THE EFFECT OF DENSITY AND VOLATILITY OF STRAIGHT RUN AND CRACKED GASOLINE ON ENGINE PERFORMANCE

THESIS FOR THE DEGREE OF M. S.

James Howard Bingham

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THESIS

Gasoline

THE EFFECT OF DENSITY AND VOLATILITY OF STRAIGHT RUN AND CRACKED GASOLINE ON ENGINE PERFORMANCE.

THESIS

Submitted to the Faculty of Michigan State College as Partial Fulfilment of the Requirements for the Degree of Master of Science.

by

James Howard Bingham

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THESIS

Acknowledgment

I wish at this time to express my appreciation of the help and kindly assistance given by Professor G. W. Hobbs during the progress of this work.

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PURPOSE

The purpose of this paper is to determine the effect of variations in the density and volatility of straight-run and cracked gasolines on engine performance.

INTRODUCTION

During the last few years a general improvement in gasoline has followed an extensive period of research. Not much more than 30 years ago it was a troublesome refinery by-product difficult to dispose of. Of the lighter petroleum distillates, kerosene was the desirable one, used as it is today for lighting, heating, and cooking purposes.

Today, gasoline is produced in quantity ten times as great as kerosene and sells for a higher price. Of the total quantity of gasoline produced in 1931, practically all of it was used in pleasure cars, motor trucks, marine and stationary engines, motor boats, motor cycles, tractors, and airplane engines.

Gasoline is produced in three ways: (1) from crude oil by what is known as straight refining methods, (2) from gas oil and other petroleum distillates by what is known as cracking methods, and (3) by extraction from natural gas.

In this experiment only two refinery products were used, straight-run and cracked gasolines. In straight refining methods the crude oil is heated without pressure until the gasoline, naturally occurring in the oil, is distilled off. The gasoline is then refined by steam distillation and by washing with acid and alkali until it is of good odor and practically colorless.

In cracking methods, the petroleum distillates, heavier and less volatile than gasoline, are heated in special stills to high temperatures under pressure whereby they break down (crack) into gasoline and other distillates.

In 1911 there were no specifications for gasoline. In 1922 there were specifications for different grades of gasoline, namely; aviation gasoline, fighting and domestic grades, and motor gasoline. In this work only the specifications for motor gasoline will be given, as that is the type of gasoline used in the average motor car.

SPECIFICATIONS AND TESTS (1922)

COLOR-method 10.1. The color shall not be darker than No. 16 Saybolt.

CORROSION TEST-method 530.2. A clean copper strip shall not be discolored when submerged in the gasoline for 3 hours at 122 degrees F.

DISTILLATION RANGE-method 100.1. When the first drop has been recovered in the graduated receiver the thermometer shall not read more than 140 degrees F. When 20 per cent has been recovered in the receiver the thermometer shall not read more than 221 degrees F.

When 90 per cent has been recovered in the receiver the thermometer shall not read more than 374 degrees F.
The end point shall not be higher than 437 degrees F.
At least 95 per cent shall be recovered as distillate in the receiver from the distillation.

PROPERTIES AND TESTS (1932)

Specifications for United States Motor Gasoline.

F4 CORROSION TEST-method 530.22. A clean copper strip shall not show more than extremely slight discoloration when submerged in the gasoline for 3 hours at 122 degrees F.

F5 DISTILLATION RANGE-method a. When the thermometer reads 167 degrees F. not less than 10 per cent shall be evaporated.
When the thermometer reads 284 degrees F. not less than 50 per cent shall be evaporated.
When the thermometer reads 392 degrees F. not less than 90 per cent shall be evaporated.
The residue shall not exceed 2 per cent.
Per cent evaporated shall be found by adding the distillation loss to the amount collected in the receiver at each specification temperature.

F6 SULPHUR-method b. Sulphur shall not exceed .10 per cent.

F7 VAPOR PRESSURE-method c. The vapor pressure at 37.8 degrees C. (100 degrees F.) shall not exceed 12 pounds per square inch.

All tests shall be made according to the methods for testing petroleum products adopted by the Inter-Departmental Petroleum Specifications Committee as published by Department of Commerce, U. S. Bureau of Mines.

SCOPE

In this paper results from tests of eight different samples of gasoline are discussed.

Sample	Sp. Gravity	Distillation Range Initial Point	Distillation Range End Point
Cracked	.7125	90 F.	300 F.
"	.7298	100 F.	339 F.
"	.7475	102 F.	416 F.
"	.7531	94 F.	448 F.
St. Run	.7157	101 F.	310 F.
"	.7305	97 F.	339 F.
"	.7420	93 F.	405 F.
"	.7539	106 F.	439 F.

These samples were obtained from the White Star Refinery at Trenton.

In all tests run, the compression ratio was raised from 4 to as high as the sample would run without detonating with spark and carburetor set for maximum power.

The following are the engine characteristics investigated; maximum brake horsepower, tendency to detonate, volatility as determined by A.S.T.M. distillation, thermal efficiency, air-fuel ratio for maximum power, and economy and ease of starting.

DESCRIPTION OF APPARATUS

The Christie test engine was used in this experiment. This is a single-cylinder, variable compression engine, very similar to that designed by the National Advisory Committee for Aeronautics. This is the only engine of this make in this part of the country so a brief description of the motor and its construction will be given.

In the Automotive Laboratory at Michigan State College the engine is directly coupled to a 150-h.p. electric dynamometer of the type used in most automotive laboratories. This makes it possible to use the dynamometer either as a motor or generator, measuring either the input or output torque.

The engine has a 3 1/16 inch bore and a 4 1/2 inch stroke and is rated at 6-h.p. at 2000 R.P.M. The cylinder barrel with water jackets is a separate part and is bolted to the cylinder head. The outside of the cylinder proper is also machined and this sets inside an outer wall. By means of a worm and thread arrangement it is possible to move the cylinder head assembly up and down, which varies the clearance space above the piston and provides the variable-compression feature. The head is raised and lowered by a hand wheel which is calibrated as to turns so the desired compression ratio may be obtained. The compression ratio may be varied while the engine is running.

The valves are located in the head and are operated by a single overhead camshaft.

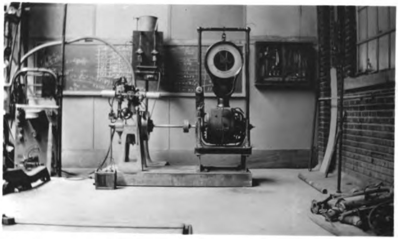
The camshaft is equipped with adjustable cams, mounted on ball bearings and lubricated by an independent oiling system.

The crank shaft of the engine is mounted with ball bearings on each end. The crank shaft is a very heavy forging of chrome-nickel steel, machined all over and counter balanced. The fly wheel is indexed in degrees and balanced with the crank shaft. The crank shaft drives a splined vertical shaft through a modified worm and gear drive. The gear oil pump is also driven directly from the crank shaft.

The ignition is a battery system running on 6 volts with a special distributor, one cylinder, two spark manually operated with Delco dual coil. The spark protractor located on the vertical shaft consists of a mircarta ring and brass sleeve mounted and equipped with a graduated scale, so that the spark advance may be read at any time when the engine is running.

The inlet and exhaust passages of the manifold are on opposite sides of the head. Dual carburetors are part of the equipment of the engine. A hot spot is also provided for dry vaporization.

The engine is equipped with a condensor for cooling so the cylinder head and cylinder can be maintained at a temperature of 212 degrees F.



General View of Apparatus

Distillation Apparatus

The combustion chamber is of cylindrical shape with a flat dome, machined all over.

PROCEDURE

The fuel system operated in the following manner: The fuel for the engine is put in an elevated tank from which it flows down through a burette containing 1/6 of a pound. By shutting off the supply from the tank, the time to burn 1/6 pound of gasoline could be very accurately obtained by use of the stop watch. A Tachometer is attached to the dynamometer so the speed in revolutions per minute can be read directly.

The air-fuel ratios were obtained by using the standard Orsatt gas analysis apparatus and applying readings to Lockwood's chart.

The gasoline distillations were run on the A.S.T.M. standard distillation apparatus as made by the Tagliabue Company and according to the procedure laid down by the A.S.T.M. Committee.

The specific gravity was obtained by use of the Standard Hydrometer which reads in A.P.I. degrees, and transferred to specific gravity by use of tables which were corrected to standard temperature conditions of 60 degrees F.

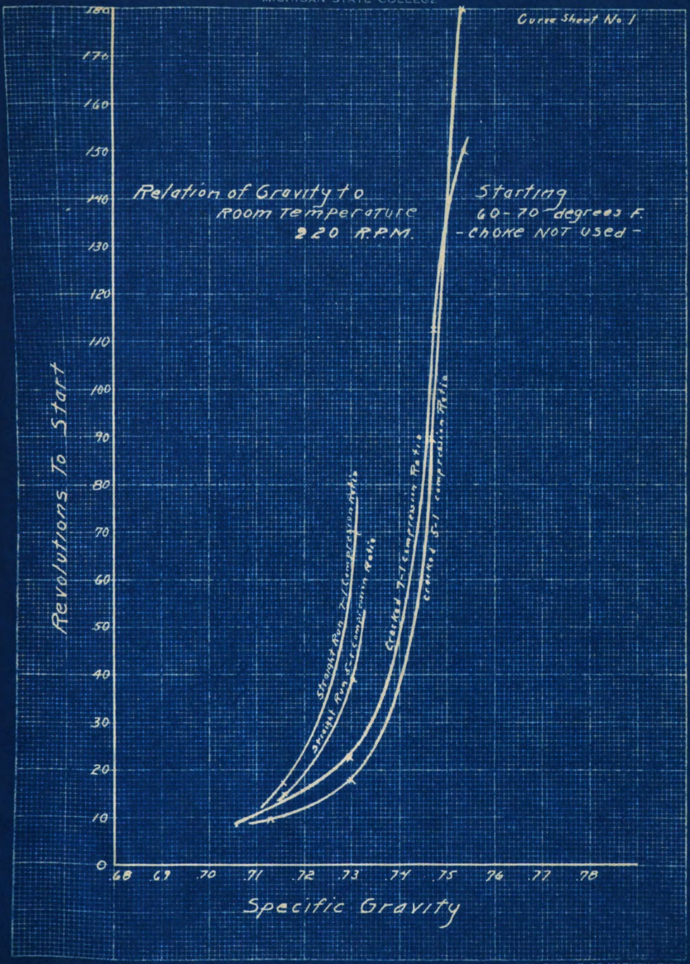
EASE OF STARTING

Ease of starting as used in this experiment will denote the relative difference in number of revolutions to start, using fuels with different A.S.T.M. distillation ranges and different specific gravities. Both straight-run and cracked gasoline made from the same crude, as well as some straight-run from a different crude, were tested.

Tests to determine this relative difference were made in the following manner: A sample of gasoline was put in the carburetor, the motor being set just at the start of its compression stroke. A counter attached to the dynamometer was set so it recorded the exact number of revolutions that the motor turned over. The motor was cranked with the dynamometer at the desired speed, and as soon as the first audible explosion was heard, the counter was stopped and the ignition switch was turned off so the motor would not heat up. The gasoline remaining in the carburetor was drained out and then the motor was cranked with the switch off to be sure all fuel was cleared from the motor.

The motor was cranked at the same speed with the same carburetor setting and the same spark advance for all tests. All tests were conducted at room temperature, no means of controlling the temperature being available.

The curves on sheet No. 1 show that: the lower the specific gravity of a gasoline the easier the starting. This will hold only for gasoline made from the same crude.


Curve Sheet No. 1
Relation of Gravity to Starting
Room Temperature 60-70 degrees F.
220 R.P.M. -Choke not used-
Revolutions to Start
Specific Gravity
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
.68
.69
.70
.71
.72
.73
.74
.75
.76
.77
.78
Straight Run 7-1 Compression Ratio
Straight Run 5-1 Compression Ratio
Cracked 7-1 Compression Ratio
Cracked 5-1 Compression Ratio

Cracked gasoline made from the same crude and having nearly the same specific gravity has a tendency to start easier than the straight-run.

Cranking speed has an effect on starting. The faster a motor is turned over the easier it will start. This statement agrees with what has already been found out by George Granger Brown as reported in the University of Michigan Engineering Research Bulletin of May, 1927.

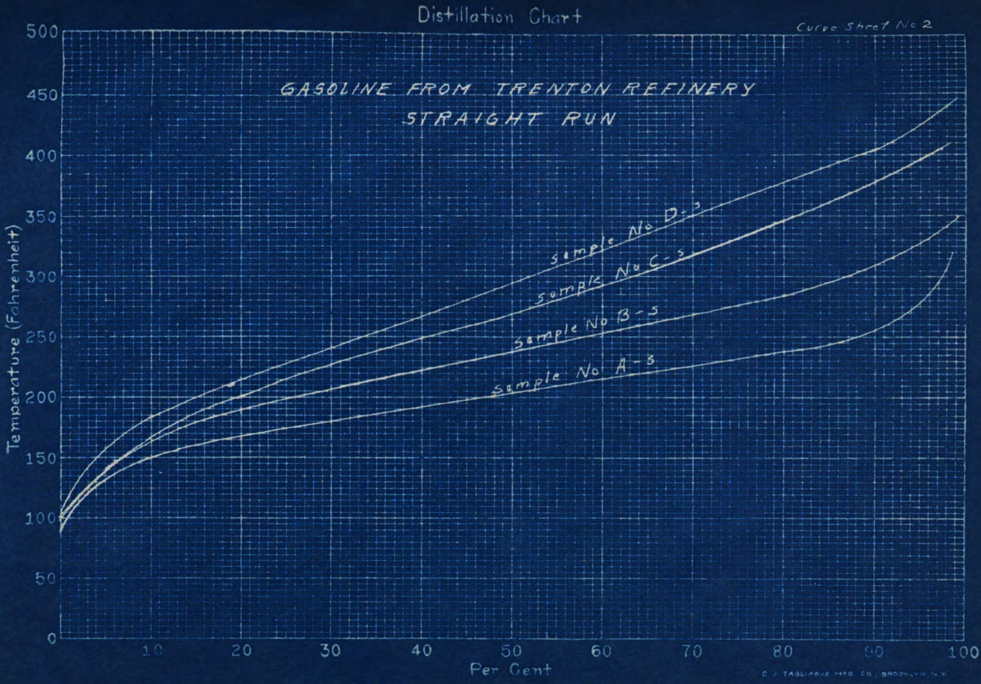
D. M. Cirxone in a paper given before the S. A. E. in Detroit, April 27, 1931, says that if the mixture ratio is correct and the fuel properly atomized, the cranking speed is of secondary importance.

When the engine is choked it starts just as easily at high compression ratios as at low, but when not choked the starting is easier at the low compression ratios.

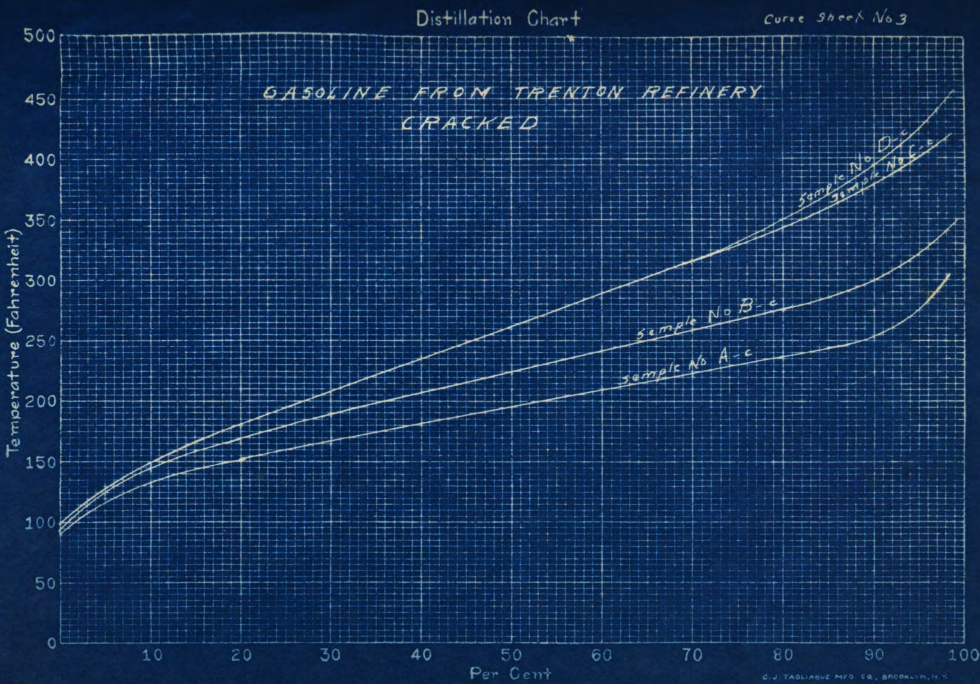
The A. P. I. rating is the inverse of specific gravity. Using gasolines from the same crude, the ease of starting varies with the degrees A. P. I.

From a study of the A. S. T. M. distillation curves of these fuels, it is seen that to have a fuel start easily at 60 to 75 degrees F., the 20 per cent point must be under 200 degrees F.

In a preceding statement it was said that the lower the specific gravity the easier the starting. This characteristic is partly due to the heavier fuels giving



Distillation Chart
Curve Sheet No 2
GASOLINE FROM TRENTON REFINERY
STRAIGHT RUN
Sample No D-3
Sample No C-3
Sample No B-3
Sample No A-3
Temperature (Fahrenheit)
500
450
400
350
300
250
200
150
100
50
0
10
20
30
40
50
60
70
80
90
100
Per Cent
C. J. TAGLIABUE MFG. CO., BROOKLYN, N.Y.



Distillation Chart
Curve Sheet No 3
GASOLINE FROM TRENTON REFINERY
CRACKED
Sample No D-c
Sample No C-c
Sample No B-c
Sample No A-c
Temperature (Fahrenheit)
500
450
400
350
300
250
200
150
100
50
0
10
20
30
40
50
60
70
80
90
100
Per Cent
C. J. TAGLIABUE MFG. CO., BROOKLYN, N. Y.

a higher air-fuel ratio at the same carburetor setting.

Work at the Bureau of Standards has shown that the 5 per cent point on an A. S. T. M. distillation, when corrected for loss, is the best indication of the ease of starting of an engine at low temperatures, when air-fuel ratio is 1-1. The controlling point goes up to the 15 per cent point for 2-1 mixtures under moderate weather conditions.

This will indicate that at 60 to 70 degrees F. temperature and at a 13-1 air-fuel ratio, the 20 per cent point on the A. S. T. M. distillation curve is the governing point for starting.

The room temperature in the laboratory varied as much as 15 degrees F. from day to day. This variation was found to affect the starting of the engine to a marked extent. The motor started easily with a certain fuel at room temperature of 75 degrees F. but difficulty was experienced at 60 degrees F. using the same fuel. This brought out the fact, that if a certain fuel is near the range of the easily starting fuels, a small change in temperature will affect its starting characteristics markedly.

MAXIMUM BRAKE HORSEPOWER

In the description of the apparatus, the method of measuring the brake horsepower was given. The scale readings were substituted in the following formula to give the corrected brake horsepower:

$$HP. = \frac{29.92}{Ob.Bar.Read.(1)} \times \frac{Ob.Temp.Ab.}{520} \times \frac{load\ on\ scales(lbs)R.P.M.}{3000}$$

The temperature of the oil was maintained between 120 and 130 degrees F.

The engine was run on the desired gasoline until temperature conditions were constant; then the carburetor and spark adjustments were made to obtain maximum power at the desired compression ratio.

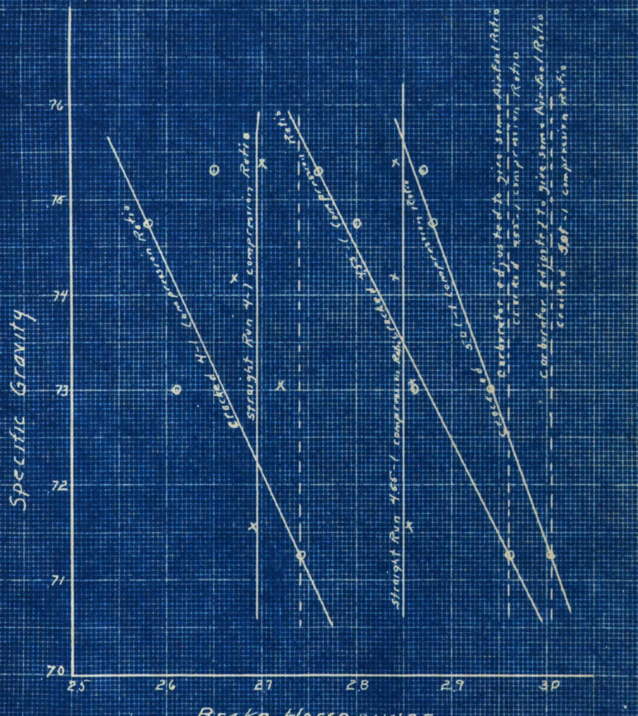
In a study of curve sheet No. 4 it is shown that the brake horsepower drops off as specific gravity increases. This is not due directly to increase of specific gravity but to a decrease in air-fuel ratio as the carburetor setting was left the same for all samples. If the carburetor is adjusted it is shown that gravity has no effect on the brake horsepower. This would show to the every-day user of gasoline who does not change his carburetor adjustment when he changes fuel that he seems to be getting better mileage out of a certain gasoline, but he will also notice a decrease of power if the carburetor is not adjusted for that fuel. It may also be seen that this tendency to make the air-fuel ratio leaner with heavier fuels with the same carburetor adjustment is not as marked with straight-run fuels as it is with cracked fuels.

With the carburetor adjusted to give maximum power

(1) Barometer Reading was corrected for humidity.

Curve sheet No 4

Maximum Power Density Curves
Carburator setting the same for all runs
Spark set for maximum power



it is shown that the cracked gasoline will give slightly more power. More power is obtainable from the cracked gasoline because it may be run at higher compression ratios without detonation. This increase in horsepower when using the cracked gasoline is due entirely to the higher compression pressure. When run at the same compression ratios the brake horsepower is the same.

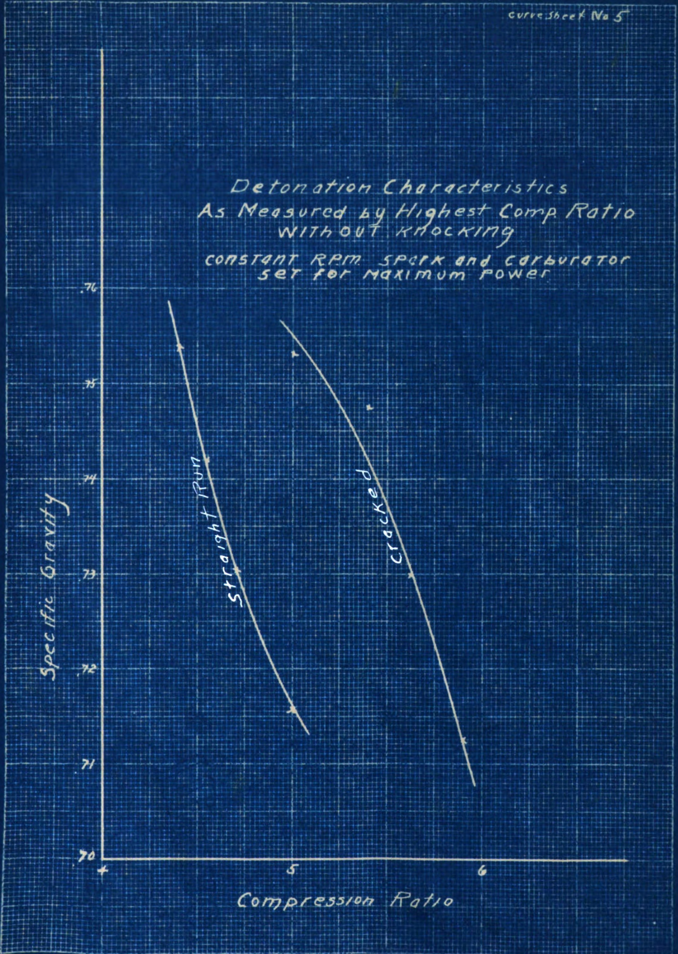
DETONATING TESTS

In these runs the same procedure was gone through as on the brake horsepower tests except that the compression ratio was varied from 4-1 until an audible detonation could be heard when spark and carburetor were adjusted for maximum power.

The curves on sheet No. 5 show that the useful compression ratio decreases as the specific gravity increases, and also that cracked gasoline has better anti-detonating qualities than the straight-run, both coming from the same crude and having the same range of specific gravities. (A straight-run gasoline from another refinery shows the same properties.)

FUEL CONSUMPTION AND AIR-FUEL RATIOS FOR MAXIMUM POWER AND ECONOMY

The fuel consumption was measured as explained in the procedure. The time to burn 1/6 of a pound of gasoline was substituted in the following formula and pounds per hour computed.


Curve Sheet No 5
Detonation Characteristics
As Measured by Highest Comp. Ratio
Without Knocking
constant RPM spark and carburator
set for maximum power
.76
.75
.74
.73
.72
.71
.70
Specific Gravity
4
5
6
Compression Ratio
Straight Run
Cracked

$$\frac{10}{\text{time to burn 1/6 pound gas. in minutes}} = \text{pounds per hour}$$

$$\frac{\text{pounds fuel per hour}}{\text{Brake Horsepower}} = \text{pounds per Brake Horsepower hour}$$

In these tests the carburetor and spark were set for maximum power and then a sample of the exhaust gas was run through the Orsatt gas analysis apparatus and the air-fuel ratio determined from Lockwood's chart.

For all the fuels tested, a 13-1 air-fuel ratio for maximum power and a 15-1 air-fuel ratio for economy seems to be the best.

In a study of curve sheet No. 6, it can be seen that better economy is obtained with the heavier fuels. This is due to the fact that the air-fuel ratio is higher with the same carburetor setting; when adjusted to the same air-fuel ratio the economy is constant.

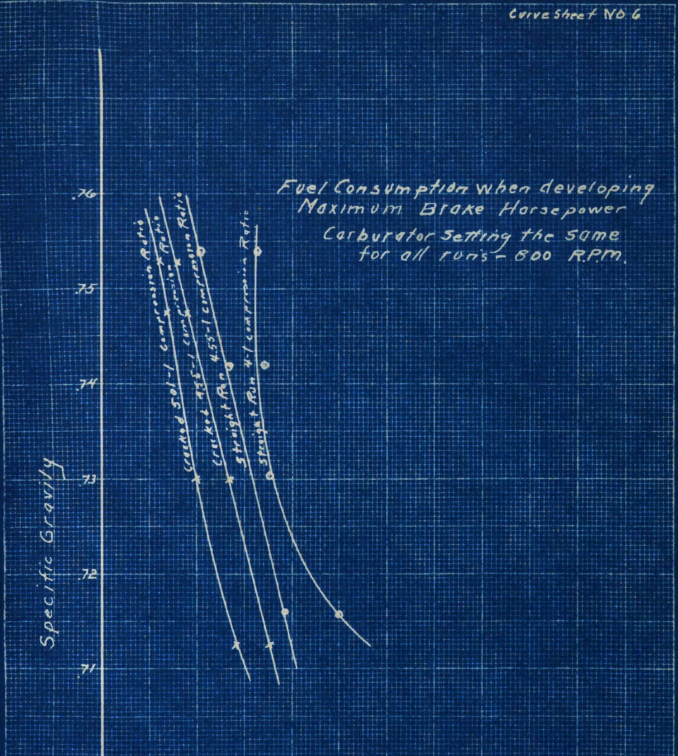
With the same carburetor setting it is shown by curve sheet No. 7 that cracked gasoline gives better fuel consumption per brake horsepower hour than straight-run gasoline, both coming from the same crude and being refined at the same refinery. This is the result of being able to run at higher compression ratios.

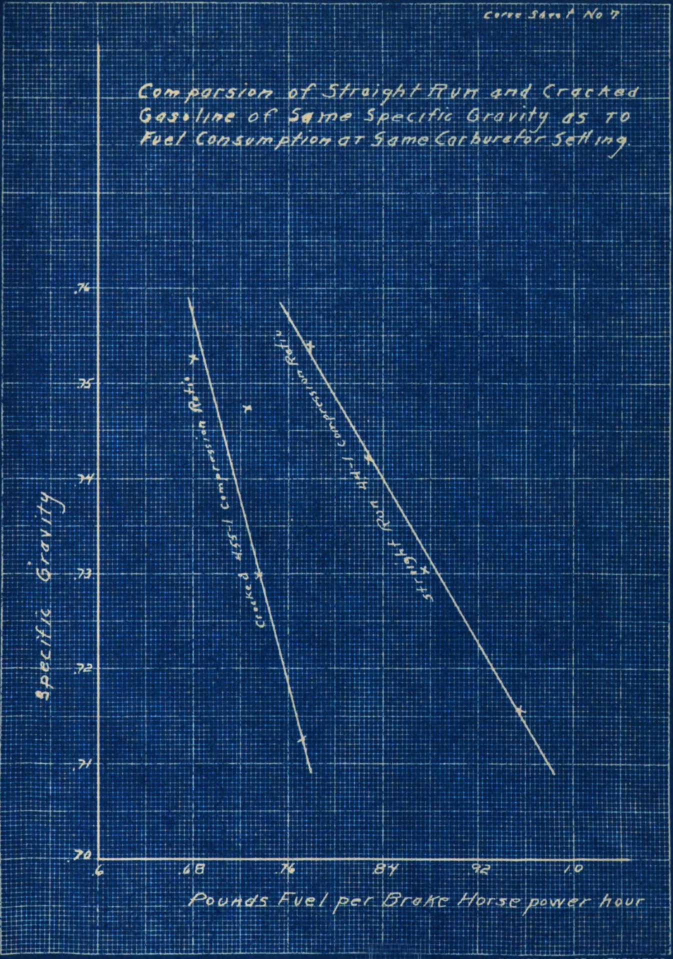
THERMAL EFFICIENCY

The thermal efficiency results are calculated results and are obtained by the following formula:

$$\frac{2546}{\text{lbs. fuel per B.HP. hour} \times 18{,}830} = \text{Eff.}$$

18,830 heating value of fuel in B. T. U.
2546 is the value of 1HP. in B. T. U.


Curve Sheet NO 6
Fuel Consumption when developing Maximum Brake Horsepower
Carburator Setting the same for all runs - 800 R.P.M.
Cracked 5.01-1 Compression Ratio
Cracked 4.55-1 Compression Ratio
Straight Run 4.55-1 Compression Ratio
Straight Run 4-1 Compression Ratio
Specific Gravity
.76
.75
.74
.73
.72
.71
.70
.69
.6
.7
.8
.9
1.0
Pounds of Fuel per B.HP. hr.


Curve Sheet No 7
Comparsion of Straight Run and Cracked Gasoline of Same Specific Gravity as to Fuel Consumption at Same Carburetor Setting.
Specific Gravity
.76
.75
.74
.73
.72
.71
.70
.6
.68
.76
.84
.92
1.0
Pounds Fuel per Brake Horse power hour
Cracked 4.55-1 Compression Ratio
Straight Run 4.4-1 Compression Ratio

The following results are shown by curve sheet No.8, plotting thermal efficiency against specific gravity. The thermal efficiency increases directly as the specific gravity, at any compression ratio. These runs were made with the engine running at 800 R. P. M. and at the same carburetor setting. This increase in thermal efficiency is due to the heavier fuels giving a higher air-gas ratio. The curves show that the cracked gasoline has a very slight advantage, as far as thermal efficiency is concerned, over the straight-run, but this advantage is so small that it would be difficult to come to any definite conclusion.

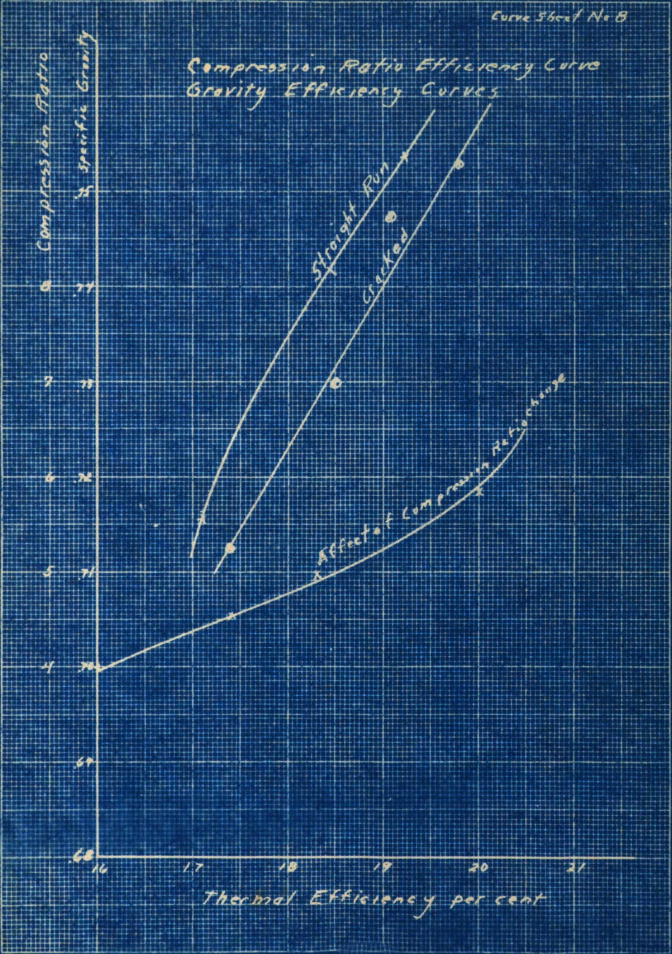
Plotting thermal efficiency against compression ratio shows that thermal efficiency increases directly as the compression ratio.

DISCUSSION OF RESULTS

In the results as set forth and shown by curves given in this paper no claim is made that they will hold for all samples of gasoline, but they do hold if all the samples come from the same crude.

It is impossible to fix the quality of gasoline by a single test. The gasoline of today is used for different purposes and is less volatile than that used even five years ago for the same purposes, because of the higher ends included in it.

A few years ago the specific gravity of a gasoline was regarded as an important specification of quality, and


Curve Sheet No 8
Compression Ratio Efficiency Curve
Gravity Efficiency Curves
Compression Ratio
Specific Gravity
Straight Run
Cracked
Affect of Compression Ratio change
8
7
6
5
4
.75
.74
.73
.72
.71
.70
.69
.68
16
17
18
19
20
21
Thermal Efficiency per cent

rightly so, because most of our gasoline supply came from a certain district and was all straight-run gasoline. The discovery of petroleum of a new type, the use of cracking processes, and the manufacture of various blends have introduced so many complicating factors that the gravity test has lost its value. It should not be a factor when comparing two similar fuels made from different crudes, because the specific gravity of a gasoline made from a western crude may be exactly the same as that of one made from an eastern crude, but one gasoline may be superior, due to the inherent qualities of the crude. The rating of different gasolines made from the same crude as distinguished by their specific gravities is of importance, however.

The fractions of gasoline are separated or "cut" by A. P. I. gravity, which for the products of each particular crude oil serves as a reasonably close index of the amount of high-boiling material present. Gasolines are blended according to their volatilities but the practical control is almost always by A. P. I. gravity. (1)

The influences of variations in volatility on the consumption of fuel and the operation of motor cars has been studied extensively by Gottschalk (2), Carlson (3), and by Dickinson and Warner (4), who have found that under

(1) Petroleum and its Products (1928) -Cruse-
(2) Journal of Society of Automotive Eng. 12-3-(1923)
(3) Idem 12-139-(1923)
(4) " 13-87-(1923)
14-154-(1924)

summer conditions, both in controlled runs and in average use, four gasolines of different volatilities gave very closely the same mileage per gallon used. A large number of automobiles were used in the road tests and variations in weather, etc. were eliminated by the cycle of operation. The fuels all had about the same initial point, but the end point on the first corresponded approximately to the 96 per cent point on the second, 92 per cent on the third, and the 86 per cent point on the fourth. While the mileage was the same, the degree of crank-case oil dilution and the tendency to knock increased, while ease of starting and operation decreased as the change to the heavier fuels was made. Under winter conditions the road tests alone were made on the second and fourth fuels together with a varient on each produced by lowering the 10 per cent point. The more volatile here gave 2.8 per cent more miles per gallon and 3.1 per cent more ton-miles per gallon than the less volatile pair. All gave 16 per cent less miles per gallon than approximately the same fuels in summer. The heavier pair gave 43 per cent greater crank-case oil dilution and more trouble in operation. The results indicated that small variations in the 15 to 20 per cent range on the distillation curve showed up markedly in the operation of a motor.

It may now be said, that specific gravity is an indication of the distillation range or volatility of a specific set of fuels made from the same crude. Therefore if volatility affects the engine characteristics as shown before, specific gravity must be an indication of engine characteristics. Cirxone (1) says that if the air-fuel ratio for starting is right, cranking speed is of secondary importance, but most carburetors are designed to give correct air-fuel ratio when the engine is cranked at rated speed. When the speed is reduced, due to heavy oil, the air-fuel ratio also changes with speed of cranking.

Specific gravity is in itself of very slight importance in determining the properties of gasoline except in the mixtures containing aromatic hydrocarbons. Gravity may serve as an index of other properties, particularly volatility, if knowledge is at hand regarding the source and method of production of a sample of gasoline.

Volatility is the basic property that determines the grade and usefulness of gasoline. It is a complex property. Different ranges of volatility are desirable for different conditions of use and are subject to wide variations. Thus it may be noted that the same type of gasoline is not equally desirable for aeroplane and truck motors, and that the type of motor fuel that would be most suitable for use in The Canal Zone might not give good results

(1) Paper given at S. A. E. Meeting, Detroit, April 27, 1931.

in Alaska. (1)

In checking over the specifications for motor gasoline for the last twenty years the following facts are shown: At first gravity was the only indication of the qualities of the fuel. This basis was dropped as being obsolete, and color and volatility as determined by A. S. T. M. distillation curve were next thought to tell everything that was necessary to know about gasoline, but now in 1932 the color test has been dropped and per cent of sulphur and Reid vapor pressure tests added in its place. The end point has been raised so the fuels we use today are slightly less volatile than they were 10 years ago. This is the reason why most of our present day cars are equipped with hot spot manifolds.

The following statement appears in the U. S. Bureau of Mines Report of Investigations, No. 3129, published August, 1931: "Gravity in itself has no particular significance with respect to the quality of a motor fuel. However, when considered in connection with other properties, gravity gives some information regarding the composition of the motor fuel, and for this reason gravity determinations are included in the semi-annual surveys."

The vapor pressure test has been added to the fuel specifications to stop the adding of too much of the very volatile fuel to heavier fuels to give good starting

(1) Motor Gasoline Properties, Laboratory methods and testing, and practical specifications, by Dean, Technical Paper No. 214, Bureau of Mines, Department of Commerce.

qualities, because the presence of these low ends tends to cause vapor lock.

In running some of the tests the carburetor was set to give maximum power for a given fuel. It was found that the carburetor must be adjusted for each fuel that has a change of specific gravity. For example, a fuel of 79 specific gravity gave maximum power at 20 notches opening of the carburetor; the cracked gasoline of 79 specific gravity also gave maximum power at this setting; but to use a 75 specific gravity gasoline the carburetor had to be opened to 34 notches to give a maximum power setting.

The work of this paper has been mainly to give the results as determined by running special tests on gasoline of varying specific gravities and of cracked and straight-run gasoline made from the same crude and having the same specific gravity range. These results are summarized in the conclusions as follows:

CONCLUSION

STARTING

1. The lower the specific gravity the easier the engine will start.

2. The cranking speed must be sufficient to insure correct operation of the carburetor.

3. Ten degrees change in temperature will affect starting characteristics of a fuel if it is near the line of easy starting fuels.

4. The 20 per cent point on distillation curve is an indication of starting characteristics at 60-70 degrees F. temperatures.

5. The 5 per cent point on distillation curve is the indication point in extremely cold weather. (1)

6. Upper parts of distillation curve have no effect on starting characteristics of a fuel.

MAXIMUM BRAKE HORSEPOWER

1. Gravity has no effect on the power obtainable from a fuel provided the air-fuel ratio and compression ratio are kept the same.

2. Cracked gasoline gives more power because it has better anti-knock rating and therefore can be used at higher compression ratios.

TENDENCY TO DETONATE

1. Tendency to detonate goes up directly as the specific gravity. The higher the specific gravity the worse the knock for fuels from any one crude.

2. A cracked gasoline has a better anti-knock characteristic than straight-run made from the same crude and having the same range of specific gravities.

THERMAL EFFICIENCY

1. The thermal efficiency increases with an increase of compression ratio.

2. The thermal efficiency of cracked gasoline appears

(1) Experiment run at U. S. Bureau of Mines.

to have a slight advantage over that of straight-run of the same specific gravity range.

3. Thermal efficiency is not affected by change of specific gravity provided the air-fuel ratio is kept constant.

AIR-FUEL RATIO

1. The carburetor must be adjusted for each fuel used, to give the same air-fuel ratio.

2. The higher the specific gravity the more the carburetor must be opened to give the same air-fuel ratio.

Tests conducted by the author on other Michigan gasolines bear out these same conclusions.

COMPUTATED DATA

Sample	Compression Ratio	Max. B.HP.	Lbs.Fuel per hour	Lbs.Fuel per B.HP. hour	Thermo Eff. %
As	4.00	2.69	2.285	.845	
"	4.55	2.855	2.26	.792	17.1
"	5.01	2.94	2.07	.695	
Bs	4.00	2.72	2.105	.774	
"	4.55	2.855	1.960	.687	19.7
"	4.69	2.88	2.01	.698	
Cs	4.00	2.67	2.06	.770	
"	4.55	2.84	2.082	.733	18.45
"	"	2.81	2.28	.812	
"	"	2.755	1.83	.644	
"	"	2.095	1.62	.772	
Ds	4.00	2.70	2.06	.762	
"	4.55	2.84	1.955	.703	19.20
"	4.4	2.81	2.001	.713	
"	"	2.615	1.80	.687	
"	"	1.90	1.58	.830	
Ac	4.00	2.738	2.525	.849	15.95
"	4.55	2.93	2.275	.776	17.4
"	5.01	3.04	2.245	.739	18.3
"	5.86	3.145	2.11	.671	20.1
"	"	2.845	1.845	.649	
"	"	2.72	1.705	.627	
Bc	4.00	2.61	2.095	.654	
"	"	2.56	1.98	.774	
"	"	"	1.915	.747	
"	"	2.315	1.72	.742	
"	4.55	2.83	2.075	.733	18.45
"	5.01	2.94	2.06	.701	
"	"	2.86	1.90	.675	
"	"	2.52	1.765	.690	
"	5.62	2.94	1.845	.627	
Cc	4.00	2.58	2.01	.779	
"	"	2.415	1.84	.761	
"	4.55	2.25	1.64	.728	18.6
"	"	2.66	1.80	.676	
"	"	2.80	1.93	.689	
"	5.01	2.88	1.92	.667	
"	5.41	2.96	1.915	.646	
Dc	4.00	2.48	1.85	.746	
"	"	2.56	1.89	.737	
"	"	2.62	2.23	.853	
"	"	2.65	2.08	.786	
"	"	"	2.105	.794	
"	4.55	2.76	1.88	.681	19.82
"	5.01	2.87	1.89	.659	

DATA; check on carburetor adjustment

Sample	Compression Ratio	Max. B.HP.	lbs. Fuel per hour	lbs. Fuel per B.HP. hour
As	4.4	2.54	2.43	.956
Bs	"	2.63	2.30	.875
Cs	"	2.66	2.19	.824
Ds	"	2.63	2.03	.774

A. S. T. M. Distillation

Sample	Per cent Distillate	Temperature Degrees F.	Per cent Distillate	Temperature Degrees F.
Ac	0	89	0	90
	5	113	5	111
10 % Point	10	129	10	133
	20	147	20	150
	30	164	30	167
	40	180	40	183
	50	195	50	196
	60	207	60	208
	70	220	70	220
	80	233	80	236
	90	253	90	254
Recovery	97.8		97.6	
End Point		298		299
Residue	1.0		1.0	
Loss	1.2		1.4	
Bc	0	99	0	101
	5	123	5	131
10 % Point	10	141	10	144
	20	165	20	168
	30	188	30	188
	40	208	40	208
	50	223	50	225
	60	240	60	242
	70	257	70	259
	80	277	80	274
	90	300	90	301
Recovery	98		97.5	
End Point		339		339
Residue	1.0		1.0	
Loss	1.0		1.5	

A. S. T. M. Distillation

Sample	Per cent Distillate	Temperature Degrees F.	Per cent Distillate	Temperature Degrees F.
Cc	0	102	0	102
	5	123	5	122
10 % Point	10	144	10	148
	20	176	20	180
	30	206	30	210
	40	235	40	237
	50	261	50	261
	60	288	60	283
	70	314	70	315
	80	343	80	342
	90	378	90	376
Recovery	97.5		98	
End Point		415		417
Residue	1.1		1.1	
Loss	1.4		.9	
Dc	0	81	0	94
	5	133	5	132
10 % Point	10	147	10	149
	20	179	20	178
	30	208	30	207
	40	235	40	234
	50	261	50	258
	60	283	60	287
	70	318	70	317
	80	350	80	349
	90	398	90	391
Recovery	98		98.3	
End Point		448		448
Residue	1.0		1.2	
Loss	1.0		.5	
As	0	101	0	101
	5	135	5	137
10 % Point	10	148	10	150
	20	165	20	168
	30	180	30	181
	40	193	40	194
	50	203	50	205
	60	215	60	215
	70	224	70	227
	80	237	80	237
	90	255	90	255
Recovery	98.2		98.2	
End Point		311		308
Residue	.9		1.0	
Loss	.9		.8	

A.S.T.M. DIstillation

Sample	Per cent Distillate	Temperature Degrees F.	Per cent Distillate	Temperature Degrees F.
Bs	0	95	0	99
	5	141	5	144
10 % Point	10	161	10	164
	20	187	20	189
	30	207	30	208
	40	222	40	224
	50	234	50	238
	60	248	60	254
	70	265	70	270
	80	281	80	289
	90	304	90	310
Recovery	98.1		98.1	
End Point		336		342
Residue	1.0		1.1	
Loss	.9		.8	
Cs	0	89	0	94
	5	141	5	142
10 % Point	10	166	10	168
	20	199	20	201
	30	227	30	226
	40	249	40	248
	50	263	50	267
	60	295	60	293
	70	321	70	320
	80	346	80	345
	90	376	90	376
Recovery	97.5		97.6	
End Point		404		405
Residue	1.1		1.2	
Loss	1.4		1.2	
Ds	0	108	0	104
	5	158	5	159
10 % Point	10	183	10	185
	20	216	20	216
	30	242	30	241
	40	266	40	267
	50	297	50	297
	60	323	60	324
	70	350	70	351
	80	374	80	377
	90	403	90	405
Recovery	98.3		98.0	
End Point		437		441
Residue	1.2		1.2	
Loss	.5		.8	

Sample	Symbol	A. P. I.	Specific Gravity
Straight Run	As	67.5	.7157
" "	Bs	63	.7305
" "	Cs	60	.7420
" "	Ds	57	.7539
Cracked	Ac	68	.7125
"	Bc	63.2	.7298
"	Cc	58.5	.7475
"	Dc	57.2	.7531

Starting

Sample	Revolutions To Start	R.P.M. Cranked	Compression Ratio	Room Temp. Degrees F.
Ac	10	220	5	72
Bc	18	"	"	"
Cc	90	"	"	"
Dc	180	"	"	"
Ac	12	"	7	"
Bc	23	"	"	"
Cc	113	"	"	"
Dc	150	"b	"	"
As	15	"	5	68
Bs	39	"	"	"
Cs	would not	"	"	"
Ds	start		"	"
As	18	"	7	"
Bs	70	"	"	"
Cs	would not			
Ds	start	"	"	"

Carburetor Adjustment

Sample	Compression Ratio	Carburetor Setting	Load on Scales#	Time to burn 1/6 # Gas. M.
As	4.4	20	9.2	4.11
Bs	"	21	9.5	4.13
Cs	"	23	9.5	4.07
Ds	"	24	9.5	4.06

Spark was set for maximum power at each carburetor setting.
Barometer Reading 29.25 in.HG.
Room Temperature 75 Degrees F.
R.P.M. 800 for all tests.

Brake Horsepower

Sample	Compression Ratio	Carburetor Setting notches	Spark Setting Deg.Adv.	Load on Scales	Time to burn 1/6 # Gasoline in minutes
As	4.00	20	28	9.7	4.37
"	4.55	"	25	10.3	4.42
"	5.01	"	22	10.6	4.82
Bs	4.00	"	28	9.8	4.75
"	4.55	"	25	10.3	5.06
"	4.69	"	24	10.4	4.97
Cs	4.00	"	28	9.7	4.86
"	4.55	"	25	10.3	4.80
"	4.55	22	"	10.2	4.38
"	"	18	"	10.0	5.47
"	"	16	"	7.6	6.18
Ds	4.00	20	28	9.8	4.86
"	4.55	"	25	10.3	5.01
"	4.4	"	"	10.2	4.99
"	"	18	"	9.5	5.56
"	"	16	"	6.9	6.33
Ac	4.00	20	24	10.0	4.30
"	4.55	"	20	10.7	4.40
"	5.01	"	19	11.1	4.45
"	5.86	"	15	11.5	4.74
"	"	18	"	10.4	5.41
"	"	16	"	9.5	5.86
Bc	4.00	20	28	9.6	4.77
"	"	18	"	9.4	5.05
"	"	"	31	9.4	5.22
"	"	16	33	8.5	5.81
"	4.55	20	26	10.4	4.82
"	5.01	"	22	10.8	4.85
"	"	18	24	10.5	5.26
"	"	16	26	9.4	5.66
"	5.62	20	18	10.8	5.41
Cc	4.00	20	28	9.4	4.98
"	"	18	31	8.8	5.54
"	4.55	16	"	8.2	6.01
"	"	18	29	9.7	5.56
"	"	20	26	10.2	5.18
"	5.01	"	22	10.5	5.20
"	5.41	"	18	10.8	5.22
Dc	4.00	18	36	8.9	5.40
"	"	19	"	9.3	5.29
"	"	20	"	9.5	4.48
"	"	"	"	9.6	4.80
"	"	"	"	"	4.75
"	4.55	"	32	10.0	5.31
"	5.01	"	26	10.4	5.29

Barometer Reading for Straight Run samples 28.975 in. Hg.
" " " Cracked " 28.5 " "

Room temperature 65 degrees F.
R.P.M. 800 for all tests

Orsatt Readings

Sample	Carburetor Setting notches	Co2 %	O2 %	CO %	Air Fuel Ratio Lockwood's Chart
As	20	10.2	1.3	4.5	13.2
Ac	20	10.4	1.0	4.6	13.0
Dc	24				13.0
Dc	24				13.0
As	16	12.2	1.3	.9	15.3
Ac	16				15.0

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