The value of Gamma (γ) for adiabatic compression of air is 1.385, and "c"=20.1 ft. lbs.

Table 3.

Revs.	$\frac{P}{P_1}$	$\frac{\theta}{\theta_1}$	γ	$\bar{c}$	Max. Temp. C°	Jacket Temp. C°	Remarks
60 V.T.	7·32	1·717	1·372	20·82	230	80·0	All values measured over range 220 – 360° crank position.
60	7·27	1·68	1·356	21·79	247	16·6	
120 V.T.	7·50	1·715	1·365	21·21	300	100·0	
120	7·71	1·69	1·345	22·20	252	20·0	
180 V.T.	7·37	1·69	1·356	21·75	315	101·0	
180	7·79	1·69	1·343	22·60	263	21·1	
240 V.T.	7·49	1·71	1·364	21·28	275	113·0	
240	8·34	1·706	1·335	23·10	275	16·5	

The values given in Table 3 for the volumetric heat (c) are mean values over the range 220° to 360° crank positions, and in the experiments when the valves were out of action $\bar{c}$ infers an approximation to an adiabatic condition, the reason being to some extent the hot jacket. Consider experiment 60 V.T. the value of $\bar{c}$ over the range 220°-300° was 18.45, which means that the gas is taking in heat from the walls. The gas will continue to take in heat till its temperature is equal to that of the jacket, then the reverse action takes place. Heat is being taken in by the gas for about three-quarters of the stroke, so that the heat loss, as shown by $\bar{c}$, takes place during approximately the last quarter of the stroke. At 240 R.P.M. V.T. a similar jacket action takes place, but the maximum temperature is higher—this would cause a greater heat loss on account of the increase of the relative thermal conductivity of the air with the increased temperature.

The experiments with the valves in action show an increase of $\bar{c}$ with the increase of speed from 60 to 240 R.P.M., the value in each being higher than for the corresponding speed with the valves out of action. The effect of the higher jacket temperature would account for some difference between these values, the principal cause of the increase of $\bar{c}$ being due to turbulence.

Although the turbulence at 240 R.P.M. is quite large compared with that at 60 R.P.M., it must be remembered that the time of action of such turbulent motion varies inversely with the speed. This would tend to make the relative effects of turbulence at all speeds more uniform.

These pressure temperature considerations showed, therefore, that turbulence does have an important bearing on the heat losses from the gas during the compression stroke.

In conclusion, the author desires to tender his thanks to Professor Hopkinson, F.R.S., for the deep interest he had taken in his experiments.

APPENDIX I.

Determination of the gas temperature from the wire and heating temperatures of the platinum wire.

A complete account of this method, devised by Professor Hopkinson, was published in Phil. Mag. for January, 1907. For the purpose of illustrating the method of calculation only the equations were included.

NOTATION.

θ'' = Heating Temperature in degrees C.
θ' = Wire Temperature " " "
θ = Gas Temperature " " "
R = Resistance of Pl. Wire.
λ = Rate of interchange of heat between the wire and the gas.

k = Capacity for heat of the platinum wire.

c = Current in Amperes.

Then $\lambda\,(\theta - \theta'')$ = Conduction of heat to the gas.

$$\lambda\,(\theta - \theta'') = k\,\frac{d\,\theta''}{dt} - c^2 R \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad 1$$

$$\lambda\,(\theta - \theta') = k\,\frac{d\,\theta'}{dt} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad 2$$

From equation 1 and 2 we get—

$$\lambda\,(\theta'' - \theta') = k\left(\frac{d\,\theta'}{dt} - \frac{d\,\theta''}{dt}\right) + c^2 R \ \ldots \quad \ldots \quad \ldots \quad \ldots \quad 3$$

The current used :—All these experiments was :

·003 Amperes for the wire temperatures

·20 „ „ „ heating temperatures

Mass of platinum wire = ·000582 grammes

k = Mass of wire × specific heat of platinum × 4·2

= Joules per degree centigrade.

= ·000582 × ·0324 × 4·2 = ·0000792.

CALCULATION :—

Take period 220° – 260° crank position for Fig 1 (60 *Rpm*)

Crank Position.	220	260	Difference	Mean.
	C.	C.	C.	C.
Wire Temperature ...	35°	53°.5	18°.5	44°.3
Heating Temperature	138·7	158·5	19·8	148·6

The increase of wire temperature = 18·5° C. during a period of 40° crank angle

$$\therefore \frac{d\,\theta'}{dt} = \frac{18{\cdot}5}{40} \times \frac{360^\circ \times 60\,Rpm}{60} \text{ degrees C. per sec.}$$

$$k\,\frac{d\,\theta'}{dt}\ {\cdot}0000792 \times \frac{18{\cdot}5 \times 360}{40} = {\cdot}01315 \text{ Watts}$$

$$k\,\frac{d\,\theta''}{dt}\ {\cdot}0000792 \times \frac{19{\cdot}8 \times 360}{40} = {\cdot}01408 \text{ Watts}$$

$$\text{diff} = -\ {\cdot}00083$$

The mean resistance over this range was 10·44 ohms.

$\therefore c^2 R = ({\cdot}2)^2 \times 10{\cdot}44 = {\cdot}4176$ Watts

$$\therefore k\left(\frac{d\,\theta'}{dt} - \frac{d\,\theta''}{dt}\right) + c^2 R = \cdot 4176 - \cdot 00083.$$

$$= \cdot 4168 \text{ Watts}$$

The mean difference in Temperature for this range was —

$$(\theta'' - \theta') = 104{\cdot}3^\circ$$

From equation (3)

$$\lambda\ (\theta'' - \theta') = k\left(\frac{d\,\theta'}{dt} - \frac{d\,\theta''}{dt}\right) + c^2 R$$

$$\therefore \lambda = \frac{\cdot 4168}{134{\cdot}3} = \cdot 00399$$

Substitute this value of λ in equation 2

$$\lambda\ (\theta - \theta') = k\frac{d\,\theta'}{dt}$$

$$= \frac{\cdot 1315}{\cdot 00399} = \theta - \theta' = 3{\cdot}28^\circ$$

$\theta' = 41^\circ$ @ 240° crank position

$\therefore \theta$ = gas temperature = $44{\cdot}28^\circ$

This gives the temperature of the gas at the mean position of the range 220 = 260. In this manner the gas temperatures have been calculated in Fig. (1—4 and 10—13)

Discussion.

MR. G. A. JULIUS said: I think a paper bearing upon the question of Turbulence is very much in season at the present time, and I feel that I am possessed of as little true knowledge in connection with the gas engine at this moment as I am in regard to the condition of affairs in Europe from the information supplied by the Sydney daily papers. I will say, however, that after having read the paper through very carefully on two occasions, and also enjoyed the privilege of hearing it read by the author, I am convinced that it will have the effect of sweeping away many doubts and difficulties in regard to the operations in the cylinders of an internal combustion engine. I think you will all agree