Investigation of Time Of Combustion in a Gas Engine Cylinder

E. H. Enander
W. S. Gaylor

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Enander, E.H.
Experimental Investigation of Time of Combustion in a

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EXPERIMENTAL INVESTIGATION
OF THE
TIME OF COMBUSTION
IN A
GAS ENGINE CYLINDER

A THESIS
PRESENTED BY
EINAR H. ENANDER
W.M.S. GAYLOR.

TO THE
PRESIDENT AND FACULTY
OF
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FLAME PROPAGATION IN A GAS ENGINE CYLINDER.

The time of combustion of an explosive mixture in a gas engine cylinder is a field in which very little practical work has been done. The "time of combustion", or what is commonly known as flame propagation, is that time which elapses between ignition and maximum pressure. It is a well known fact that the ignition of a charge in the gas engine must occur before "dead center" is reached so that the maximum pressure is exerted at this point. The ignition must be made earlier, with reference to the crank position, for an increase in speed and the usual method by which the proper point of ignition is determined is by means of the indicator. The type of card that usually gives the best results is well known and the ignition is shifted until the desired card can be obtained. If the time of combustion of the charge was known the point of ignition could be determined without the aid of an indicator.

The results that are quoted in textbooks on gas engines are drawn chiefly from two sources; namely experiments by M. M. Hallard and Le Chatelier; also, determinations made by Mr. Dugald Clark. The data given by the above experimenters on the time of combustion were obtained with conditions differing from those actually existing in the cylinder. M. M. Hallard and
Le Chatelier made their first experiments along this line to
disprove the results obtained by Bunsen. Bunsen had found by
experiment that two volumes of hydrogen and one of oxygen burn
at a rate of 111.5 feet per second. He also found that the velocity
of the flame in carbon monoxide was 5.28 feet per second. MacLaure
and Le Chatelier, with the same mixtures and conditions with which
Bunsen made his experiments, determined that the velocity of com-
bustion in hydrogen and oxygen was 65.6 feet per second while in
the case of carbon monoxide the velocity was 7.2 feet per second.

The results obtained by these two men, although they are very
interesting, are somewhat difficult to apply in the present form
to the gas engine.

The results obtained by Mr. Dugald Clerk are given in a
practical form so that it is easy to them in determining the
proper point of ignition in a gas engine without compression. The
apparatus he used to obtain his results consisted of a cast iron
cylinder seven inches in diameter and eight and one quarter inches
long. This cylinder was filled with the explosive mixture
which was ignited by means of an electric spark. The pressure
in the cylinder was recorded by the pen of an indicator on
a paper fastened to a rotating drum that was driven by clock-
work so as to make one revolution in .5 seconds. The distance
between ignition and maximum pressure was then measured from the
Dugald Clerk made many tests with this apparatus and obtained some very valuable data on the time of combustion under the conditions under which the tests were made, but not conform with those of the gas engine in operation. All the tests were made with the mixture at atmospheric pressure (14.7 pounds per square inch) before ignition. Mr. Dugald Clerk states that he found that a mixture of 1 to 1.1 was the most economical in a gas engine. From his determinations of flame propagation, he found that the time of combustion for this mixture was 18 seconds. Let us take these results and see if we can apply them to a gas engine in operation. Assume the speed to be 240 revolutions per minute or 1440 degrees swept out by the crank in one second. If now we want the maximum pressure to occur at "dead center," the ignition of the charge, according to the above data, should be 18 x 1440 or 2688 degrees before "dead center." 

This, of course, is never found in practice and shows that the determinations can not be applied in their present form to a gas engine with compression. It would be possible to compress the explosive charge in a cylinder similar to that used by Mr. Dugald Clerk but even in that case the conditions would differ slightly from that found in the gas engine since in the latter the compression varies after the charge is ignited.
The experiments of the above mentioned men and many others that worked along this line have all been carried out with special apparatus. The advantage that they gained by this was the easy of observation and the elimination of all points that might prevent them from obtaining consistent results. The results obtained by these men lack the practical features of those obtained from a gas engine in operation. The best method to determine the time of flame propagation that will be applicable to the actual engine is to make the observations from the engine direct, then there can be no question of assuming ideal conditions that do not exist in the cylinder. The first thing we decided in connection with this test was to make all our observations relative to the time of combustion on the gas engine.

The next question that arose was, what method should be employed to obtain the time between the spark and maximum pressure? The apparatus employed by Mr. Duiaid Clerk could be easily be applied. A second method although similar to Clerk's apparatus in principle yet differs somewhat in the feature could be made to give, we think, a fairly reliable record. This apparatus would consist of: indicator, tuning-fork with nails or pencil, motor, two drums. A long strip of paper could be fastened to one of the drums, wrapped around the second so that when the motor rotated the first drum the paper would wind upon the same.
The coming forth could be so arranged as to have the plate fastened to the same directly over a point of the indicator. The indicator would record the different pressures of the moving paper, while the coming forth would take a curve from which the rate could be computed. The point of ignition and maximum pressure could be easily determined from the curve taken, and the two between the two calculated. This scheme has the advantage over that used by Mr. Dickie Clerk in the ability of speed, also in the elimination of any error due to the friction of the plate of the indicator. These two plans, although they would undoubtedly give the results sought with both in originality and scope, are methods suggested by Prof. R. Barran for taking photographs of the explosion and they promised to give accurate results but also a physical conception of that is taking place inside of the cylinder during combustion, the principle upon which this method works is very simple: a photographic plate is allowed to fall in front of an opening in the gas engine cylinder and a continuous picture is taken of the combustion. The plate first gets the impression of the spark, the combustion of the mixture, then starts and the various stages of the same to include in the falling plate. The plate is then developed and the different portions of the plate are colored according to the light of the cylinder when that portion of the plate was exposed.
The engine in which the observations were taken was a Fairman Horse Stationary gas engine. This engine was located in the Gas Engine Laboratory of the Armour Institute of Technology of Chicago.

A short description of this engine and the reasons and functions of the various parts is essential. The engine used was a horizontal stationary four-cycle engine size 6 3/4" x 12", rated 7 horse power at 240 R.P.M. A four-cycle engine has only one explosion or impulse in two revolutions. The events in this type of engine are: first, explosion driving the piston forward; second, exhaust: the piston expels the burnt gases on the backward stroke; third, the new charge is drawn in by suction when the piston again moves forward; fourth, compression of charge on return stroke. The method of igniting the charges is by what is known as the "make and break" process. In brief this consists of two terminals in contact inside the cylinder of the engine. One of the terminals is connected to a spring shown in the view of the cylinder head. The method of operation is as follows: a pin runs a sleeve, which is fastened to the spring, and then releases it. The spring acts, in the meantime,
been in tension, causing the tappets to move and jolt the valves. An electric current has, during this time, been passing through the terminals and as soon as they are brought apart a spark leys the gap and ignites the charge. There are two main valves in this engine, one being of sectional type, the other being controlled by the same lever as the exhaust valve and is kept closed while the exhaust valve is opened. The reason for this can readily be seen when the type of governor is discussed. The governor consists of two weights held together by springs. The operation of the governor is as follows: The speed increases and the governor weights fly outward due to centrifugal force. The outward movement of the weight causes a sleeve to slide along the shaft. A long pin which is fastened to the sleeve is placed in sight of the exhaust valve, thus preventing the closing of that valve. The exhaust valve also held open only the other gases are drawn into the cylinder on the next section stroke so no work is done in the next few revolutions and therefore the engine slows up. From this it can be seen how necessary it is to have the intake valve mechanically operated so that it may be held closed during the time the exhaust valve is open otherwise the fuel drawn in would be wasted. The water jacks were supplied from the city main and therefore no pump was
necessary. The engine was fitted with a mixing and by turning the handle of the valve we were able to vary the proportion of gas and air. The engine had two fly wheels, puberty indicator, cock, and accuired motion by taking cards.

The gas motors were used in this locomotive for illuminating gas, the other for natural gas. The same can be said regarding the pressure regulator, the gas being set for illuminating gas, and other for natural gas. When used the engine on natural gas we had to take this gas through the illuminating gas pressure regulator and, after the engine had been in operation some time, change over to the natural gas pressure regulator. The natural gas pressure regulator was made by the Westinghouse Co. and delivered the gas at atmospheric pressure. The illuminating gas pressure regulator was of the telescoping inverted water sealed tank type. A lever of a valve in this gas pipe was attached to the top of the pressure regulator, so that when the tank became filled with gas the upward movement of the inner tank could interupt the gas supply and ultimately shut off the gas. This gas regulator was used in starting the engine no matter what gas was used as it allowed a constant supply for a large quantity of gas under pressure so that the engine did not have to do any work of taking in gas on the suction stroke.
The water from the cooling jacket flowed into a large steel tank but as no account was kept of the water used during the first few minutes of apparatus used not to be discussed. After a number of preliminary runs had been made, an air meter was connected to the air side of the valve mixing valve. The air meter was made by Harris Griffin Co. and is shown in the figure in figure 2. On starting the engine it was necessary to uncouple this connection to the air meter as it was impossible for the engine to draw sufficient quantity of air through the meter, like to start up. After the engine had been running for about two minutes we could connect the meter to the air line and had no trouble in drawing the air through the same. The meter was never made by the Westernhouse Co. Where the meter used for illuminating gas was manufactured by John G. Griffin Co.

The "plate dip" was the name we gave to the vertical plate holder which was fastened to the engine. The reason for this name was to distinguish it from the plate holders used for holding the plates before they were exposed. The "plate dip" shown in figures 7 and 8, was, as has been stated, made by Pratt & Burnham. It consisted of long brass strips fitted together so as to leave a slot 1/16 by 1 1/8 inches for the plate. The entire apparatus was light proof having caps for each end.
The plate had not been put into the "plate drop" for the reason and was brought out just as a precaution. The plate was pivoted on a pin fixed on the side of the engine. A small piece of iron was placed on the plate as is shown in Figure 7. A small piece of iron was placed on the side of the electro-magnet and the pin was extended to the level where the electro-magnet is mounted on the frame. One continuation of the pin was being made at a thinning plate. The other end of the "plate drop".

When a current was allowed to flow through the coil, the magnetic attraction caused the iron to drop to about the upper part of the moment. At this point, the iron dropped onto the plate and allowed the same to fall. A little over an inch below the tin was an opening in the "plate drop" which was careful cut somewhere over a piece of thin metal in the frame. It was through this opening that the sheet that was to rest on the plate had to pass. In front of the opening, in the "plate drop" was a ring to prevent the right from falling out. The plate, after it was fitted, was suspended from a supporting ring and the cylinder of the engine while the cylinder of the tube was mounted a plate in which the tube was mounted. The ring was held in place by a metal ring which pressed it against the side of the face plate.
The box was divided into two parts by cutting the...

out side of a large stick, in which a hole was made in the..." was supposed to be cut in the bark of the tree, when...closed, and the two caps were placed in position. The "place...was then fastened to the two nailed sticks, with which the...much labor was wasted in securing pieces of wood which...to make place-holders.

The place-holders were made in the following manner: Boxes with holes for the plants, a right-angled compartment, were placed on top of the "place-plate." The boxes contained two long, thin, blank tubes and the frames of the box were made of wood nailed with glue so as to make them very strong and also serve as a support for the blank tubes so as to insure firm and rigid walls. These place-holders were made eleven inches long as intended at first, to use place-holders by ten inches, a short tunnel was placed in the middle of the..." are the place-holders missing. In the box was nailed...roughly. The caps were cut in line with the place-holders, w...
throughout. The framework for the upper right angle equipment is shown in Figures 4 and 5. The plate-holders in position is shown in Figure 5. The cap, it will be noticed, is movable so that the plates in the reversed plate-numbered slots upon the table of the framework, the plate-holders can be pushed along between the two access gullies and determine the travel of the holder, in Figure 4, which is the top view of the upper framework, we can see a shot which leads directly to the plate-ends in the "plate-chute", and one can readily see that when the plate-numbered pistons push the shot out of the holder and through the slots, the person in charge of the plate dropping could easily tell when a plate had entered and the resultant into the "plate-chute" by setting the slight jar that was caused when the plate struck the pin. The lower right light compartment was made so as to support a plate holder, and the original plan being to place an empty holder as is shown in Figure 6 to catch the plates as they came through the "plate-chute". When it started making the pots it was found it necessary to sink the plates so one man had to have his hand in the compartment, so it was easier to place the plates into a ruin-board dog after they had been lapped. The photos taken show the frame with
The coverings consisted of three thicknesses of black cloth. The upper compartment had no openings, but there was a plate-cover, which to put the plate-holders, the second through which a person could get their hand so as to remove the cover from the tank. The bottom stand had only one opening and a person could get one hand in so as to catch the falling plate, while now, the plate would remain in card-board boxes. This scheme of plate-holders worked very well and caused but very little trouble.

The entire success of raising in timing the falling plate, so as to have the same in front of the opening at the "plate dip" of the composition depended on the correct covering. The coverings shown in Figure 1, was to the engine before we assumed the test so as thought it best to give it a trial. The "plate dip" was moved to one and a half with an oscillating motion. The plate was indicated into the engine. The third position C passed through a cup in G, B slipped over the plain surface of C and pressed down by E as spring, in B kept the part in its extreme position. There was a slot in B through which a pin fastened to G extended and prevented oil from flowing off. The sliding part D was connected by a copper line to the sliding part of the electric supply. These copper coil storage batteries were used in series giving about 12 volts. The other terminal of the series of batteries was
was connected to the driving part of the "plate drop" from the description of the contact device it can be readily seen that when the nut B comes into contact with the circuit would be closed and would cause the cam to push down the cam and allow the plate to fall. The unused portion of G was used to allow a greater range of adjustments for timing the plates. In the description of the different cams it will be found that this adjustment did not give consistent results so a new contact had to be devised.

The contact of the cam was most successful. One end of the cam had a perforation that never gave us any trouble. The point of contact was this: A portion of the cam was insulated and a strip of brass held by a block of glue pushed against the face of the cam. A copper wire was attached to the strip of brass and was connected to the terminal of the points of contacts whose other terminal was connected to the driving part of the "plate drop." The circuit was open as long as the strip of brass pressed upon the insulation but as soon as the brass came into contact with the surface of the cam the circuit was closed and the catch would allow the plate to fall. We first tried to glue a piece of paper on the cam and have this for the insulation but the paper could not stay on after the glue got dry. Our second attempt of using-
ing insulation material to the can was made by wrapping a piece of mica in the shape of the face of a clock, to the portion of the mica array so that the brass strip would be in contact for 180 degrees of crank movement. By calculation we determined that the plate should be 28 degrees of crank position before the crank position 28 degrees of crank position before the crank position of revolution. The mica was held to the can by a strip of rubber. A brass strip was also fastened to the wooden block and was for the purpose of pressing the brass strip against the can. The first step was made with this contact and another end of brass strip was made a groove through the mica and 28 degrees of crank was placed in the mica. We inserted, by means of rubber, a piece of paper in the mate. The paper was found was essential to prevent the loose end and wear of the constant rubbing of the brass strip than the mica.

Particularly in the fourth case, a number of plates of different cranes were run through: (1) Hammer; (2) Sand's Gift Edge; (3) Cranes - Isotachrome. The developer used was Eiko-Hyso Developer. Upon development of these plates it was found that one is the most of the plate in future, no trace of the spark of explosion was found. Except in the case where due to inaccuracy in setting, the plate stuck and the expansion
discolor as a result of this. No conclusions could be drawn from this regarding the probability of the 8\"x10\" plates.

On the advice of Maj. de Kenter, 1 oz per plate of plates of size 8\"x10\" were prepared. The developer he recommended was a concentrated solution; the formula being:

I part saturated solution Sodium Carbonate
2 " " " Potassium "
2 " " " Sodium Sulfite

All the hydrosulphite was then stripped off in absolutes.

The plates were put into the required size and number of runs made in these pieces. No trace of the spark of explosion could be found except in the case, a slight impression of the explosion. The conclusions drawn from this part of the work were: 1. (1) that owing to the faulty contact design, no popping the plates, the pieces slipped back into place after the explosion; (2) that the plates used were not sensitive enough to yellow light to be affected. This necessitated a change both in the contact and in the kind of plates used. The plates were sensitive to yellow light and were rated "C" on the system, and this plate was used in the remainder of the work. The formula for the developer recommended by the S. & A. Co. for these plates is as follows:
Curve Showing Relation Between $S$ and $t$

from Relation $S = \frac{1}{2} a t^2$

$S$: distance along plate in inches

$t$: calculated time in seconds
"A"  Pure water  40 oz.
       C.P. Sulph. Soda  2 oz.
       Baking Soda  240 gr.
       Hydrogenperoxide  60 gr.

"B"  Pure water  18 oz.
       C.P. Baking Soda  1 oz.

Use  ({ "x" = 8 oz.,
       "B" = 1 oz.,

The question of a suitable contact was still to be considered. After a consideration of many possible methods, the following one was chosen, in which proved very successful. The smallest vessel can was partly filled with a share of the baking soda, the same of a sheet of shellac, a strip of a piece of wood pressed against the can and then melted from the edge by being heated to a block of wood placed in a stove. The top cup of the can-shield and the main specimen as mentioned in the theory section, were used as a shield for the soft shell. Thus can be used to shield the can from the temperature. According to theoretical calculations, the plates should melt it at the desired point. In actuality, this is not the case. The plates were placed opposite the shell and ignited. No explosion occurred. We adjusted the contact so that the plates would melt about 20 degrees below ignition. Sample plates were very thin and papered, but no explosion appeared. The reason for this was not due to the
The methods of doing this were several: (1) By cutting
and shaping the case open; (2) by using a machine on...
the inside of the case. Thus method was chosen as it
was more applicable and in those circumstances could be made
period of the work was cut and another period was stopped.
These plates gave in ordinary shocks in numbers II part of 13
which only the lower part of the explosion. This method of coming
to the explosion and stopping the shocks was continued until the
lower shock. Shocks III part of 13 show the explosion in
properly cut, so the bottom was closed 150 degrees below
the head and "cable failure", and the shock backed 143 degrees from
and "cable control".

The mechanical difficulties caused by the necessity
for us to achieve this in one piece, possible to obtain an impression
of both the shock and explosion. The cases had shown up so well
at the preliminary tests that there was no question of being
a picture of the explosion. The shock, on the other hand, are no
Now, the author shared some interesting observations and experiments related to the propagation of a spark. The actual conditions of the spark were as follows:

1. The spark was produced by a machine designed to observe the propagation of the spark. The machine was set up in such a way that it could be observed from different angles and positions.

2. The spark was observed in various gases, with different pressures and concentrations. The observations were made at various pressures and in different gases. In order to record the conditions of the spark at the time of observation, the observations were made at the time. The observations were made for different gases and pressures.
In addition to the reactions of the elements, the reactions of the products of the reactions are also important. When the reaction is complete, the gas is removed and the final volume is measured.

The final volume is used in the calculation of the final pressure and temperature. The volume is then used to calculate the final temperature. The final temperature is used to calculate the final pressure. The final pressure is then used to calculate the final volume.
In order to understand the concept of the question, we need to compute the expression for the velocity. The expression for the velocity can be computed as follows:

\[ v = \frac{S}{t} + \nu \]

where:

- \( S \) is the space provided in the equation plane.
- \( t \) is the time of listing in seconds.
- \( \nu \) is the initial velocity in terms of seconds. But of the plane.

The value of \( S \) is 1.5 in the equation plane. 

The value of \( t \) is 5 in the equation plane. 

The value of \( \nu \) is 8 in the equation plane. 

The value of the velocity was 10.83\% seconds. 

The value shown on the following page is the result of the calculation from the above formula for every 20 meters at a.
\[ S \text{ is the length of path expressed in inches} \]
\[ g \text{ is gravity in inches per second per second} \]
\[ t \text{ is time in seconds} \]

**Initial Velocity in Inches per Second**

<table>
<thead>
<tr>
<th>S</th>
<th>t</th>
<th>S</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>.05</td>
<td>.00744</td>
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<td>.01496</td>
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<tr>
<td>.10</td>
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<td>3.75</td>
<td>.16749</td>
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<td>138.760</td>
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</table>
If measuring with the device described above, the device is to be put on the bottom of the plate and let down until it touches the plate and rest on a place that the surface of the spark indicates. You will observe to the corresponding line in the instruction as above. The plate was then put on such a place in the state only a cut the piece that of the explosion and the instant of the inference. Let’s measure the difference between the old readings and the new readings between the spark and maximum pressure. These results are found by measuring the place in the instruction. The distance between the spark and upper level of the plate is measured 1 centimeter. The distance from the spark to the position of the plate was measured from the negative side of the plate. The position of the plate was found by reading on the plate. Then the

...
The time of the explosion was at 10:05 on the 24th of November, 1855, showing that the wind was blowing from the west.

Moreover, the explosion was accurately timed by the onlookers and the writer who described it.

By 10:05 the wind had changed direction and the explosion was witnessed by many.

Developed in the following experiments, it was observed that the wind had changed direction.

For the remaining duration of the explosion, a wind speed of 25 to 30 miles per hour was recorded.

As very little data is available on the wind, it is difficult to accurately determine its direction.

This development led to the conclusion that there was a connection between the wind and the explosion.
In making the calculations for other objects, I have
placed a line "After all" which is generally useful
for the purpose. If I do not appear in the position of
the example, it is essential to very clearly
understand the calculation. In this case if we
ought to employ the calculation, we ought to make
the position of the line. If you have any question,
the first or second column may be very rapidly
understood. The time of obtaining your row
points or the line, you must write it as the time.

The calculation involves very rapidly the fact, but
that point
The fact of obtaining the row points in the first
row may come very quickly the table of calculation.

The second column of which a horizontally written place in the table.

The third indicates only the move of the reader of calculation,
and the second column putting but in not of calculation.
may be said that this paper is only written to indicate some of the methods of determining the time of explosion. The physical conception of an explosion is left to the investigator.

Am. S. Taylor.

Cinar I. Chandler.
<table>
<thead>
<tr>
<th>Runs</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td>54</td>
<td>45</td>
<td>37</td>
<td>30</td>
<td>24</td>
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<tr>
<td>Gas in cubic feet</td>
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<td>10</td>
<td>9.4</td>
<td>9.2</td>
<td>6.5</td>
<td></td>
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<td>78</td>
<td>79</td>
<td>79</td>
<td>78</td>
<td></td>
<td></td>
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<tr>
<td>Temperature gas F</td>
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<td>76</td>
<td>75</td>
<td>76</td>
<td>75</td>
<td></td>
<td></td>
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<tr>
<td>Pressure at gas base in inches</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Hg above atmosphere pressure</td>
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<td>.26</td>
<td>.29</td>
<td>.75</td>
<td>.65</td>
<td>.26</td>
<td></td>
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<tr>
<td>Air cu.ft. at 72° F and 30&quot; Hg</td>
<td>83.1</td>
<td>85.5</td>
<td>65.4</td>
<td>78.8</td>
<td>78.4</td>
<td>66.8</td>
<td></td>
</tr>
<tr>
<td>Gas cu.ft. at 52° F and 60&quot; Hg</td>
<td>0.2</td>
<td>7.6</td>
<td>9.7</td>
<td>8.5</td>
<td>8.42</td>
<td>7.56</td>
<td></td>
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<tr>
<td>Proportion air to gas</td>
<td>19.7</td>
<td>19.4</td>
<td>9.83</td>
<td>9.18</td>
<td>9.55</td>
<td>9.14</td>
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</tr>
<tr>
<td>Barometric inches Hg</td>
<td>29.55</td>
<td>29.56</td>
<td>29.55</td>
<td>29.55</td>
<td>29.55</td>
<td>29.55</td>
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</tr>
<tr>
<td>Time of combustion calculated from the points expressed in seconds</td>
<td>.089</td>
<td>.040</td>
<td>.0277</td>
<td>.072</td>
<td>.023</td>
<td>.028</td>
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<tr>
<td></td>
<td>.056</td>
<td>.0199</td>
<td>.0215</td>
<td>.0272</td>
<td>.025</td>
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<tr>
<td></td>
<td>.006</td>
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<td>.006</td>
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<td>.006</td>
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</tr>
<tr>
<td>P.m.</td>
<td>253</td>
<td>269</td>
<td>260</td>
<td>260</td>
<td>268</td>
<td>265</td>
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</tr>
<tr>
<td>x. P.m.</td>
<td>84</td>
<td>119</td>
<td>119</td>
<td>119</td>
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<td>119</td>
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</tr>
<tr>
<td>Run</td>
<td>Z</td>
<td>B</td>
<td>G</td>
<td>L0</td>
<td>L1</td>
<td>L2</td>
<td>L3</td>
</tr>
<tr>
<td>------</td>
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<td>---</td>
<td>---</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>in cubic feet</td>
<td>100</td>
<td>163</td>
<td>85</td>
<td>160</td>
<td>80</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>in cubic feet</td>
<td>4.49</td>
<td>5.45</td>
<td>7.72</td>
<td>1.34</td>
<td>3.42</td>
<td>1.12</td>
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</tr>
<tr>
<td>temperature of air F.</td>
<td>73.5</td>
<td>74.5</td>
<td>72</td>
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<tr>
<td>temperature of ces F.</td>
<td>73</td>
<td>72</td>
<td>72</td>
<td></td>
<td>6</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>Pressure at gas exit in inches</td>
<td></td>
<td></td>
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<tr>
<td>g. above atmospheric pressure</td>
<td>15</td>
<td>15</td>
<td>17</td>
<td>19</td>
<td>17</td>
<td>11</td>
<td></td>
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<tr>
<td>in cu.ft. at 50° and 70° Hg.</td>
<td>20</td>
<td>25.5</td>
<td>23.4</td>
<td>14.9</td>
<td>73</td>
<td>16</td>
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<tr>
<td>in cu.ft. at 32° and 50° Hg.</td>
<td>40.6</td>
<td>3.56</td>
<td>6.1</td>
<td>10.66</td>
<td>1.92</td>
<td>0.45</td>
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<td>Repetition of air to gas</td>
<td>22.18</td>
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<tr>
<td>manometer inches Hg.</td>
<td>17.03</td>
<td>24.55</td>
<td>18.55</td>
<td>19.65</td>
<td>12.55</td>
<td>24.66</td>
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<tr>
<td>Time of Combustion expressed in seconds calculated from pressure</td>
<td>0.857</td>
<td>1.657</td>
<td>0.28</td>
<td>0.49</td>
<td>0.68</td>
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<tr>
<td></td>
<td>0.53</td>
<td>0.52</td>
<td>0.75</td>
<td>0.75</td>
<td>0.80</td>
<td>0.83</td>
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<tr>
<td>F.P.M.</td>
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<td>254</td>
<td>255</td>
<td>254</td>
<td>255</td>
<td>250</td>
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<tr>
<td>Ex. F.P.M.</td>
<td>110</td>
<td>115</td>
<td>110</td>
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