TEST OF A POLYFUEL ENGINE
(HVID TYPE)

A Technical Problem
Submitted to the Faculty
of
MICHIGAN AGRICULTURAL COLLEGE

by

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Candidate for the Degree
of
Bachelor of Science
in
Mechanical Engineering.

-June, 1921-

THESIS

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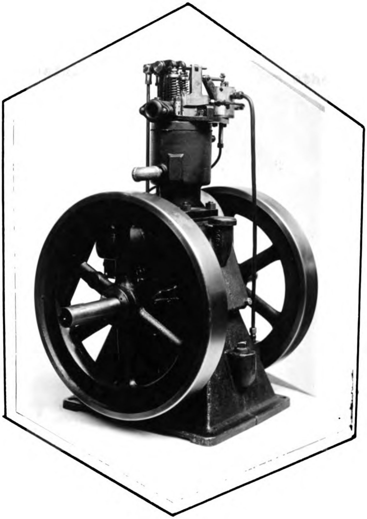


TEST OF A POLYFUEL ENGINE.

-INTRODUCTION-

In the last few years several high compression internal combustion engines have been developed. All of these types have been developed with the intention of burning heavy grade oils. Some of the types have been more successful in this respect than others.

The last two years have shown the necessity of this type of engine by the shortage of gasoline and by its uncertain price. Kerosene seems the next best fuel to use in the engine. Due to these things there has been a growing demand for an engine which would handle this heavy fuel and at the same time get away from the complicated parts of the Diesel and Semi-Diesel Engines, but would still have the high thermal efficiency found in this type. This demand has lead to the development of the Hvid type which seems to meet most of the demands and which has also eliminated the ignition system which causes so much trouble in the conventional type of gasoline engine.

This engine will operate successfully on kerosene, fuel oil, gas oil and the like, but will not

operate on gasoline. This is due to the relative low flash point of gasoline which will cause preignition and stopping of the motor.

-PURPOSE-

The purpose of this problem was to determine the operating characteristics while running on differant fuels; the objectionable features and to design new parts to overcome the faults found.

The testing of the engine as now constructed, was conducted in the following order,

a. Fuel consumption.

b. The effect of compression pressures in starting.

c. Study of explosion pressures.

d. The effect of different size holes in the fuel cup.

e. Power out put. B. H. P.

f. The control of the governor.

-GENERAL DESCRIPTION OF APPARATUS-

Before starting the actual test on the engine proper it was necessary to make several different pieces of apparatus.

A description of the engine used follows, together with a description of the apparatus.

The Engine.

The engine used was of the Hvid type as previously stated, built in the machine shop laboratories of the Michigan Agricultural College. It was an internal combustion engine of the four cycle type, stationary, vertical, circulating water cooled, 3 inch bore, $4\frac{1}{2}$ stroke, and rated as $1\frac{1}{2}$ H. P. at 500 revolutions per minute.

It was different in many respects from the convention four cycle engine which are of low compression and designed to operate on kerosene or gasoline for the most part. This engine was developed by Hvid with the idea of meeting the demand for a simple, reliable machine which would successfully operate over a large range of petroleum distillates. Ignition is by high compression and neither carburetor or ignition devices are employed. In this respect it resembles the Diesel and also with respect to the fuels it uses. Compared with the Diesel it does not use neither air spray nor direct injection of fuel as is used on some Semi-Diesel types. Instead, the fuel is drawn into the cylinder on the suction stroke by the piston, thus eliminating many of the complicated fuel injection pumps.

The detailed operation of the engine is as follows:

The fuel flows by gravity from the fuel

reservoir #5 (see fig. #1) through the shut off 7 pass the needle valve 8 to valve #11. As the fuel valve 11 opens it admits a measured charge of oil and air into the fuel cup 12 located in the cylinder head. At the same time a charge of air is drawn into the cylinder. On the compression stroke this air is raised to a pressure of about 450 pounds per square inch and the resulting high temperature spontaneously ignites the lighter parts of the oil in the cup. This immediately raises the pressure to a point that drives all of the oil into the cylinder through two small atomising holes in a very fine mist. As this strikes the highly heated air in the cylinder it is ignited and complete combustion takes place, exerting its pressure against the piston and thereby supplying the motive power for the engine.

The valves are mechanically operated from cams in the crank case through suitable push rods and rocker arms. The fuel valve being operated by a rider working under the rocker arm which operates the intake valve, this causes the fuel valve and intake valve to open at the same time. In operating the engine considerable trouble was experienced with this arrangement. If the fuel valve had been operated independently it would have been possible to experiment with different timing for the fuel valve. From indications (a tendency to blow fuel back) it would seem that the fuel valve should open before the intake, thus creating a suction on the fuel which would tend to draw it in instead of depending upon the action of gravity alone.

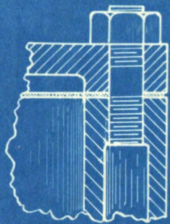
The cylinder head of this engine was not water cooled and after a hard pull over a period of time, a tendency to preignite was noticed. This is probably due to hot valves. A great deal of trouble developed with the gasket between the cylinder and head. The surface of the head where it fits against the cylinder was finished smooth making it impossible to hold a gasket in place. Repeated trials were made employing a plain asbestus material and also an asbestus wire gauze packing, but without success. If the surface had been rough finished like the cylinder it might have held for the head was fastened down with five 7/16" studs.

The cylinder and head were dismanteled and a tongue and groove turned in them as shown by fig. #2. This prevented the force of the explosion from acting directly upon the packing and proved a remedy. By doing this the effective width of the packing was reduced from a minimum of 5/16" to one of 1/8".

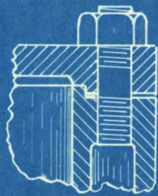
CYLINDER HEAD GASKET DETAIL

FIG 2

AS ORIGINALLY CONSTRUCTED



AS CHANGED



DRAWN BY R.R.C. 6-1-21

The governor.

The governing of this engine is accomplished in a rather unusual way. A description of the mechanism is as follows: (see fig. #1 and #3).

The governor is really a combination fuel feed and governor, as shown by fig. 1. This is accomplished by feeding the fuel from a gear pump, fig. 3, making use of the pressure developed by the pump to operate against piston 2, thus causing it to move upward in cylinder 3 in direct proportion to speed of engine. Fuel passes into by pass 6 and out past needle regulating valve 4. Needle valve 4 is provided for adjusting pressure which is necessary due to varying viscosity of the fuels used. As the fuel passes the valve 4 it is caught in reservoir 5 until it is of sufficient depth to flow through fuel shut off valve 7. From valve 7 it flows by gravity by the needle valve 8 which valve regulates the fuel passing into the cylinder of engine for each explosion. The fuel pump is geared to the cam shaft in such a way that it runs at the same speed as the crank shaft. As the engine speeds up the pressure from the pump increases which results in piston 2 being forced up, which in turn will act on adjusting screw 14 and rocker arm 9, thus transmitting an up and down motion to adjusting nut 17 which is screwed onto needle valve 8, and thereby controls fuel feed and speed of engine. Reservoir 5 is provided with an overflow pipe 13 which carries excess fuel back to the main fuel tank in the base of engine. The fuel pump, fig. 3, has a safety valve and by pass which protects piping, etc. from excessive pressure which might be generated.

In order to decrease the speed of the engine it is only necessary to tighten screw 4 and in order to increase the speed loosen or back up the screw.

The oiling of the entire engine is accomplished by the splash from the crank pit which is completely enclosed.

Brake equipment.

A water cooled Promy brake was constructed. This was of the common type consisting of a light beam equipped with a steel strap having friction blocks on it. The degree of friction was regulated by means of a hand wheel which increased the tension of the straps. The straps and blocks encircled a hollow water cooled pulley mounted directly on the crank shaft. The water in the pulley was allowed to evaporate, no attempt being made to keep the temperature below the boiling point.

The effective brake arm was 25.2" and the tare load of 2 pounds 2 ounces.

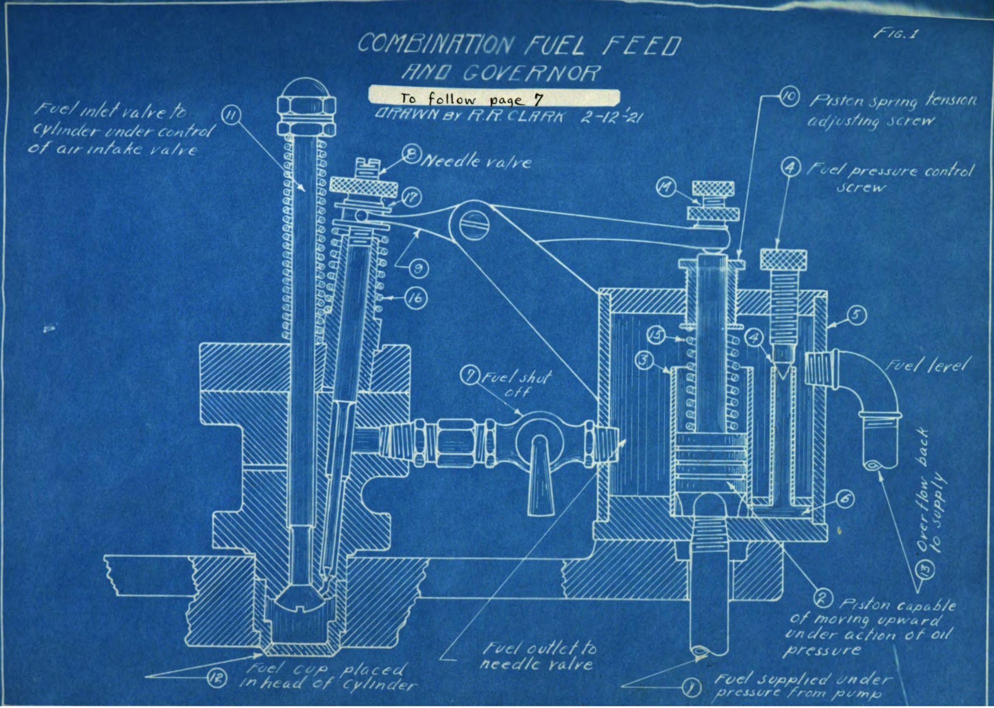


FIG. 1
COMBINATION FUEL FEED
AND GOVERNOR
To follow page 7
DRAWN BY R.R. CLARK 2-12-'21
11 Fuel inlet valve to cylinder under control of air intake valve
8 Needle valve
17
9
16
14
10 Piston spring tension adjusting screw
4 Fuel pressure control screw
15
3
4
5
Fuel level
7 Fuel shut off
6
13 Over flow back to supply
2 Piston capable of moving upward under action of oil pressure
Fuel outlet to needle valve
12 Fuel cup placed in head of cylinder
1 Fuel supplied under pressure from pump

To follow page 9

Fig 3

COMBINATION FUEL FEED AND GOVERNOR PUMP

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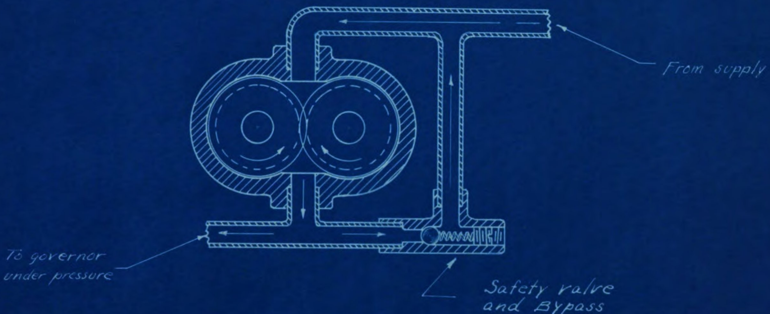


The brake load was measured by a small platform scale graduated in $\frac{1}{4}$ pounds.

Fuel Measuring.

The fuel being fed from the reservoir was supplied under a constant head inasmuch as the pump maintained a constant level in the reservoir. It only remained to measure the amount of fuel suppled the engine. This was accomplished by using a gallon can mounted on a Fairbanks scale graduated in $\frac{1}{2}$ ounces. The section pipe from the pump was disconnected from the base and placed about a $\frac{1}{2}$" from the bottom of the can, but not touching it, also the overflow from the reservoir was allowed to flow back through a copper tube to the can. By this method the weight of the fuel actually used was obtained direct.

The Indicator.

A Crosby gas engine indicator was chosen for the test. Because of the extreme high pressures handled the indicator was equipped with a small cylinder and piston having an area of $\frac{1}{4}$ of a square inch. By using a #200 spring (double with a $\frac{1}{4}$ sq. in. piston) it was possible to obtain cards.

A special connection had to be made in order to connect the indicator to the cylinder. This was necessary in order to keep the clearance volume as near constant as

possible. The outer barrel of the indicator was removed and a new one made with a small pressure valve built in. A 1/8" hole was drilled through the cylinder head and the indicator connected to this by a 1/8" pipe. The clearance volume of the indicator when set for highest pressure reached, is about 0.167 cubic inches which is 13.8 per cent of the clearance volume of the engine. The increased volume due to the indicator connection is 0.021 cubic inches with the pressure valve closed or 1.74 per cent of the engines clearance volume. This is the usual test condition.

A reducing motion was connected to the end of the crank shaft and was perfectly timed with the piston of the engine. This motion furnished the reciprocating motion for the indicator and was connected to it by a heavy cord. Considerable difficulty was experienced with the cords breaking at the higher speeds. This was due to the inertia of the moving parts of the indicator. By putting a new cord on every time a set of cards were to be taken this difficulty was overcome. In the latter part of the experiment this cord was replaced with a light piano wire.

The heating up of the reducing motion, due to the large friction area running at high speed made it necessary to remove it when not actually taking a card.

-TESTING PROPER-

-LIST OF TEST RUN-

Series A was on Kerosene.

Series B was on Fuel Oil.

Series A-1	Working in of the engine, leakage by rings discovered. New piston needed.
Series A-2	Equipped with new piston. Push rods adjusted with sufficient clearance to make engine run with best result. (See Log Sheet).
Series A-3	Exhaust cams filed to increase included angle. Best timing possible with present cams. (See Log Sheet) max power, fuel consumption for max load and governing.
Series A-4	Same timing as A-3 fuel consumption test for different loads.
Series A-5	Same timing as A-3 max power test to determine best speed.
Series B-1	Fuel consumption on Fuel Oil, valve timing same as A-3.

-ADJUSTMENTS AND TESTING PROPER-

After making the change in the method of holding the cylinder head gasket the test proper was started. During the time that the cylinder head was off the clearance volume of the engine was determined. This was accomplished by placing the cylinder head in a level position with all valves closed and filling it level full of water. Care was taken to get the water into the fuel cup. This water was then poured into a graduate and measured. Correction was made for the tongue of the cylinder which projected into the cylinder head. This gave a net combustion volume of 1.428 cubic inches with a 3/32" plate between the cylinder and the crank case. This plate was the necessary correction due to the change in the cylinder head mentioned above.

The engine proved very hard to start and after having used much energy an electric motor was belted to one of the fly wheels. The belt was thrown off during all tests.

After the engine had been worked in, it was noticed that it had very little compression when turned over slowly and by listening closely one could hear the air blowing by the piston into the crank pit. One of the covers was removed and it was found that the oil was very thin due to fuel leaking by the piston. Compression pressures were then taken with the following results:

Hand rotation 325 pounds per square inch.

Motor rotation 430 R. P. M. 450 pounds per square inch.

The above clearly demonstrated the necessity of using more than three rings on the piston as it was then equipped. A new piston was made carrying six rings. A core from the foundry was filed so as to allow enough metal in the wal of the piston for the extra rings. This core was then used in casting a new piston.

When the new piston was put in a thinner plate (1/16" thick) was placed under the cylinder instead of the 3/32" plate. This made the combustion volume 1.209 cubic inches or a decrease of 15.3 percent.

The engine was run for a period of 4 hours starting with no load and gradually working to a full load before any tests were attempted. This was done so as to work the new piston and rings in.

Test No. A-2 was started and run as indicated on log sheet (original data). At the end of the test compression pressures were again taken with the following results:

Hand rotation 400 pounds per square inch.

Motor rotation 430 R.P.M. 500 pounds per square inch.

Explosion pressure 500 pounds per square inch.

Several indicator cards were taken, one of them being reproduced in fig. 4. This card clearly shows that the valve timing was wrong, exhaust valve closing too early, (shown by rise at A). The timing was then checked and the results as given in fig. 5a were found. This probably accounted for the fuel blowing back as noted in some cases, and it also accounts for the engine not developing its rated power.

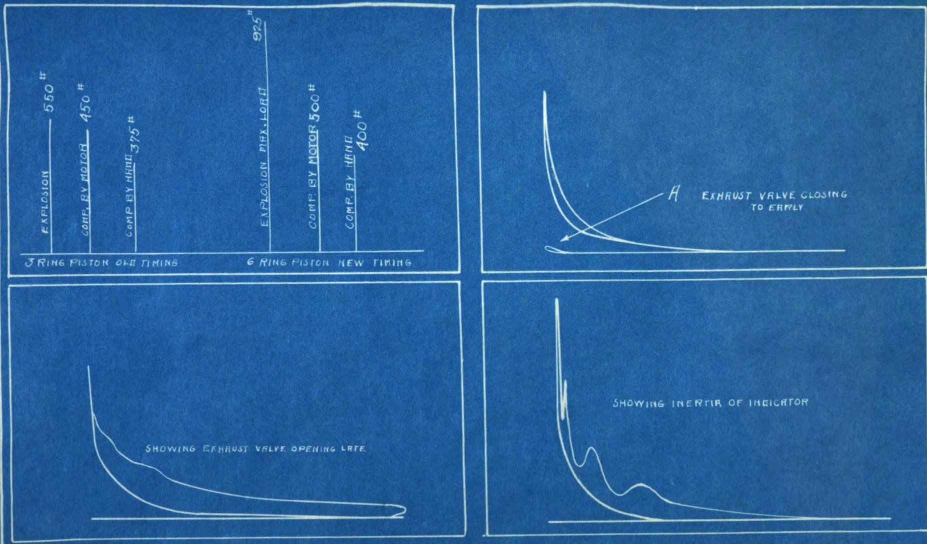
The cam shaft was removed and it was found to be badly bent (due to accidently running a piece of cloth into the gears) running out about 1/16" at the center. The shaft was straightened and the back of the exhaust cam machined away, thus giving a greater included angle. The cam shaft was then put back in the engine and so adjusted that the timing shown in fig. 5b was obtained. This was the best timing that could be obtained with the cams as made. The exhaust opening was too late and the intake opened too late and closed too early. A timing something like fig. 5c should be used. Due to the lack of time it was impossible to make new cams so the tests were all run with the timing as shown in fig. 5b.

Fuel consumption, maximum power and governing tests were run on kerosene without any further trouble except that efforts to obtain indicator cards were abandoned. The inertia of the moving parts on the indicator at high speeds

FIG 4

TO FOLLOW (14)

VERTICAL SCALE 1" = 400 LBS. PER SQUARE INCH



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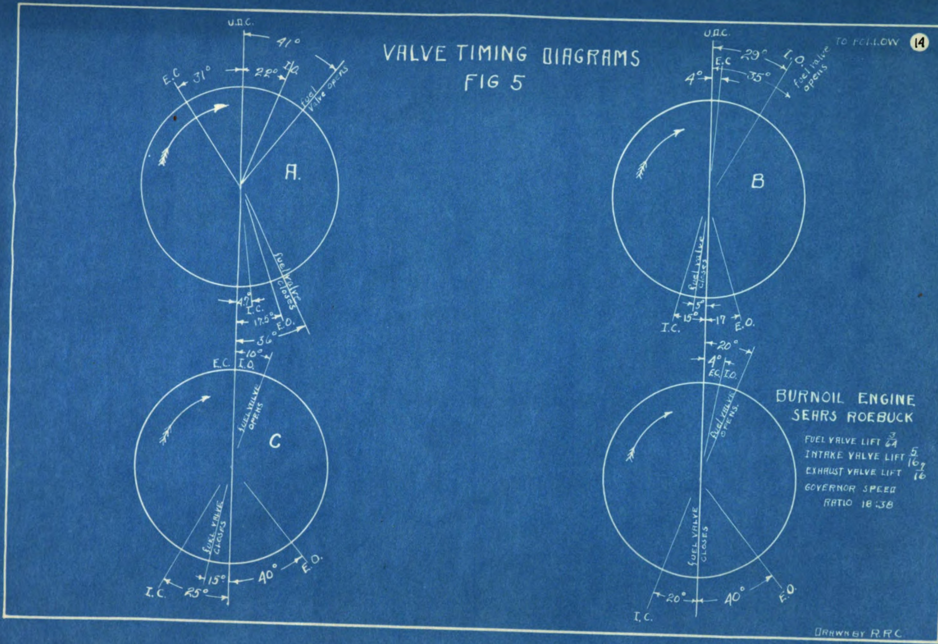


VALVE TIMING DIAGRAMS
FIG 5

made the card worthless when it was obtained.

A short fuel consumption test on fuel oil was run. Also a quantity of oil from the crank pit was burned with good results. The engine starting easily on both fuel and pit oils.

The fuel cup used on the above tests had two holes .031 in diameter. A second cup with one hole .044 in diameter was used and seemed to give the same results as the first one. Due to the short time it was impossible to run an exhaustive test along this line.

-DESCRIPTION OF RESULTS-

Table I contains a summary of all data taken.

Curve sheet I gives a graphical representation of the results.

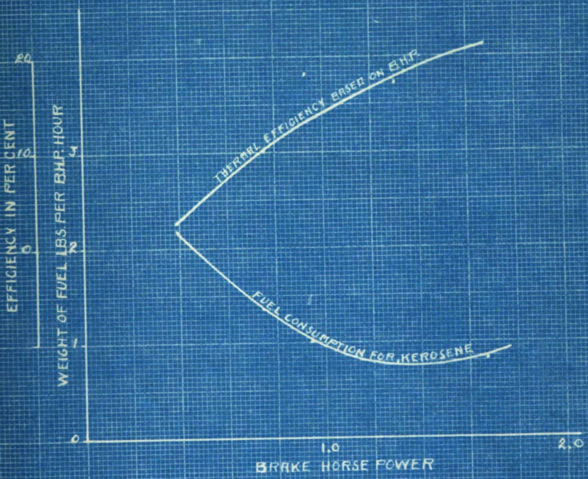
-SUMMARY-

From the results obtained this engine ought to develope two horse power or an over load of 33 1/3 per cent if it had the proper cam shaft, although the crank shaft is not heavy enough to stand that much.

The operation of the engine was very satisfactory after once adjusted, demanding very little attention. The fuel consumption was about .8 of a pound per horse power hour when fully loaded, which was very good for such a small engine.

The compression pressure necessary for easy

THERMAL EFFICIENCY AND FUEL CONSUMPTION CURVES
FOR
POLYFUEL ENGINE (HVID)



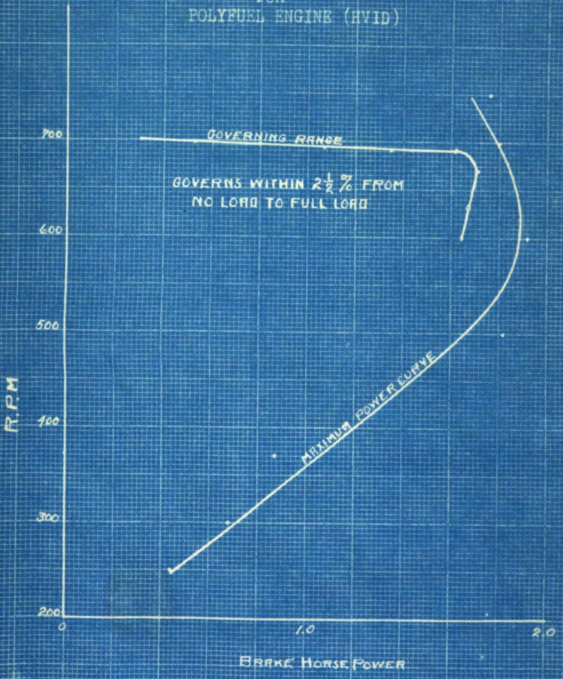
THERMAL EFFICIENCY CALCULATION

B.T.U. Value of Kerosene ---------- 20,376
from formula $H = 14600 \times C + 52{,}230 \times H$
in which C = carbon percentage
H = hydrogen percentage
The percentages were found by distillation

$$\text{THERMAL EFFICIENCY} = \frac{\text{B.T.U. Developed}}{\text{B.T.U. Used}} = \frac{1.67 \times 2547}{20{,}376 \times .978} = .213$$

To follow 15

MAXIMUM POWER AND GOVERNING RANGE CURVES FOR POLYFUEL ENGINE (HVID)



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starting has to be 400 pounds per square inch or more. When dropped to 375, starting was very hard while at 500 it was very easy to start.

The explosion pressure is only a little more than compression pressure at light loads but rises very rapidly with increased loads reaching a maximum of twice the compression pressure at full load.

-GOVERNOR CONTROL-

The governor held the engine speed very close allowing a variation of less then 3 per cent from full load to no load. By experimenting with different pistons, pressures, and needle points, a closer regulation could be obtained. Experience seems to indicate that the blunter the needle and the smaller the piston, the better the regulation.

Provisions will have to be made for different fuels for when the governor is set for 700 R. P. M. on kerosene it will only allow the engine to run at 300 R. P. M. on fuel oil. This is due to the difference in viscosity o~ the two oils. When the crank pit oil was used the engine would not run until the governor was changed. A larger over flow is needed for the heavier oils.

Due to the impossibility of obtaining indicator cards the thermal and mechanical efficiency could not be obtained.

-COPY OF ORIGINAL DATA-

12-20-1920—3M 2510 Form M. E. 16.

Sheet No. 1

MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGE

Running Log of [illegible]

[illegible]

Observers [illegible]

Date [illegible] 19[illegible]

[illegible]

[illegible]

R.P.M. [illegible]	[illegible]	[illegible]	[illegible]
405	[illegible]		[illegible]
470	"		[illegible]
585	"		[illegible]
4[illegible]	"		[illegible]
5[illegible]	"	3·4 [illegible]	[illegible]
4[illegible]	"		[illegible]
[illegible]	"		[illegible]
497 mean.			

[illegible] [illegible] range

Power developed

(7.5 − 2[illegible]) 497 × .00[illegible] = 1.27 HP

[illegible]

Timing of engine

E.O. [illegible] L.H.C. = 17.5°

E.C. 18" " H.C. = 31.1°

I.O. 3½" [illegible] H.C. = [illegible]°

I.C. [illegible]" [illegible] L.H.C. = 4.[illegible]°

[illegible] 3" [illegible]

[illegible] wheel 26.[illegible]

[illegible]

[illegible]

[illegible]

Remarks:

The engine h[illegible] tendency to slow up which was corrected by increasing the feed

12-20-1920—3M 2510 Form M. E. 16. **Sheet No.** 1

MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGE

Running Log of [illegible] ([illegible])

Observers [illegible]

Date [illegible] 192[illegible]

[illegible]

Fuel consumption

No.	R.P.M.	Scale load in lbs	[illegible] in oz.	[illegible] in oz.	Time	Wt. of fuel per HP hour in Lbs.
1	630	7 3/4 [illegible]			[illegible]	
2	630	"			[illegible]	
3	625	"			[illegible]	
4	630	"	[illegible]	[illegible]		.825

[illegible]

([illegible]) [illegible] =

1.67 H.P.

Timing

E.O. [illegible] [illegible] [illegible]
E.C. [illegible] " [illegible]
I.O. [illegible] " [illegible]
I.C. [illegible] " [illegible]

Fuel valve opens [illegible] [illegible]
" " closes [illegible] " [illegible]

[illegible]

Remarks:

12-1-1919-3M 2510 Form M. E. 16

Sheet No. 2

MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGE

Running Log of Test of [illegible] Engine [illegible]

Observers { .... } { .... } **Date** 2-2[illegible] 1921

[illegible] Test

NO.	R.P.M.	[illegible]	H.P.	[illegible]
1	675	6.5	1.16	
2	670	6.5	1.17	
3	725	6.75	1.2[illegible]	
4	700	6.65	1.[illegible]	
5	600	7.25	1.0[illegible]	
6	650	6.60	1.5[illegible]	
7	65[illegible]	7.75	1.3[illegible]	

Series H-2

Governing

NO.	Load	R.P.M.	R.P.M.	H.P.	[illegible]
1	3.25	[illegible]	6[illegible]0	0.35	
2	4.20	725	6[illegible]	0.549	
3	5.[illegible]0	700	670	0.[illegible]	
4	6.00	675	670	1.0[illegible]	
5	7.00		670	1.245	
6	7.[illegible]0		670	1.62	
7	8.50		670	1.71	
8	8.75		6[illegible]	1.67	
9	[illegible].00		600	1.65	
10	9.[illegible]	5[illegible]	450	[illegible] stops.	

Quick [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible].

[illegible] [illegible] [illegible]
piston & cylinder [illegible],
[illegible] 284 [illegible] [illegible]
[illegible] [illegible] [illegible]
7 lbs. [illegible] 291 [illegible] [illegible]
[illegible] [illegible] [illegible]
in pounds [illegible] [illegible]
[illegible] [illegible] [illegible].

Remarks:

Engine [illegible] [illegible]

[illegible] R.P.M. [illegible] [illegible] [illegible]
[illegible] [illegible]

12-20-1920—3M 2510 Form M. E. 16.

Sheet No. 1

MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGE

Running Log of Test of [illegible] Fuel Engine (Hvid Type)

Observers Clark[illegible]

Date 5-[illegible] 1921

Fuel Consumption

Series A-4

Kerosene

R.P.M.	Scale Load	Fuel Wt. lbs.	Fuel Consumed	Time	H.P.	[illegible]
640	3½	5 lbs.		[illegible]:46		
640	"			[illegible]		
645	"			11:[illegible]		
640	"		50.0	11:[illegible]	.2[illegible]6	2.16
640	3½	[illegible]		[illegible]		
645	"			11:25		
640	"			11:31		
640	"		12.5	11:37		2.06
640	5½	5[illegible]		11:00		
640	"			11:10		
640	"			11:21		
640	"		[illegible]5	11:32	.44[illegible]	1.01
640	7	30.5		11:34		
640	"			11:40		
640	"			11:45		
640	"		44.5	11:57	1.25	[illegible]

[illegible] connection leaking

Remarks:

12-20-1920—3M 2510 Form M. E. 16. Sheet No.

MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGE

Running Log of Test of [illegible] Engine
([illegible] Type)

Observers: Clark

Date 7-21 1921

Series A-5 Test for Max power at [illegible] speed

No.	R.P.M.	Scale load	H.P.
	250	6½	0.44
	300	7¾	0.63
	310	8	0.87
	500	11¼	1.62
	610	10	1.915
	700	8½	1.71
	750	8	1.765

Series B-1 Fuel consumption (Fuel oil)

R.P.M.	Scale load	[illegible]	[illegible]	[illegible]	H.P.	[illegible]	Time
550	9½	50.5					5:05
545	·						4:5[illegible]
550	·						4:11
550	·		40		1.40	.877	4:27

Fuel not fully burned as the [illegible] smoky exhaust.

Max power

R.P.M.	Scale load	H.P.	
530	11	1.68	Very smoky exhaust.

Governing.
[illegible] R.P.M. [illegible]
[illegible] full [illegible]
[illegible]
[illegible] of the [illegible] oil [illegible]

Remarks:

The engine ran very good on the oil with the exception of the smoky [illegible] running [illegible].

MECHANICAL ENGINEERING LABORATORY
MICHIGAN AGRICULTURAL COLLEGE

Running Log of [illegible] Engine
([illegible])

Observers { Clark

Date [illegible] 19[illegible]

Miscellaneous

Oil was taken from the crank pit and used as fuel with the following result.

450 R.P.M. [illegible] B.H.P. [illegible] the same as fuel oil.

With [illegible] R.P.M. [illegible] [illegible]

1 Gal of [illegible] [illegible]
1 " " fuel oil " [illegible]

[illegible]

-THE ENGINE DESIGN AS SUGGESTED-

THE NEW DESIGN.

Due to a tendency toward preignition when the engine was pulling hard for a long period it was deemed necessary to water jacket the head. The preignition is probably due to the hot exhaust valve and for that reason the following has been suggested.

By so arranging a sleeve valve about a poppet valve that both incoming and outgoing gases pass through the same valve the cool incoming gas will cool the hot valve and also receive heat which will give a better explosion.

This is accomplished in the following manner: See sheet #1.

F is a cylinder sleeve valve with ports cut in such a manner that on the exhaust stroke when poppet valve G is open the port in the sleeve will uncover port H in the head, thus allowing the gas to pass out. On the suction stroke the sleeve moves down closing port H and uncovering port I, thus allowing air to enter. The poppet valve remaining open during the entire time of exhaust and intake. It is believed by this method that the poppet valve will remain comparatively cool.

The valve and sleeve are to be operated by cams through push rods and rocker arms. A cam for each valve.

The sleeve valve requires a travel up and down of one inch, this is necessary due to the fact that each port is ½" wide and one port has to be fully closed before the other can open. Owing to the fact that a cam with a one-inch lift is very impracticable a rocker arm with a two to one ratio is recommended, thus making a cam with a ½" lift necessary.

As the engine is now designed it will be necessary to cut a small opening thru the case to allow the large cam to rotate. A scoop-shaped cover can be fastened with screws over this opening.

Sheet 2 shows a detailed drawing of the head and sheet 3 shows the cylinder which goes with the head. Six 7/16" studs instead of five are used and a wider gasket between head and cylinder. It is believed that this will overcome the trouble experienced in the first part of the test.

It will also be noticed that the fuel valve cage is cylindrical and fastened in by a ring nut. A small thin brass ring is used between the nut and cage making the joint tight and thus preventing any leakage of fuel from the fuel passage. By making the cage round it is possible to make a ground joint between the fuel cup and head, and the cup and cage. It is also much easier to machine as the needle valve hole and guide are in the cylinder head and not at an angle. Care will have to be taken to line up the fuel passage in the cage with that in the head, but once lined up it can be marked making it easy to replace.

A new breather pipe or cap should be designed as the one now in use collects the oil on the under side of the cap and allows it to drip outside of the breather pipe. This feature makes a very dirty engine and wastes a lot of cylinder oil from the crank pit.

When this engine is redesigned provision should be made to allow a crank shaft of at least ¼" larger in diameter both on main bearings and crank pin. The crank shaft now used is over loaded about 200 per cent when developing rated power.

Assembly - new design
Sheet I

Cylinder head detail
Sheet 2

Cylinder detail
Sheet 3

Assembly -old design