AN INVESTIGATION OF KEROSENE AS A FUEL FOR INTERNAL COMBUSTION ENGINES.

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Note:- This thesis was worked at State College, Pa.
and presented by the writer for the degree of M.E.

THESIS

INTRODUCTION.

To make the problem we are attacking more clearly understood, we feel that it is not out of place to briefly state the situation at the present time in regard to the design of internal combustion engines. Also to put certain data, regarding crude oil and its products, before the reader in order that he may more fully appreciate the urgent need of a more plentiful fuel than gasokine or at keast a standardization and constancy in the grade of fuels which we already have.

THE PROBLEM OF DESIGN.

An internal combustion engine is ordinarily designed to meet certain requirements in such a way as to give its best operation at a certain load, with a definite kind and grade of fuel.

This being true, if either the grade or kind of fuel is changed, it could not be expected that the fuel economy of the engine would be equal to, what might be attained in an engine designed to use the new fuel or grade of fuel.

This is the perplexing problem that confronts the designer of internal combustion engines in this day of unstandardized fuels. He designs a gasoline engine for a certain grade of gasoline and in a few years it is impossible to obtain this grade and his engine does not exactly meet the requirements of the new grade of fuel.

An engine may be able to burn a large variety of fuels but probably less economically than the engine designed for and operated on one grade of one fuel.

THE PROBLEM OF FUEL.

Today we have a condition that calls for the adaptation of a fuel to the engine.

There are millions of dollars invested in engines constructed to use gasoline of a high grade. The refineries have used every means known to increase the supply to meet the increasing demand.

The last, and always effectixe means of controlling the demand has been resorted to; that of raising the price until the supply and demand balance. (See Chart No;1.) The margin of operation of many gasoline engines is so small that at the advanced price of gasoline, they must remain idle.

The problem of the engineer is to adopt a cheaper and more plentiful fuel to the lines of de-

sign already used in the construction of these engines. The interest in this question is shown by the fact that the largest money prize now open to engineers and chemists is the prize of $100,000 offered by the International Association of Recognised Automobile Clubs, for the best substitute for gasoline.

The prize is to be given only for some product that can be used in existing internal combustion engines. The substitute must be available in large quantities and must be of such a nature that it cannot be monopolised by trust.

The only source of relief in sight to-day lies in crude petroleum or some of its products more plentiful than gasoline.

Chart II shows the highest and lowest price of Pennsylvania crude oil since 1859 to date. Also the production.

Chart III shows the estimated gallons of gasoline used per year for power in automobiles.

PRODUCTS OF PETROLEUM.

In the process of refining crude oil by

distillation there is a wide range of products varying from a light volatile gas to the heaviest lubricating oils.

Early in the history of oil production the lighter distillates were of little worth, and due to their explosive properties, very dangerous. For these reasons the refiner of oils realized little but troubles from these products which they called gasoline. Gasoline then consisted of a small percent of total product of distillation and was, hence very explosive and often the line between gasoline and kerosene was crowded so high that even kerosene became explosive at ordinary temperatures and caused many serious accidents.

This high quality of gasoline was very conducive to the successful development of the internal combustion engine. With its high thermal efficiency and adaptability, the gasoline engine became widely used in all fields of industry and by it many new avenues of development were made possible. Chief among these new applications of the gasoline engine is the automobile industry.

HOW THE GASOLINE WAS INCREASED.

With these new markets for gasoline the

the supply was quickly surpassed by the demand. Now the problem of the refiners became the one of how to increase their supply of gasoline. The question was easily solved for a time. The solution was in changing the grade of gasoline so that it would include more of the naptha products. This process of adulteration has gone nearly to its limit. Originally 1.5 o/o of the crude oil was taken as gasoline. Now gasoline includes from 15 to 20 o/o or practically all of the naptha products.

Another method of increasing the supply of lighter oils for internal combustion engine use is by the process of cracking the heavier oils into two or more com ponent hydro carbon products. This cracking is accomplished by distilling the heavier products under pressure greater than the atmospheric pressure. It is claimed, however, that this means of increasing the lighter products is only "robbing Peter to pay Paul" for the residue which is subjected to this cracking distillation would make lubricating oil, if properly treated, but after the cracking process has been preformed the lubricating properties are distroyed. Hence, the gain of motor oil and the loss of lubricating oil.

There is a plant in Pennsylvania manufacturing gasoline of a very excellent quality by condensing natural gas. This is done by subjecting it to high pressure under low temperature conditions.

GASOLINE PRODUCING CRUDE OIL, DECREASING.

The government figures place the production of crude petroleum in the United States for 1912 at 220,200,000 barrels, or 250,000 barrels less than in 1911. There has been a decrease in all the old oil fields but an increase in California and from the gulf districts. However, the crude petroleum from California and the gulf districts are very low in the lighter distillates, which has meant a considerable decrease in the production of gasoline.

KEROSENE THE LARGEST PRODUCT OF CRUDE OIL.

In the process of refining crude oil by distillation assuming that already the naptha products have been included in the class of fuels

known as gasoline or motor fuels, the next product and by far the largest product of the crude oil is the product that comes over at temperatures from 300° to 600°F. and is known as kerosene. Kerosene may be said roughly to make up 50 o/oof the crude oil and at the present time there are millions of barrels of kerosene in storage as it has been impossible to market this product as fast as it was necessary to produce it in order to supply the demand for the lighter products.

KEROSENE.

Keresene is known in the markets in these grades according to its fire test. Kerosene that burns at 110°F and is known as 110° standard white, 130° standard white and 150° water white. The degrees in each case indicating the fire test. There is very little of the 110° kerosene used in this country. In some states it is unlawful to sell kerosene in such a low fire test. This grade is usually exported.

THE FIRE TEST OF FUELS.

The fire test is to determine the flashing point and is in general conducted by heating the fuel under test until a lighted taper held at a standard distance from the surface of the liquid will cause a flash from the gas given off from the surface.

The degrees, as 110° is the temperature at which this flash occurs.

See Charts NO. 4.

KEROSENE AS FUEL FOR THE GASOLINE ENGINE.

The gasoline engine is designed with the idea of gasoline only as a fuel. The same design will give very satisfactory results with a heavier fuel such as kerosene, if certain requirements are met. Gasoline vaporizes at ordinary atmospheric temperatures by merely atomizing it into the intake manifold of the engine.

To use kerosene in such an engine it is necessary to use higher temperatures, for kerosene does not vaporize at atmospheric temperatures.

There is an abundance of heat available for heating purposes both in the exhaust and in the cooling jacket water.

CARBURETION OF GASOLINE.

The function of a carburetor is to first convert the liquid fuel into a vapor and second to mix this fuel vapor with air in the right proportion to cause complete combustion of the fuel.

The most common means of vaporizing gasoline for gasoline engine use is by atomizing it into the proper amount of air, as it is drawn into the cylinder.

Heat is necessary to change a liquid into a vapor, hence if the gasoline is completely vaporized it must take its heat of vaporization from the air with which it is mixed.

Now the heat of vaporization of gasoline is 320 B.T.U. per pound. The Specific Heat of air is about .26 B.T.U. per pound. The proportion of fuel to air by weight for a good complete combustion, is about (1) to (14) Now let t = the change in temperature of air necessary to vaporize gasoline and we have the equation.

$$(1 \times 320) = (14 \times .26)t$$

$$t = \frac{320}{14 \times .26} = 88°F$$

The lowest point at which gasoline vaporizes is about the freezing point of water; hence, if all the heat of vaporization is furnished by the air it must be heated to approximately 32°F + 88°F = ~~112~~ 120°F in order that the final temperature will be above 32°F.

CARBURETATION WITH KEROSENE.

The heat of vaporization is about 400 B.T.U. The proportion of fuel to air for best combustion is assume 1 to 14. Now letting (t) = the temperature change in air necessary to compeltely vaporize the kerosene and we have the following equation.

$$\text{H of V}$$

$$(1) \quad (400) = t(14 \times .26)$$

Or tha air must change 151° in temperature to furnish the heat necessary to form a vapor of the fuel.

But the lowest fire test of kerosene is 110°F so that the lowest temperature at which the air should go to the carburetor would be 151° + 110° = 261°F. This is also assuming that the kerosene itself is heated to 110°F before entering the craburetor.

These temperatures are not noticed in most gasoline engines as the air is constantly taking heat from the metal parts of the engine, and also it is quite certain that a large part of the fuel is mechanically mixed with the air instead of being in a vapor state.

DIFFICULTY OF COMPRESSION.

The boiling point of gasoline ranges from 100°F to 300°F, while the boiling point of kerosene ranges from 300°F to 600F, but strange as it may seem, kerosene will not permit of as high compression without auto-ignition as will gasoline. This makes the problem of adapting kerosene to the gasoline engine a very difficult thing to accomplish.

NOTE: I might say here that none of our tests were conducted at this high temperature, and I feel that a further study and experiments at much higher temperatures might present some interesting results.

Here are the two horns of the dilemma. If you keep your cylinder cool to prevent auto ignition much of the heavier products will not be burned and carbon or soot will be deposited on the walls of the cylinder and clog its action, giving a smokey exhaust.

On the other hand if you run the temperature high you will burn your fuel much more completely, giving better exhaust conditions, but at anything but very light loads the compression at these temperatures will produce auto ignition, made evident by a sharp pounding sound.

This pounding can be oversome by injecting water into the cylinder with the fuel. However, this injection of water slows down the point of ignition and also the rate of flame propogation both of which make serious inroads upon the economy of the use of fuel

APPARATUS USED.

Most of our tests were conducted on a Jacobson 10 H.P. Engine. A description of the engine and other apparatus is here given.

JACOBSON ENGINE.

GENERAL DESCRIPTION.

This engine is a single-cylinder, horizontal, 4-cycle, stationary type. The engine is rated at 10 horse power with a normal speed of 300 R.P.M. The piston diameter is 6½ inches and the length of piston stroke is 10½ inches.

ENGINE BASE: The upper portion of the base supporting and making up the main bearings is of the double box housing type. The lower part of the base serves also as the tank for gasoline.

CYLINDER: The wearing part of the cylinder is made separate from the water jacket part. This provides for the expansion, due to heat, without disturbing the cylindrical shape of the wearing surface. The opening in the combustion chamber for inlet valve is on the top of the chamber, while the openeing for the exhaust valve is directly below.

This leaves the combustion chamber perfectly smooth when both valves are closed.

PISTON: The piston is of the trunk pattern. Piston pin is placed well back on the piston. Piston rings are of cast iron. They are machined eccentric.

The crank pin is made extra large.

The connecting rod is made of malleable iron of I beam section provided with liberal bronze bearings. The bearings are adjustable to compensate for wear.

VALVE GEAR: The side shaft driving the valve mechanism is operated by a spiral gear connecting with the main shaft. The cam operating the exhaust valve is keyed to the side shaft. The igniter trip is driven directly from the side shaft by means of a crank pinned rigidly to the shaft.

GOVERNORS: The governor is of the fly ball type, the balls are separated, due to increased speed, the latch engages a latch block, on the upper end of the exhaust lever, which holds the valve open until the governor balls assume a position which releases the latch.

IGNITER: The igniter is provided with

an eccentric roller shaft with handle attached. The electrodes are mounted in a removable plug which may be removed from the cylinder for purposes of cleaning.

LUBRICATION: Oil is admitted to the wearing surface of the piston near the front end of the cylinder chamber. The main bearings are lubricated by means of grease cups.

CARBURETOR: The Carbureter provided with the engine was of the jet type drawing fuel from the base of the engine. This was removed and the carburetor to be tested connected as near the engine as possible.

COOLING SYSTEM: The cooling water for the engine was circulated by high static pressure, being connected to the city water supply. By this means the temperature of the cylinder could be kept at practically any temperature above that of the water in main.

Temperature was the only data we were interested in as the efficiency of the

engine either thermal or mechanical was not sought.

EXHAUST: The exhaust of the engine came from the engine through a 2½" pipe, about three feet long to a muffler. From the muffler it passed into a 4" pipe and rose about 8'-0 to the main exhaust pipe for the laboratory which was a 6" pipe.

A by-pass was provided as near to the engine as possible, for the purpose of forcing the exhaust gases through carburetor,(if provided for such heating) A valve was placed in the by-pass and another in the main pipe, in such a way as to make it possible to turn any part, or all of the exhaust gases through the carburetor.

IGNITION: The ignition system is of the make and brake, or contact spark type. Part of the tests were run with the coil connected to the lighting system through lamp resistance. And part of the tests were run by the use of six dry cells, as the source

of current.

INDICATORS: We used Tabor Indicators. The first one was an internal spring type and worked well up to the limit of its spring, but due to the excessive pressure at time of pounding, we were unable to use this indturment without danger of exceeding the capacity of the spring (100 pounds) and breaking the swivel joint.

Due to several accidents of this kind we changed to an external spring type which had a heavier spring(150 pounds)

BRAKE: The brake used on the engine was of the Prony type attached to the pulley of the engine, which is an 18" pulley, 7 " wide. Water piping was so arranged that we could allow a small stream of water to flow into the inside rim of the pulley wheel for cooling. Width of the brake was 6".

FUEL TANK: The fuel tank used in these

tests was made of galvanized iron provided with a guage glass to show the level of fuel in the tank. Also a cock at bottom of tank for turning off fuel when not in use. This tank was placed about 20" above the carburetor the connection between the two being made by a flexible tube (See Sketch)

SCALES: The scales used to weigh the fuel in these tests were Fairbanks No. 0 equal beam scales, graduated to read in hundredths of a pound, capacity 25#.

The scales used to weigh the brake load were of the ordinary platform scales with capacity of about 500#. This scales had two sliding weights. One of these weights was set for tare, enabling us to read the net load on brake from the other beam.

SPEED COUNTER: The speed was taken with the ordinary type of speed counter and a watch.

THERMOMETERS: The thermometers were all of the Fahrenheit scale and read to 300° standard make.

THE OBJECT OF TEST.

The object of these tests were to compare some of the carburetors now in use, using both kerosene and gasoline and also to study the general principles of carburetration of kerosene.

In order to have data for comparison we tested each carburetor on gasoline, a mixture of one half gasoline and one half kerosene, and on kerosene.

Some carburetors would not operate on kerosene alone but most of them would give very good operating conditions on a mixture of half gasoline and half kerosene. This seemed to be pretty generally true of all carburetors.

It was not our purpose to determine efficiency, or heat values of the fuel, but simply to operate each carburetor on the same fuel at its best adjustment.

DESCRIPTION OF THE TEST.

After adjusting the grease cups, and filling the fuel can,placing the thermometers in the wells, and seeing that the spark was retarded, we started the engine and turned on the cooling water. If we expected to run on kerosene it was always necessary to start the engine on gasoline and when the cylinder and carburetor had become heated sufficiently the kerosene was turned into the carburetor.

After the engine was started on the test fuel we would adjust the needle valve of the carburetor and the auxiliary air valve to give the best operating conditions on a medium load. When these conditions were satisfactory the test was started by taking the weight of the fuel at a definite recorded time and every five minutes thereafter. We then read the thermometers and took the spped, always keeping the load at the brake constant. We usually started with 20# net load on the brake. The second load we took at 30#, then we changed the net load by 5# steps to as high a load as the engine would carry. It was usually necessary to open the needle valve slightly upon the higher loads, especially with kerosene. All the conditions were kept as constant as possible during a test.

Fuel economy and good working conditions being the thing aimed at in all tests.

Indicator cards were taken in order to

study the burning conditions in the cylinder. A few cards are shown herewith.

The temperature of the fuel was taken at a point in the intake manifold about eight inches from the engine. At this point a thermometer well was placed in the path of the mixed fuel, passing to the engine.

The temperature of the cooling water was taken about two feet from the engine on each side by the use of a thermometer well, similar to the one used for the fuels.

DESCRIPTION OF CHARTS.

CHART NO. 1.

This chart was plotted from data obtained as follows:

The prices for the years 1897 to 1904 were taken from the Geological Survey Report of the Government. The prices for years from 1904 to 1913 were gotten from the Oil Company of Bellefonte, Pa. and are grades 86° to 88°B., which, of course, is a high grade of gasoline.

CHART NO. 2.

The data for this chart was taken from the latest available government report and the last two years from News Paper reports.

CHART NO. 3.

This charts shows the enormous increase in the demand for gasoline, due to the automobile industry. Values were obtainable for years 1910,11,12. With these three points the curve was continued to make an estimate of the gasoline which will probably be used in 1913, which amounts to nearly 16,000,000 barrels.

CHARTS NO. 4.

The ddta for this chart was taken from "Crews" book entitled "Practical Treatise on Petroleum". The following is a quotation from this book in regard to the data plotted. It also shows the worthlessness of gasoline at that time(1887)

"We do not mean to be understood to say that the first distillates make their appearance at 167°F. Products of .630 specific gravity pass over at 122°F, but as there is very little demand for such light oil comprising benzine, gasoline, etc., it is in most instances allowed to run into the sea."

This chart simply shows that there are products being given off at all temperatures between the highest and lowest, and that its flashing point increases as the temperature of distillation increases, and also that the products become heavier about in the same proportion that the flashing point rises.

CHART NO. 5.

This chart is used in changing readings of specific gravity in the Baum scale to term as referring to the percent of weight of the liquid to the weight of an equal volume of water, and was plotted from a table of the two scales taken from the book mentioned above by Mr Crew.

CHART NO. 6.

The chart was gotten up for the purpose of facilitating the work of computing the horse power hour costs from the fuel consumption, taking into account the specific gravity of the fuel.

This curve was constructed for values ranging between the limits of our readings and test conditions. It can readily be seen that for very low consumption and very low price this chart would not be very accurate, but for most conditions I feel that it is sufficiently accurate for practical commercial purposes.

CARBURETORS.

Holley Carburetor is described in the Scientific American of January 11, 1913.

The Air Friction Carburetor does not preheat either the air or fuel but by a vigorous agitation of the air secures an intimate mixture of the air and fuel.

The built up carburetor used in these tests, called on the data sheets, the Moyer Carburetor, differed slightly from the later type, (a blue print of which appears in this thesis.) The exhaust pipe was much more restricted and the whole device was smaller.

Aside from these changes the design is similar to the one shown here. With the new type it is hoped to secure much higher temper-

atures, and therefore, much better operation. The new carburetor was not completed in time to allow the tests to be included in this thesis.

CONCLUSIONS.

1st- The following fact we consider the most important result of our tests.

That which has usually been considered preignition, causing a sharp pounding sound at the connecting rod, is not preignition as is shown by many of the indicator cards included herewith. These cards were taken while the pound was very severe. The ignition is automatic as was shown by the fact that the engine would continue to run after the electric circuit had been disconnected. The explosion,however, which by the way appears to be a very violent and almost instantaneous burning, does not occur until after the piston is started on the return stroke. The cause of this may be due to a cracking of the heavier portion of the kerosene, which due to the lack of high temperature and quantity of heat necessary to vaporize it, has been carried into

the cylinder in small drops and under the high temperature and high pressure of compression, brakes up into an explosive gas and a very heavy oil or even carbon. As the pressure begins to be released, this explosive portion bursts into flame and causes a very sudden high pressure which throws the reciprocating parts against their supports, making the sharp pound. I believe if the kerosene could be thoroughly vaporized and all temperatures kept high enough to maintain the fuel in the vapor form until ignited, that this very serious objection and also the smokey exhaust could be eliminated.

2nd- The operating conditions are very much in favor of gasoline, but owing to the great difference in price between gasoline and kerosene, the cost of operation would seem to warrant the use of kerosene in stationary gasoline engines.

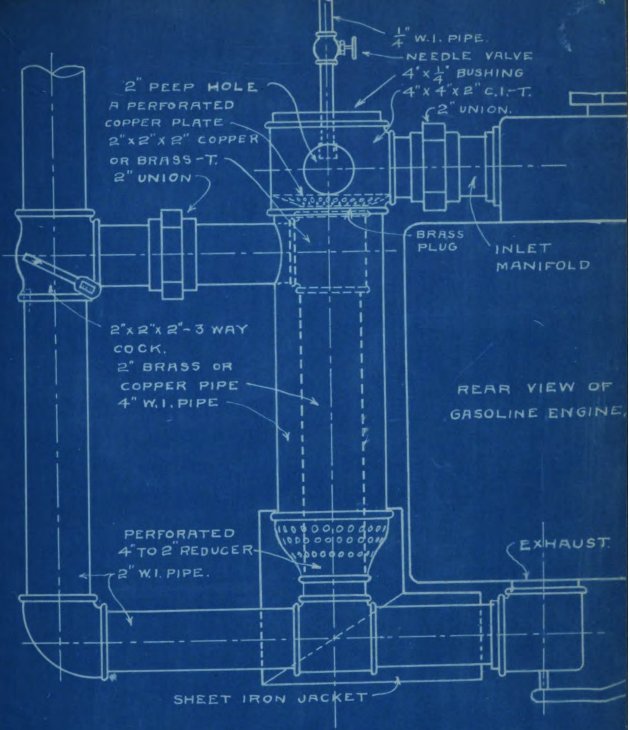
In the summation that follows wetookm the price of gasoline at 24 cents per gallon and kerosene at 9 cents per gallon. We took the specific gravity of gasoline at .720 and for kerosene we took .810 and chose the best reading in each test to make our comparisons. By this we mean that in comparing the costs per B.H.P. hour, we took the reading in each test that gave the lowest cost, for this condition could have been continued indefinitely under the same conditions of fuel and load. Now in comparing the maximum load that could be carried on any fuel, we compared the highest B.H.P. attainable although this did not always occur at the load of most efficient operation.

We conclude from our results that the capacity of the engine is not impaired by changing from gasoline to kerosene and even seems to be increased if the fuels are mixed in proportion of 1/2 gasoline to 1/2 kerosene(by volume)

The consumption of fuel per B.H.P. hour is practically the same for gasoline and 1/2 gasoline and 1/2 kerosene mixtures, but is practically 23 o/o greater for kerosene. This shows a poor thermal efficiency in the use of kerosene for its calorific value is about 10 o/o higher than the calorific value of gasoline, but owing to the great discrepancy in the price of the two fuels we still have kerosene by far the cheaper fuel to use.

For the same power, gasoline costs 152 o/o more than (1/2 gasoline and 1/2 kerosene mixture) and 245 o/o more than kerosene. Or we might say kerosene costs 40 o/o less than (1/2 gasoline and 1/2 kerosene mixture) ans 60.6 o/o less than gasoline. To be more concrete one dollar's worth of gasoline power is equal to 65.7 cents worth of (1/2 gasoline and 1/2 kerosene) power or is equal to 39.4 cents worth of kerosene power.

By these results it would seem that kerosene may well be considered a commercial fuel for gasoline engines in the near future.



THE MOYER BUILT UP CARBURETER.

THIS CARBURETER WAS BUILT UP AT THE COLLEGE FOR THE PURPOSE OF OBTAINING HIGH TEMPERATURES FOR FUEL MIXTURE TO ENGINE AND ALSO TO STUDY THE EFFECT OF SPRAYING THE FUEL INTO THE AIR UNDER PRESSURE


CHART NO. 1.
CHART SHOWING THE AVERAGE
YEARLY PRICE OF GASOLINE

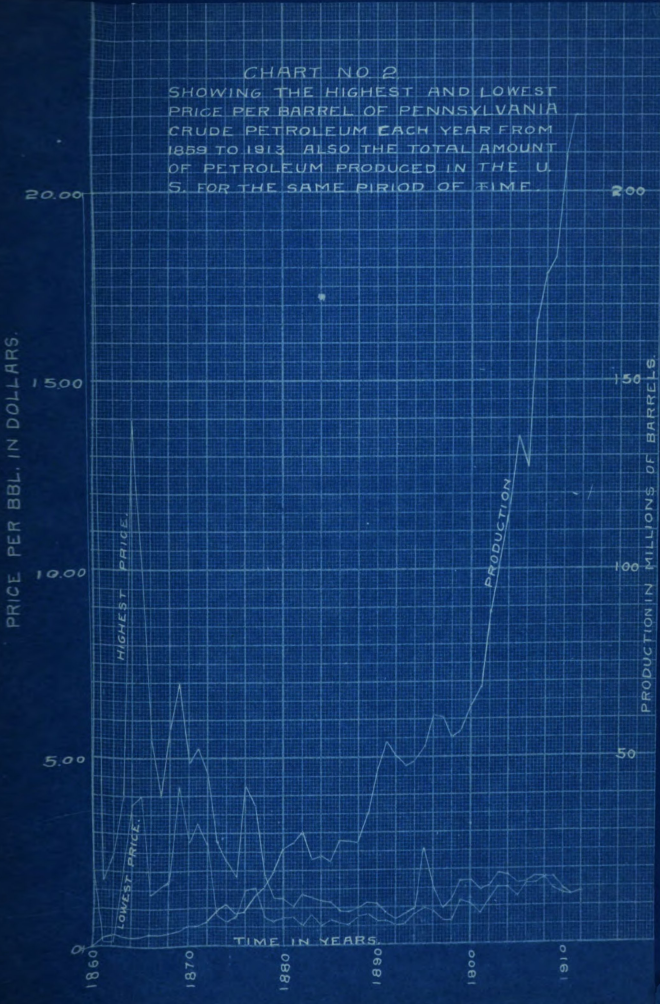


CHART NO. 2.
SHOWING THE HIGHEST AND LOWEST PRICE PER BARREL OF PENNSYLVANIA CRUDE PETROLEUM EACH YEAR FROM 1859 TO 1913. ALSO THE TOTAL AMOUNT OF PETROLEUM PRODUCED IN THE U. S. FOR THE SAME PIRIOD OF TIME.

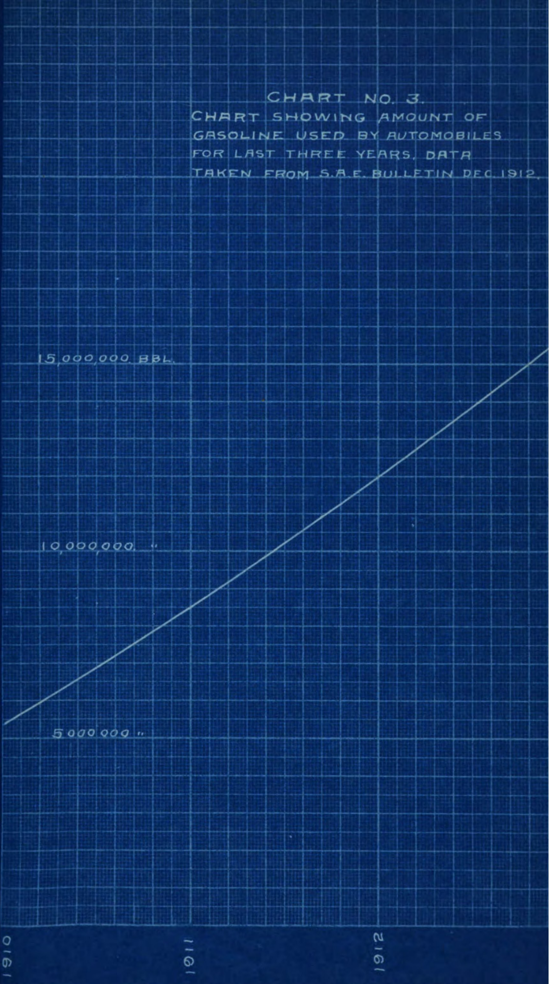


CHART NO. 3.

CHART SHOWING AMOUNT OF GASOLINE USED BY AUTOMOBILES FOR LAST THREE YEARS. DATA TAKEN FROM S.A.E. BULLETIN DEC. 1912.

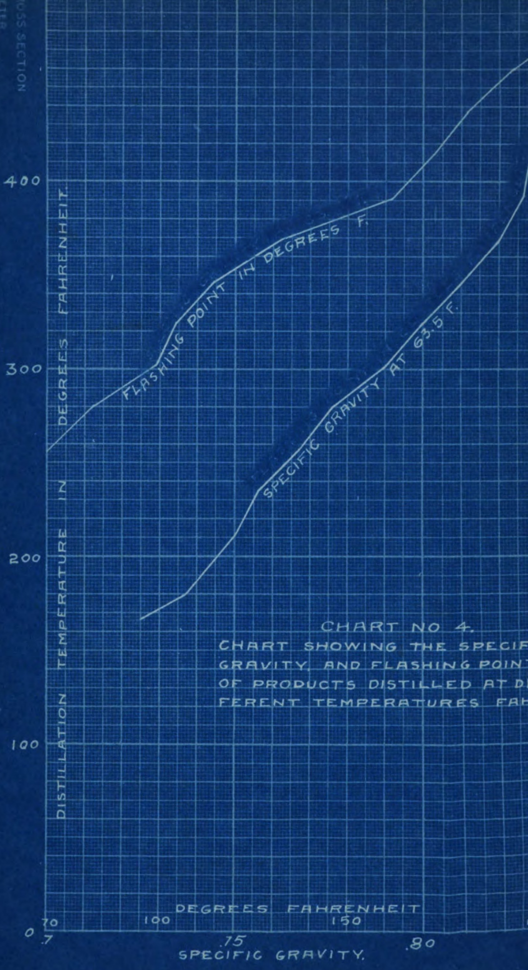


CHART NO 4.

CHART SHOWING THE SPECIF
GRAVITY AND FLASHING POINT
OF PRODUCTS DISTILLED AT DI
FERENT TEMPERATURES FAH

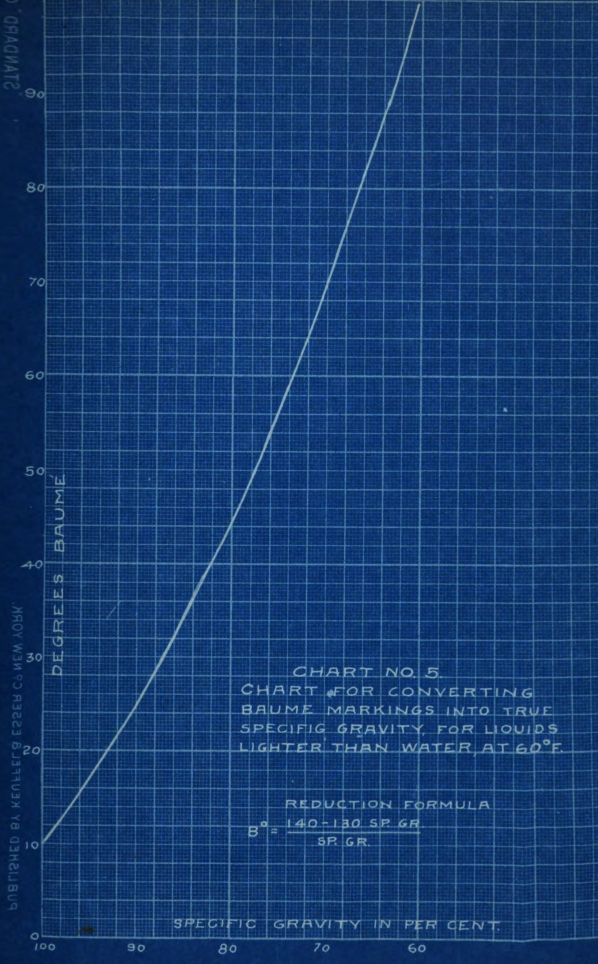


CHART NO. 5.
CHART FOR CONVERTING
BAUME MARKINGS INTO TRUE
SPECIFIC GRAVITY, FOR LIQUIDS
LIGHTER THAN WATER, AT 60°F.

REDUCTION FORMULA

$$B^\circ = \frac{140 - 130\ \text{SP. GR.}}{\text{SP. GR.}}$$

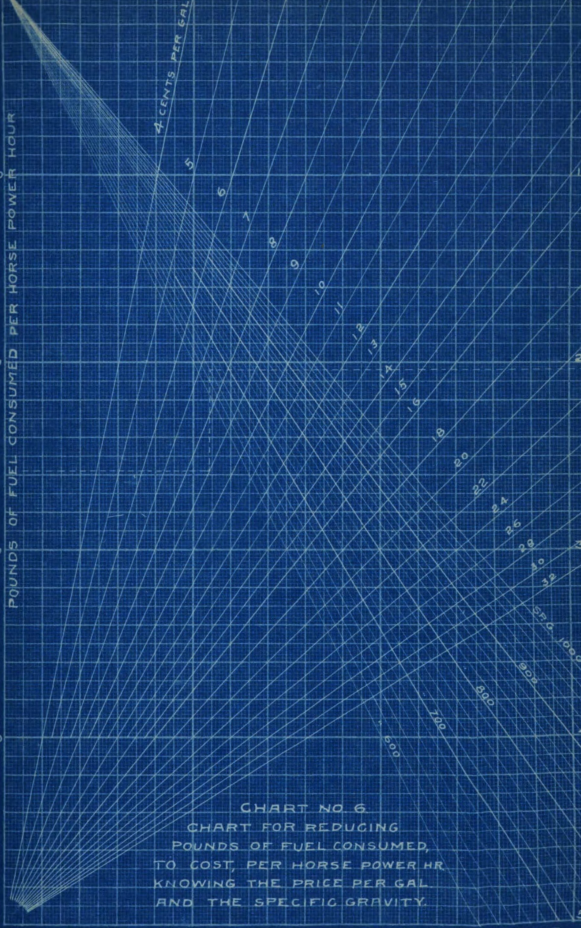


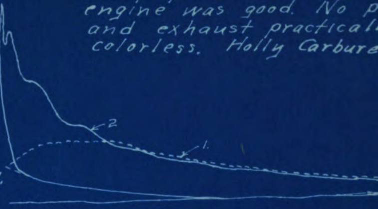
CHART NO. 6.
CHART FOR REDUCING
POUNDS OF FUEL CONSUMED,
TO COST, PER HORSE POWER HR.
KNOWING THE PRICE PER GAL.
AND THE SPECIFIC GRAVITY.

PROBLEM – ENGINE CONSUMES 1.21# PER H.P. HR FUEL 9.¢ PER GAL. SP. GR. = 640. FIND COST OF OPERATION PER H.P. HR. ANSWER = 2.04 CENTS.

Card No. 1.

Engine.-
Jacobson.
Fuel- Gasoline
Load-Lbs. on
brake net-12
Explosions in
set - two.
Spring-100#
R.P.M.- 271.
Spark-Advanced.

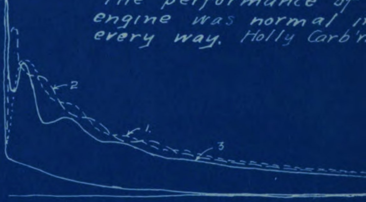
The performance of th
engine was good. No p
and exhaust practical
colorless. Holly Carbure



Card No. 2.

Engine- Jacobson
Fuel -Motor Gasoline
Load-net 20#
Explosions in
set-three.
Spring 100#
R.P.M. 271.
Spark fully
advanced

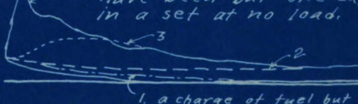
The performance of
engine was normal i
every way. Holly Carb'r



Card No. 3.

Engine-Jacobson with Holly Carbureter.
Fuel- Half Motor gasoline
and half kerosene
Load net. - 0
Explosions in
set - four
Mixture-very
weak.
Spring-150#
Spark-advanced
R.P.M. 300

The performance o
engine was poor the
was smokey. There sh
have been but one ex
in a set at no load.



1. a charge of fuel but

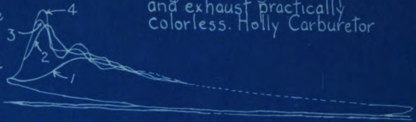
Card No. 4.

Engine-Jacobson
Carbureter- Holly.
Fuel- ½ K. ½ G.
Load net 20#
Explosions in set- 4.
Mixture-normal.
Spring-150#
Spark-advanced
R.P.M. 300.

The performance of the
was good. There was a sli
in exhaust, no poundi
to auto ignition.

Card No. 5

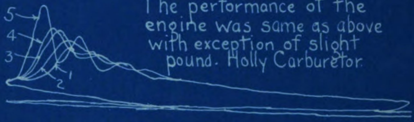
Engine:- Jacobson
Fuel:- 50% Gasoline
50% Kerosene
Load net:- 30#
Explosions in set:- 4
Spring:- 150*
Spark:- Advanced
R.P.M.:- 311



The performance of the engine was good. No pound and exhaust practically colorless. Holly Carburetor

Card No. 6

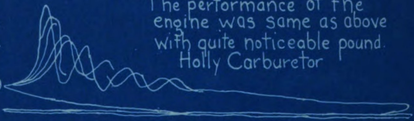
Engine:- Jacobson
Fuel:- 50% Gasoline
50% Kerosene
Load net:- 35#
Explosions in set:- 5
Spring:- 150*
Spark:- Advanced
R.P.M.:- 308



The performance of the engine was same as above with exception of slight pound. Holly Carburetor.

Card No. 7

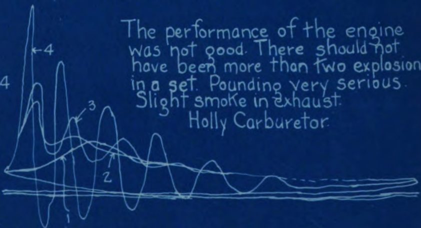
Engine:- Jacobson
Fuel:- 50% Gasoline
50% Kerosine
Load net:- 40*
Explosions in set:- 8-9
Spring:- 150*
Spark:- Advanced
R.P.M.:- 300



The performance of the engine was same as above with quite noticeable pound.
Holly Carburetor

Card No. 8

Engine:- Jacobson
Fuel:- Kerosene
Load net:- 20*
Explosions in set:- 4
Spring:- 150*
Spark:- Advanced
R.P.M.:- 300
Mixture:- Normal



The performance of the engine was not good. There should not have been more than two explosions in a set. Pounding very serious. Slight smoke in exhaust.
Holly Carburetor.

Time		Fuel Weight			Speed	Temperatures			Load On Brake Arm	Horse Power	H.P. Per Pound Of Fuel	Lbs. Fuel Per H.P. Hr.	Remarks
							Jacket Water						
Reading 5	Net Min.	Scales Reading 5	Net Wt.	Pounds Per Hr.	R.P.M.	Fuel	Intake	Exit					
4:15		17.2	.78		395	96	53.5	81	15	3.67			
4:17	5	16.52	.78	9.3	403	95	55	94.5	15	3.75	40	2.50	
4:22	5	15.86	.66	7.9	398	92	53	72.	15	3.70	47	2.12	3.62
4:27	5	15.26	.60	7.2	399	93	51	70	32	7.90	1.10	.91	← cents per B.H.P. Hr.
4:32	5	14.47	.79	9.5	385	93	51.5	70	32	7.63	.81	1.23	
4:37	5	13.40	1.07	12.8					32				

No.1

Test of:- Moyer Carburetor

Fuel:- Gasoline

Date:- 3/20/13

Observers:- Bates & Corl

Time		Fuel Weight			Speed	Temperatures			Load on Brake Arm	Horse Power	H.P. Per Pound of Fuel	Lbs. Fuel Per H.P. Hr.	Remarks
Reading	Net Min.	Scales Reading	Net Wt.	Pounds Per Hr.	R.P.M.	Fuel	Jacket Water Intake	Jacket Water Exit					
2:20		19.55			402	64	73	102	15	3.7			
2:30	10	18.45	1.10	6.6	395	66	58.5	103	15	3.67	.56	1.78	
2:40	10	17.85	.60	3.6	395	70	54	84.5	15	3.67	1.03	.97	
2:50	10	16.82	1.03	6.18	395	73	53	86.	15	3.67	.60	1.67	
2:55	5	16.20	.62	7.45	395	68	54	88.5	25	6.12	.82	1.22	
3:00	5	15.53	.67	8.05	385	66	53	89.5	25	5.97	.74	1.35	
3:05	5	14.88	.65	7.8	389	67.8	53	90.5	25	6.03	.77	1.30	
3:10	5	14.26	.62	7.45	392	69	53	90.5	25	6.08	.81	1.23	
3:15	5	13.68	.58	6.95	393	70	53	90.7	35	8.53	1.225	.81	← 1.08 cents per B.H.P. Hr.
3:20	5	12.78	.72	8.65	396	69.5	53	90.7	35	8.60	.99	1.01	
3:25	5	12.15	.63	7.55	387	68	53.4	91.	35	8.40	1.11	.90	
3:30	5	11.48	.67	8.05	368	67.1	53.2	91.6	35	7.98	1.00	1.00	

No. 2

Test of:- Moyer Carburetor

Fuel:- Kerosene.

Date:- 3/20/13

Observers:- Bates & Corl

Time	Fuel Weight

Time		Fuel Weight			Speed	Temperatures			Load on Brake Arm	Horse Power	H.P. Per Pound of Fuel	Lbs. Fuel Per H.P. Hour	Remarks
Reading	Net Min.	Scales Reading	Net Wt.	Pounds Per Hr.	R.P.M.	Fuel	Jacket Water						
							Intake	Exit					
3:30	5	15.70			394	90	58	83	15				
:35	5	15.23	.47	5.64	405	92	57	78	15	3.75	.665	1.50	On this reading the engine began to pound so badly that reading was not finished.
:40	5	14.65	.58	6.95	396	90	56	77	20	3.68	.528	1.89	
:45	5	14.10	.55	6.6	400	88	56	78	20	4.96	.75	1.25	
:50	5	13.52	.58	6.95	391	86	56	78	25	4.85	.696	1.44	
:55	5	12.80	.72	8.6	395	88	55.5	82	25	6.12	.709	1.41	
4:00	5	12.30	.50	6.0	368	90	55	81	30	5.71	.951	1.05	← 1.34 cents per B.H.P. Hr
:05	5	11.48	.82	9.8	385	91	54	81.5	30	7.16	.727	1.37	
:10	5	10.70	.78	9.35	385	92	54	81	35*	7.16	.764	1.31	

No. 3

Test of:- Moyer Carburetor

Date:- 3/21/13

Fuel:- Kerosene

Observers:- Bates & Corl

Time	Fuel Weight	Speed

Time		Fuel Weight			Speed	Temperatures			Load on Brake Arm	Horse Power	H.P. Per Pound Fuel	Lbs. Fuel Per H.P. Hr.	Remarks
							Jacket Water						
Reading	Net Min.	Scales Reading	Net Wt.	Pounds Per Hr.	R.P.M.	Fuel	Intake	Exit					
9:45		14.52			400	90	56	88	15	3.72			Engine began to pound.
9:50	5	14.15	37	4.45	400	92	56	86	15	3.72	.835	1.19	It was found that pound-
9:55	5	13.79	.36	4.3.	400	90	56	83	15	3.72	.86	1.16	ing could be prevented to
10:00	5	13.43	.36	4.3	400	88	55	84	15	3.72	.86	1.16	some extent by making
10:05	5	13.00	43	5.15	385	86	54	88	25	3.58	.694	1.44	mixture richer.
10:10	5	12.55	45	5.4	385	88	54	90	25	5.97	1.105	.905	*Could not be carried for
10:15	5	12.08	.47	5.65	390	81	53	78	25	6.04	1.07	.935	more than 5 min. on account
10:20	5	11.55	.53	6.35	392	80	53	74	30	6.07	.955	1.05	of excessive pounding.
10:25	5	10.92	.63	7.55	388	78	52	72	35	7.22	.955	1.05	With spark dis-connect-
10:30	5	10.26	.66	7.9	392	76	52	74	40	8.51	1.075	.931	ed, engine ran for some
10:35	5	9.50	.66	7.9	392	74	51	76	45	9.72	1.225	.816	time, due to pre-ignition.
10:40	5	8.75	.75	9.0	392	74	51	76	55*	9.72	1.08	.926	2.18 cents per B.H.P. Hr.

No. 4

Test of:- Moyer Carburetor

Fuel:- 50% Gasoline 50% Kerosene

Date:- 3/22/13

Observer:- Bates

No. 5

Time		Fuel Weight			Speed	Temperatures
Reading	[illegible]	Scales	Net	Pounds		

No. 5

Time		Fuel Weight			Speed	Temperatures							
							Jacket Water						
Reading	Net Min	Scales Reading	Net Weight	Pounds Per Hr.	R.P.M.	Fuel	Intake	Exit	Load On Brake Arm	Horse Power	H.P. Per Pound of Fuel	Lbs. Fuel Per H.P. Hr.	Remarks.
11:16	5	12.8	.55		419	74	52	62	10				Brake Arm: 40"
:21	5	12.25	.57	6.8	414	75	54	66	10	2.65	.402	2.49	
:26	5	11.68	.40	4.8	418	74	61	83	20	2.62	.383	2.61	
:31	5	11.28	.40	4.8	390	80	55	73	20	5.30	1.105	.905	
:36	5	10.88	.42	5.05	390	82	54	70	25	4.90	1.02	.98	
:41	5	10.46	.43	5.15	392	85	54	71	25	6.17	1.23	.813	
:46	5	10.03	.43	5.15	399	85	54	71	25	6.21	1.21	.826	
:56	10	8.91	1.02	10.2	388	82	53	70	30	7.60	1.24	.805	←2.15 cents per B.H.P. Hr
12:01	5	8.04	.87	10.4	390	81	53	70	40	9.84	.682	1.46	
								No.6					
2:25		11.47			296	56	55	72	20				Brake Arm: 40"
:35	10	10.86	.61		294	58	54	90	20	3.76	1.16		Density of Fuel: 65B
:45	10	10.43	.80		289	61	51	68	30	5.56	1.16	.863	←3.45 cents per B.H.P. Hr.
:55	10	9.51	1.09		296	62	51	72	40	7.33	1.12	.892	

No.5

Test of:- Moyer Carburetor

Fuel:- 50% Gasoline 50% Kerosene

Date:- 4/2/13

Observers:- Bates & Corl

No. 6

Test of:- Moyer Carburetor

Fuel:- Motor Gasoline

Date:- 4/8/13

Observers:- Bates & Corl

Time		Fuel Weight			Speed	Temperatures			Load on Brake Arm	Horse Power	H.P. Per Pound of Fuel	Lbs. Fuel Per H.P. Hr.	Remarks
							Jacket Water						
Reading	Net Min.	Scales Reading	Net Wt.	Pounds Per Hr.	R.P.M.	Fuel	Intake	Exit					
2:45	5	14.85	[illegible]		294	64	55	69	20	3.715	.968	1.032	Brake Arm = 39½"
2:50	5	14.53	.32	3.84	292	64	55	69	20	3.7	1.186	.843	← 3.38 Cents per B.H.P
2:55	5	14.27	.26	3.12	292	64	52.5	70	30	5.55	1.102	.908	
3:00	5	13.85	.42	5.05	.290	63	51	67	30	5.52	1.000	1.000	
3:05	5	13.39	.46	5.5	.290	61	51	66	35	6.44	.853	1.173	
3:10	5	12.77	.62	7.45	.286	59.6	51	66	35	6.345	.896	1.113	
3:15	5	12.18	.59	7.05	.286	58	51	67	40	7.26	.747	1.34	
3:20	5	11.37	.81	9.7	.286	58	51	67	40	7.26	.747	1.34	

No. 7

Test of:- Air-Friction Carburetor

Date:- 4/9/13

Fuel:- Motor Gasolene

Observer:- Corl

Time		Fuel Weight	Speed	Temperatures Jacket Water	Load on	Horse	H.P. Per Pound of Fuel	Lbs. Fuel Per H.P. Hr.	Remarks.

Time		Fuel Weight			Speed	Temperatures							Remarks
							Jacket Water						
Reading	Net Min.	Scales Reading	Net Wt.	Pounds Per Hr	R.P.M.	Fuel	Intake	Exit	Load on Brake Arm	Horse Power	H.P. Per Pound of Fuel	Lbs. Fuel Per H.P. Hr.	
9:50	5	14.05			298	65	53	67	20	3.715	1.372	.95	Brake Arm = 40"
9:55	5	13.75	.30	3.6	298	64	52.5	65	20	3.7	1.279	.728	White, Smoky Exhaust.
10:00	5	13.56	.23	2.75	298	66	52	65.5	30	5.55	1.302	.782	At 30# Load Engine
10:05	5	13.15	.37	4.45	296	66	52	68	30	5.52	1.262	.768	began to pound.
10:10	5	12.79	.36	4.3	294	65	52	71	35	6.44	1.102	.792	Full Load = 53#
10:15	5	12.36	.43	5.15	293	64.2	52	74	35	6.345	1.029	.908	2.79 cents per BHP Hr.
10:20	5	11.87	.49	5.9	288	63	52	74	40	7.26	1.218	.972	
10:25	5	11.30	.57	6.8	288	63	52	74	40	7.3	1.07	.822	
10:50	5	13.06	.50	6.00	288	64	53	64	45	8.21	.964	.935	
10:55	5	12.42	.64	7.7	288	62	53	67	45	8.21	.895	1.037	
11:00	5	11.71	.71	8.5	282	60	53	68	50	8.93	.892	1.117	
11:05	5	10.88	.83	10.0	282	58	53	68	50	8.24	.892	1.222	
11:10	5	10.11	.77	9.25	260	58	53	68	53	8.17	.887	1.119	

No. 8

Test of:- Air-Friction Carburetor

Date:- 4/10/13

Fuel:- Motor Gasoline

Observers:- Bates + Corl

Time		Fuel Weight			Speed	Temperatures			Load on Brake Arm	Horse Power	H.P. Per Pound of Fuel	Lbs. Fuel Per H.P. Hr.	Remarks
Reading	Net Min.	Scales Reading	Net Wt.	Pounds Per Hr.	R.P.M.	Fuel	Jacket Water Intake	Exit.					
2:30	5	13.99			307	74	55	75	20				Brake Arm: 40"
:35	5	13.67	.32	3.84	308	76.2	56	87.5	20	3.95	1.029	.972	
:40	5	13.36	.31	3.72	305	78	55	89	20	3.86	1.039	.964	
:45	5	12.98	.38	4.55	304	78	55	85.5	30	5.78	1.028	.789	
:50	5	12.57	.41	4.9	301	78	55	75	30	5.72	1.162	.861	
:55	5	12.14	.43	5.15	301	76	55	76	35	6.67	1.281	.774	←2.06 cents per BH.P.H
3:00	5	11.68	.46	5.5	301	74	54	76	35	6.67	1.208	.828	
:05	5	11.08	.60	7.2	300	74	54	77	40	7.6	1.055	.947	
:10	5	10.37	.71	8.5	300	70	54	76	40	7.6	.891	1.122	

No. 9

Test of:- Air Friction Carburetor.

Date:- 4/15/13

Fuel:- 50% Motor Gasoline 50% Kerosene

Observers:- Bates & Corl

No.10

Time		Fuel Weight			Speed	Temperatures			Load on Brake Arm	Horse Power	H.P. Per Lb. of Fuel	Lbs. Fuel Per H.P. Hr.	Remarks
Reading	Net Min.	Scales Reading	Net Wt.	Pounds Per Hr.	R.P.M.	Fuel	Jacket Water Intake	Jacket Water Exit					
10:02		14.70				58	56	74	20				Brake Arm = 40"
10:07	5	14.46	.24	2.88	306	61	53	68	20	3.888	1.35	.74	At 35# there was a
10:12	5	14.19	.27	3.24	302	60.5	53	68	30	3.823	1.18	.848	pound at practically
10:17	5	13.84	.35	4.2	300	60	53	71	30	5.71	1.36	.735	every stroke. Slight
10:22	5	13.52	.32	3.84	294	60	53	71	35	5.6	1.459	.686	smoke in exhaust.
10:27	5	13.15	.37	4.44	302	60.5	53	73	35	6.7	1.5	.663	← 2.64 cents per B.H.P.
10:32	5	12.77	.38	4.50	302	62.	53	73	35	6.7	1.469	.682	
						No.11							
11:00		11.31				70	53	112					
11:10	10	10.59	.72	4.32	276	68	55	112	35	6.12	1.418	.705	← 2.82 cents per B.H.P.
													With water injection.
													exhaust quite clean and
													pound reduced

No. 10

Test of:- Holly Carburetor
Fuel:- Motor Gasoline

Date:- 4/17/13
Observers:- Bates & Corl

No. 11

Test of:- Same as No. 10 With Water injected with fuel

No. 12

Time		Fuel Weight			Speed	Temperatures							Remarks
							Jacket Water						
Reading	Net Min.	Scales Reading	Net Wt.	Pounds Per Hr.	R.P.M.	Fuel	Intake	Exit	Load on Brake Arm	Horse Power	H.P. Per Lb. of Fuel	Lbs. Fuel Per H.P. Hr.	
10:30		13.04				72	60	98	20				
10:35	5	12.70	.34	4.08	308	73	55	70	20	3.9	.956	1.046	Brake Arm = 40"
10:40	5	12.38	.32	3.84	306	74	55	70	30	3.87	1.01	.993	
10:45	5	11.98	40	4.8	304	74	55	71.5	30	5.785	1.202	.832	
10:50	5	11.59	.39	4.68	304	76	55	72	35	5.785	1.23	.81	
10:55	5	11.18	41	4.92	296	77	55	73	35	6.56	1.33	.75	← 2 cents per B.H.P. Hr.
11:00	5	10.74	44	5.28	296	79	55	75	40	7.5	1.421	.703	
11:05	5												
11:10	5	9.92	.82	4.92	272	82	54	70	40	6.89	1.4	.713	
11:15	5	9.55				84	54	70	40				
11:20	5	9.15				88	55	81	40				
							No. 13						
10:05		11.9			403	81	60	88	25				
10:10	5	11.36	.54		400	92	57	75.5	25	6.18	.952	1.049	Brake Arm = 39"
10:15	5	10.81	.55		393	96	55	69	30	6.06	.918	1.08	
10:20	5	10.33	.48		394	96	55	58	30	7.295	1.263	.791	
10:25	5	9.86	.47		394	98	55	69	35	7.295	1.292	.723	← 1.43 cents per B.H.P. Hr.

No. 12

Test of:- Holly Carburetor
Fuel :- 50% Gasoline 50% Kerosene

Date:- 4/22/12
Observers:- Bates & Corl

No. 13

Test of:- Moyer Carburetor
Fuel :- 25% Gasoline 75% Kerosene

Date:- 4/26/13
Observers:- Bates & Corl

Time		Fuel Weight			Speed	Temperatures			Load on Brake Arm	Horse Power	H.P per Lb. of Fuel	Pounds Fuel/HP. Hr.	Remarks.
							Jacket Water						
Reading	Net Min.	Scales Reading	Net Wt.	Pounds Per Hr.	R.P.M.	Fuel	Intake	Exit.					
10:55		15.19			312	92	63	169	20				Brake Arm = 40"
11:00	5	14.82	.37	4.44	312	92	62	166.	20	3.89	.875	1.14	Heavy pound up to 40#
11 10	5	14.44	.38	4.56	314	92	62	167	30	3.90	.855	1.17	load. From here quieter.
11:15	5	13.92	.52	6.24	308	92	59	116.3	30	5.93	.947	1.05	Could not obtain clear
11:20	5	13.32	.60	7.20	307	92	58	99.	35	5.86	.815	1.23	exhaust.
11:25	5	12.68	.64	7.68	310	92	59	118.5	35	6.88	.895	1.12	1.35 cents per B.H.P. Hr.
11:30	5	12.04	.64	7.68	300	94.3	59	128	40	6.76	.880	1.13	
11:35	5	10.62	1.42	17.04	300	99	60	143	40	6.10	.720	1.39	
11:40	5	9.21	1.41	17.04	240	96	64	187	40	6.10	.720	1.39	

No. 14

Test of:- Holly Carburetor

Date:- 5/7/13

Fuel:- Kerosene

Observers:- Bates & Corl

Name of Carburetor	Fuel Used	Maximum Load during test		Minimum Pounds Fuel per B.H.P. Hr.	Temp. of Fuel.	Cost in Cents Per B.H.P. Hr.	R.P.M.	Remarks.
		B.H.P.	% Full Load					
Moyer	Gasoline	7.90	79	.91	93	3.62	399	R.P.M. above normal.
"	Kerosene	8.60	86	.81	70	1.08	393	"
"	"	7.16	72	1.05	90	1.34	368	"
"	½G ½K	9.72	97	.816	74	2.18	392	"
"	"	9.84	98	.805	82	2.15	388	"
"	¼G ¾K	7.3	73	.723	98	1.43	394	"
"	Motor Gas.	7.33	73	.863	61	3.45	296	
Air Friction	Motor Gas.	7.26	73	.843	64	3.38	292	
"	"	8.93	89	.728	64	2.79	298	
"	½MG ½K	7.6	76	.774	76	2.06	301	
Holly	Motor Gas.	6.7	67	.663	60.5	2.64	302	
"	"	6.12	61	.705	68.	2.82	276	Water Injection.
"	½MG ½K	7.5	75	.75	77.	2.00	296	
"	Kerosine	6.88	69	1.05	92.	1.35	308	

Summary of Data

Average % of Load

Gasoline % of Load	½ Gasoline ½ Kerosene	Kerosene	¼ Gasoline ¾ Kerose
79	97	86	73
73	98	72	
67	76	69	
73	75		
89			
Average 76	86.5	75.7	73

Average Minimum Pounds Per B.H.P. Hr.

.91	.816	.81	.723
.863	.805	1.05	
.843	.774	1.05	
.728	.75		
.663			
.705			
Average .785	.786	.97	.723

Average Cost Per B.H.P. Hr.

3.62	2.18	1.08	1.43
3.45	2.15	1.34	
3.38	2.06	1.35	
2.79	2.00		
2.64			
2.82			
Average 3.20	2.10	1.26	1.43