THESIS

AN EXPERIMENTAL STUDY OF CARBURETERS

BY

D. C. BLACK W. E. SAVAGE

1917

THESIS

Carburetters

THESIS

Carbureters

An Experimental Study of Carbureters

A Thesis Submitted to

The Faculty of

MICHIGAN AGRICULTURAL COLLEGE

By

D. C. Black

W. E. Savage

Candidates for the Degree of

Bachelor of Science

June, 1917.

C O N T E N T S.

PART I.

PART II.

PART III.

PART IV.

Acknowledgment.

The authors of this thesis wish to extend their thanks for the valuable suggestions and help given by the department. Especially so because of the extra burden of work and responsibility on them, incident to the recent occupancy of the new engineering buildings.

May 24, 1917.

T H E S I S.

The first essential in this discussion is to know what a carburetor is, and what is generally expected of such a piece of apparatus. A carburetor is a device which is used in connection with an internal combustion engine, its peculiar function being the supplying of the source of heat (usually hydrocarbon oil) and air, in the proper proportions, to the engine intake manifold and hence to the combustion chamber.

This discussion will be limited to gasoline as the sources of fuel heat. The gasoline used on this test was ordinary commercial oil as sold by the Standard Oil Company for gasoline combustion purposes. There was obtained fifty-five gallons of this distillate which was set aside and used as needed. Soon after the supply tank was filled samples were taken. It will be noted here that the fuel was not allowed to stand and that the samples were therefore true specimens of the quality of the oil as a homogeneous liquid. The reason for taking these samples was to analyze to some degree of accuracy the fuel we were to use. The action of a carburetor will always depend directly upon the quality of fuel that is used in it.

In the testing or analysis of gasoline as a heat fuel, one of the most valuable means of examination is that of quantitative distillation. A few years ago kerosene was the most wanted petroleum product, but recently, greatly because of the advent of the gasoline engine and carburetor the distillate commonly or commercially called gasoline is the most desired of the hydrocarbon group. Gasoline is a very hard oil to analyze or to define. It is extremely difficult and practically impossible to obtain the same oil from time to time having the same mixture, and there seems to be no way at present to tell what we do get without extensive experimental testing. The reason we are testing the gasoline used is to approximately know what we are using for the experimental comparative tests which are to follow.

Gasoline is generally sold on the basis of its specific gravity, certain gravities being regarded as most desirable. Too light gasolines are not desirable on account of their disadvantages and dangers in handling and storing them. Heavier gasolines must be handled differently when used in internal combustion engines. In fact, the property of density is important only because it bears an approximate relation to the important property of gravity. To measure the specific gravity of a gasoline is easy, but to measure its volatility is difficult, and for this reason the present system of grading continues, although its inadequacy is becoming generally recognized. Specific gravity does not bear a constant relation to volatility of gasolines. A gasoline made up of constituents too light to be safe and partly of others too heavy to vaporize easily may be of an average specific gravity that approaches the mark considered most desirable by purchasers.

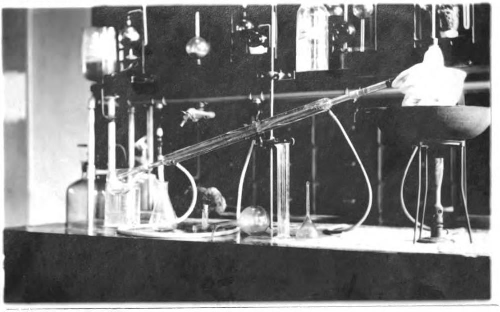
The only satisfactory and accurate method of gasoline testing is by analytical distillation. Volatility, as indicated by distillation range, is the most important property in determining the value of the product.

The mechanism of the process of distillation may be briefly described in the following discussion. When any mixture is subjected to distillation the composition of the vapor just as it leaves the liquid is controlled by the properties of the liquid. The proportions of the various constituents, their vapor pressures, and the mutual relations of solubility of the vapors in the liquids all play a part in determining the composition of the mixture to be given off. In general, however, the vapor is richer in the more volatile constituents than is the original liquid.

Nearly all processes of distillation involve partial condensation of the vapors, so that all of the vapor escaping from the liquid does not pass over into the condenser. The tendency towards condensation is the greatest with the constituents of lesser volatility (higher boiling point); and the loss of the mixture that liquifies and returns to the retort of the distilling vessel causes a still further change in the composition of the remaining vapor, again in the direction of enrichment with the more volatile constituents.

Still another factor of importance is the washing that occurs when the returning condensate and the ascending vapors come in contact. Here again the readjustment of conditions towards equilibrium results in still further enrichment of the vapor in volatile constituents. It appears, therefore, that all the effects of distillation tend toward separation of the

more volatile from the less volatile constituents, the more volatile predominating in the distillate and the less volatile in the residue. When a distillation is carried to completion, the first fractions contain most of the more volatile and later most of the less volatile substances.



The first and fundamental need in this distillation test is accurate temperature measurement. In the set-up used by us a mercury thermometer was used which had a range of 0° 250°C. At the beginning of a run the mercury in the thermometer stood at about 25° C. This thermometer was of an accurate and high-grade class as used for such purposes in the chemical laboratory at M. A. C.

The rate of distillation is an important factor in the distillation of gasoline. The matter of time has little to do with the value of the results, although violent ebullion that causes unvolatilized spray to come over with the vapor should be avoided. To insure as far as possible a proper rate of distillation a sand bath was used and the exposed parts of the gasoline container, (a Wertz (250 C.C.) flask) was jacketed with dry cloth. This gave a very satisfactory, uniform, and well distributed rate of distillation.

A condition which affects a distillation test of this kind is atmospheric pressure. Tests were made on different days when the atmospheric pressure varied as much as 5 M. M. of Hg. Room temperature and air current about the flask would have little effect as it was blanketed by cloth and sand.

The source of heat used was a (Mecker) gas burner with rubber tube connection. This allowed regulation of the amount of heat as needed and allowed a maximum temperature of 206° C.

The distillate was trapped after passing thru a condenser in an Enlemeyer flask which fitted loosely over the end of the condenser tube; the Enlemeyer flask was set in a bell jar of water. The distillate was allowed to gather in the Enlemeyer flask through a temperature range of 10° C; then the flask was removed and the collected distillate measured in C. C., recorded, and bottled. This procedure was repeated for the several ranges of temperatures. The thermometer Hg. bulb was located at the junction of the column and leg of the Wertz Flask. For it is at this point that the distillate distilles over.

The specific gravity of several of the distillates was obtained. A specific gravity bottle was used to obtain this data. The capacity of this bottle was 10 C. C. at 15° C. for water. The weight was obtained very accurately by use of counter weight and scale pan weights thus the weight was found when filled with each of the several distillate samples and from this the specific gravity determined. On the curve sheets curve #2 corresponds to distillation and specific gravity test #2, and likewise for the other curves and tests.

After every run there were just a few drops of residue left in the Hertz flask, but after cooling down this was increased by condensation on the sides of the flask to about two C. C. The color of this heavy oil was like that of steam engine lubricating oil and possessed a slight odor of kerosene. A sample of gasoline from the residue collected in the actual tests of the carbureter was saved and a complete fractional distillation test made upon this sample. Also specific gravity tests were made to several of the fractional distillates. These relations are shown by the curves designated as test number 4.

The property of viscosity is not ordinarily associated with liquids as light as gasoline. It is a fact however, that to some extent the flow of gasoline thru the nozzle of a carbureter is directly affected by changes of temperature. Thus, if a carbureter nozzle is adjusted to give a proper mixture at a working temperature of 100° F. it will discharge under certain conditions a little over 71% of the requisite fuel when the temperature falls to 50° F. which is the very time when an excess of fuel is needed. Like other characteristics of gasoline, its viscosity varies with its composition, therefore definite regulation of the fuel orifice, thermostatic or otherwise, is consequently difficult.

J. T. Stoddard, Professor of Chemistry in Smith College, in a book "Introduction to Organic Chemistry", 1914, gives the following table:

		Boiling between	Sp. Gravity
Gasoline	(Petroleum ether	$40^{\circ} - 60^{\circ}$	0.665 - 0.670
	(Benzine or naphtha	$70^{\circ} - 90^{\circ}$	0.680 - 0.720
	(Ligroin	$150^{\circ} - 300^{\circ}$	
	(Lubricating oils	above 300°	

Contains chiefly

C_5H_{12} - C_6H_{14}

C_6H_{14} - C_7H_{16}

C_7H_{16} - C_8H_{18}

Tabulated Data

Fractional Distillation of Gasoline.

Temp. °C.	Test #1 Amt. Dist- c.c.	Test #2 Amt. Dist- c.c.	Test #2 Sample	Test #3 Amt. Dist- c.c.	Test #3 Sample #	Test #4 Amt. Dist- c.c.	Test #4 Sample	Temp. °F.
25								77
55	0.3							131
60								140
65	0.8							149
70								158
75	1.4	11.2	1					167
80								176
85	2.3	1.8	2					185
90				8.6	1			194
95	3.5	2.7	3					203
100								212
105	5.5	10.5	4	8.6	2			221
110								230
115	11.0	3.6	5	6.7	3			239
120								248
125	16.9	8.3	6	7.2	4			257
130								266
135	8.5	8.1	7	9.0	5			275
140						6.4	1	284
145	7.9	7.8	8	9.7	6			293
150						14.3	2	302
155	8.1	10.7	9	13.0	7			311
160						23.1	3	320
165	8.0	11.0	10	10.3	8			329
170						20.5	4	338
175	7.3	7.8	11	7.6	9			347
180						15.3	5	356
185	5.6	3.8	12	5.3	10			365
190						8.8	6	374
195	Res 1.4	6.8		3.6	11			383
200						4.9	7	392
210	Res	2.1	(206)	4.1	12	2.8	8	410
215					13			419
			Res.	1.4	Res	1.9		
Total	94.3	96.2		95.5		98.0		

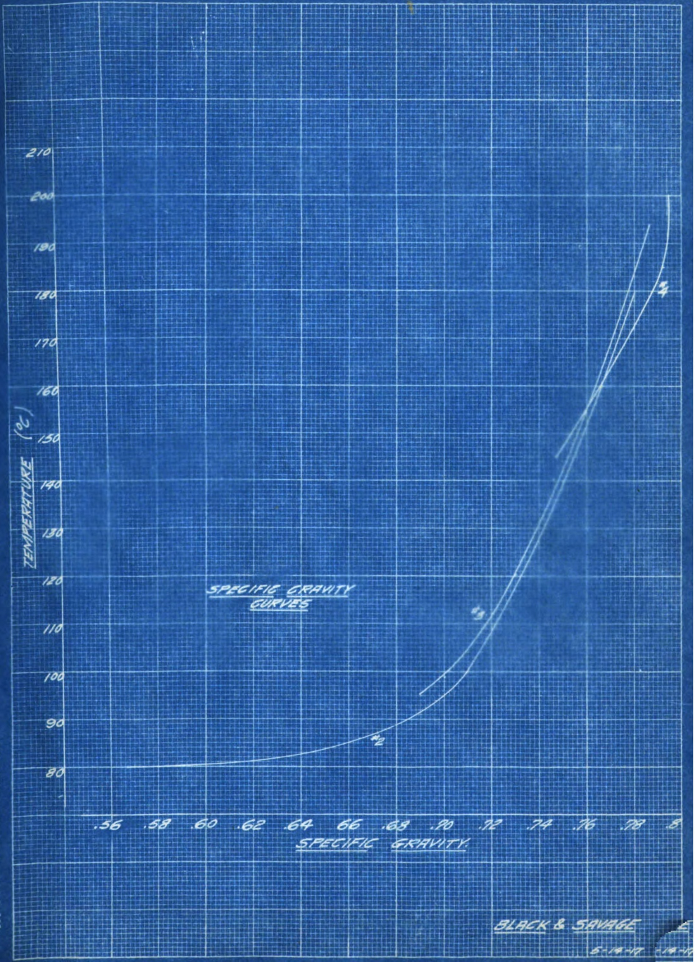
Tabulated Data & Results

Fractional Distillation of Gasoline.

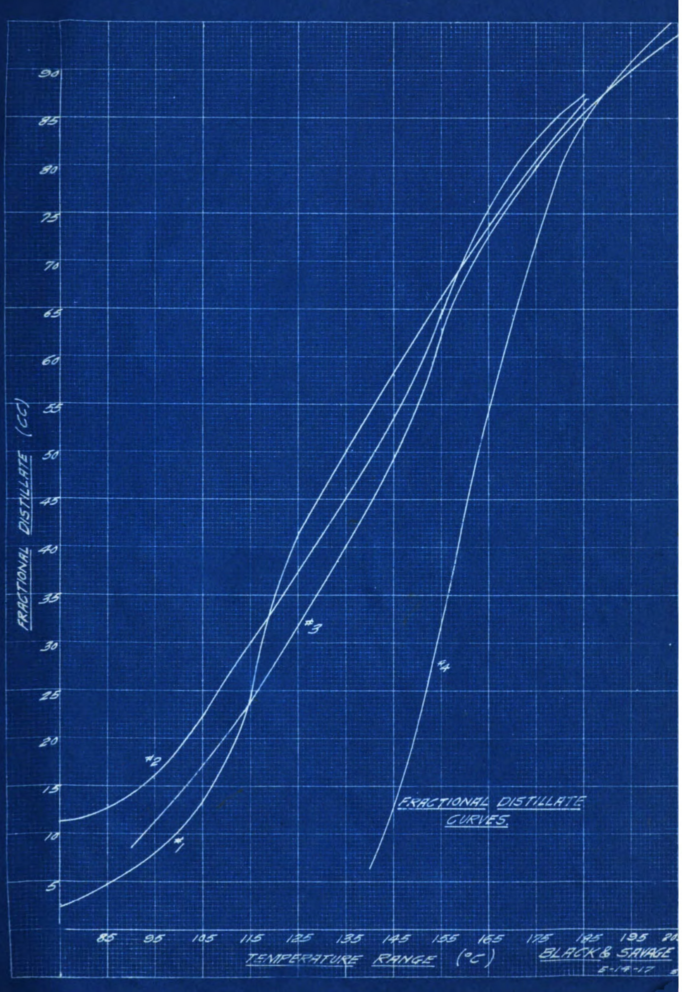
Specific Gravity Tests.

Unbalanced Weight = 0.0079 grams.
Temperature Correction = 0.99756 grams.

Sample	Gross Wt. (gm)	Net Wt. (gm)	S.G. Corrected for Temp.
	Test #2.		
1-2	5.67083	5.66293	0.5675
3-4	7.0930	7.0851	0.7110
5-6	7.3310	7.3231	0.7340
7-8	7.4852	7.4773	0.7495
9-10	7.6072	7.5993	0.6200
	Test #3		
1-2	6.8712	6.8633	0.6880
3-4	7.2720	7.2641	0.7290
5-6	7.4439	7.4360	0.7460
7-8	7.6338	7.6359	0.7660
9-10	7.9100	7.9021	0.7940
	Test #4.		
1-2	7.4771	7.4692	0.7490
3-4	7.7329	7.7250	0.7780
5-6	7.9340	7.9261	0.7950
7-8-9	7.9540	7.9461	.7980
	Test #5		
Undistilled Gasoline	7.4170	7.4091	0.7440



210
200
190
180
170
160
150
140
130
120
110
100
90
80
TEMPERATURE (°C)
SPECIFIC GRAVITY CURVES
#2
#3
#4
.56 .58 .60 .62 .64 66 .68 .70 .72 .74 .76 .78 .8
SPECIFIC GRAVITY
BLACK & SAVAGE
5-14-17



90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
FRACTIONAL DISTILLATE (CC)
85
95
105
115
125
135
145
155
165
175
185
195
TEMPERATURE RANGE (°C)
#1
#2
#3
#4
FRACTIONAL DISTILLATE CURVES.
BLACK & SAVAGE
5-14-17

General Discussion and Explanation.

The carbureter is a device which, like many other mechanisms, is of practically no real value except when used as an integral part of the machine for which it is designed. It must, as a part of an automobile, preform its particular function so as to give satisfactory results from the standpoint of a self-propelled vehicle,. and to accomplish this function with the best economy and efficiency with satisfaction.

But in the study of the automobile the scope is far too broad. The number of variables and the relation of the various units becomes so intricate. Therefore the only way to study or investigate the machine is to take each unit individually. Also by taking each part variables and combinations of variables can often be avoided giving definite data and results of value.

In the growth and development of the science of carburation there has been a series of types brought forth. Some of these are taken up in the following paragraphs.

On curve sheet #9 will be found two curves one a high power curve and the other a high efficiency curve. The zone between these two lines covers the range of quality within which it has been found desirable that the quality should be maintained. The boundaries of this zone may not be universally accepted as the best, but are approximately the best.

The types of carbureters in order are these:

1. Elemintary Fixed Orifice.

2. Compensated " "

Air valve class of carbureters.

1. Elemental air valve, without fixed air orifice.

2. Simple, with compensating air valve and fixed orifice.

3. Air valve with supplemental gasoline jet.

4. Air valve with metering pin attached to air valve.

5. Air valve, with needle valve controlled by cam on throttle.

6. Air valve, using friction control of gasoline.

7. The two stage carbureter.

Some of the inherent characteristics of the types will next be given.

With the first, elementary fixed orifice carbureter the quality will pass out of the zone when less than eighteen cubic feet of air are used. This makes it impossible to enrich small quantities of air. Therefore this type cannot be used with success, and it becomes necessary to embody in the carbureter some means for increasing the gasoline supply where it is deficient. Various devices are used for this purpose. Some affect the necessary compensation by acting on the gasoline supply, others on the air, and still others on both.

The second, the compensated fixed orifice carbureter is provided with supplemental or compensating devices which increase the supply of gasoline, particularly at the part where it is most deficient.

Under this class of air valve carbureters first comes the elemental air valve carbureter without fixed air orifice. This type is not a practical success, but the principle involved is to allow all the gasoline to be admitted thru a fixed orifice and all the air thru a spring-closed air valve.

The second type under the air valve classification is the simple carburetor with compensating air valve and fixed orifice. This type is well known in a variety of forms. The fixed air orifice is often called the "strangle valve" or the "venturi choke" and ordinarily the gasoline nozzle terminates in this passage. The gasoline as before is regulated by a fixed orifice or the gasoline orifice remains unchanged in the operation of the carbureter. A second air passage in this type is closed by a spring opposed air valve which opens as the suction increases.

The third type under this class is the air valve carbureter with supplementary gasoline jet. Various means have been used to cause a second gasoline jet to come into action before reaching maximum capacity, thus augmenting the supply where it has become deficient. If this second jet comes into service abruptly, as it does in many cases, it causes the quality diagram to make an abrupt change which is undesirable.

The forth type is the air valve carbureter with metering pin attached to the air valve. The effect is desirable for medium and high air quantities but when small quantities are being used the result is an extremely lean mixture.

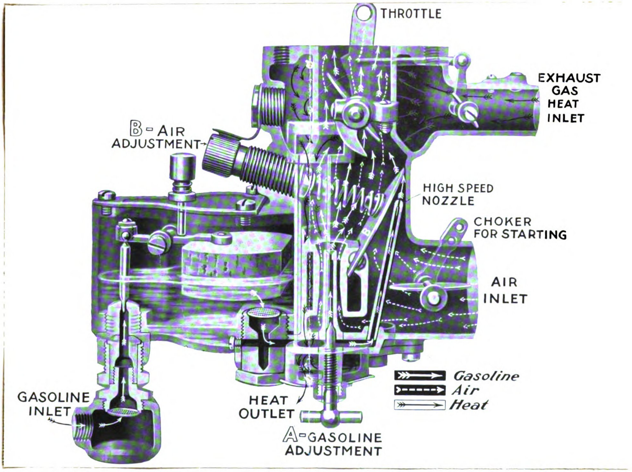
The fifth type is the air valve carbureter with needle valve controlled by cam on throttle. For this type, if the load at certain speed is such that the necessary position of the throttle causes the needle valve to supply the amount of fuel required by the air that is being used, then a normal

quality of mixture is supplied, but under all other conditions the mixture is either too lean or too rich. This is a condition that is always found when gasoline orifice is varied by opening and closing the throttle.

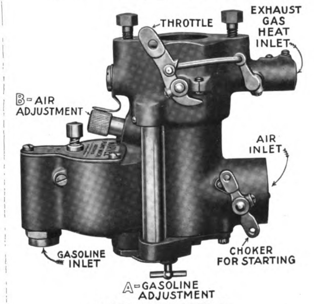
The sixth type is the air valve carbureter using friction control of gasoline. This type gives a quality line that remains within the zone and is nearly constant for a large range but has the eliminating disadvantage that fluctuations in temperature make a great variation in the flow of gasoline.

The seventh and last type is the two-stage carbureter. It is essentially two carbureters, the primary having twice the capacity of the secondary. The quality curves have a tendency to cross the zone especially when the primary stage is in use which is used about 90% of the time. The secondary stage is about parallel to the extent of the zone and should give good results. The carbureters selected for the experimental work were a Marvel and Zenith. These carbureters are comparatively simple, embodying the principals required and allowed changing of carbureter in set-up without a change in the set-up itself, thus keeping the running conditions more nearly constant.

The Marvel carbureter is of the type discussed previously under the second and third type of the air valve carbureters.



Some of the features are: a heat jacket around the throttle which is connected with a heat jacket around the venturi and low speed gasoline needle. These jackets are kept warm by hot exhaust gases. The fixed air orifice or "venturi choke" surrounds the low speed fixed orifice nozzle. The high speed fixed orifice nozzle is argumented by a spring opposed air valve which opens when the suction increases. The gasoline is regulated by a needle valve which acts on both fixed orifices.

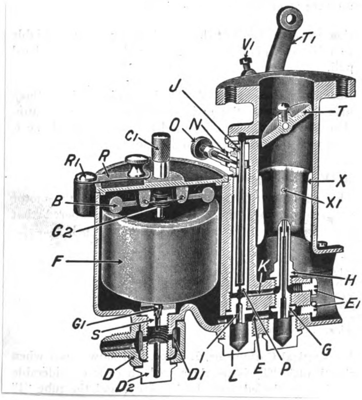


STANDARD MODEL E

The jackets warmed by exhaust gases from the engine exhaust are led to the carbureter by a flexible tube to the exhaust gas heat inlet as shown in cut. It enters the jackets of the carbureter under control of a damper which acts automatically with the throttle. As the throttle opens the damper closes. The vertical pipe which shows plainly in the small cut is a pipe for the purpose of conducting the heating exhaust gases to a vent in the bottom of the carbureter.

The Zenith carbureter is of the type as discussed principally under the second of the air valve carbureters. The feature of the Zenith carbureter is the compound or compensating nozzle.

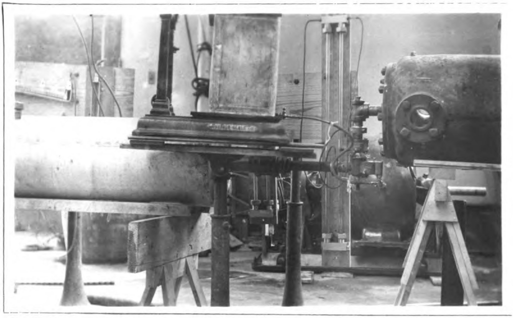
Model "L"



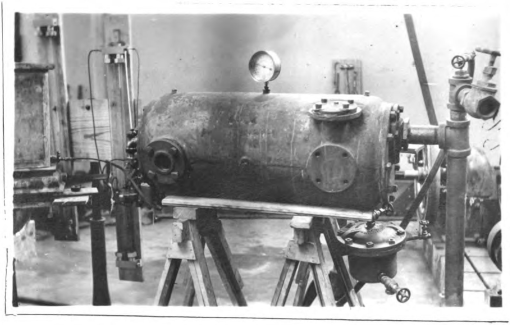
As shown in cut, the nozzle is composed of two parts. The outer part is under the influence of the engine suction which causes the flow of gasoline to increase faster than the flow of air, giving a mixture of increasing richness. To counteract this effect the inner part of the nozzle is constructed so that it is under only atmospheric pressure because of the open well, and the gasoline flow is determined by the size of opening. This compensator or inner part of the nozzle then delivers a steady rate of flow per unit of time and as the suction increases more air is drawn up, while the amount of gasoline remains the same and the mixture grows poorer and poorer. By combining the two parts the compound nozzle is obtained, in which there is both direct suction, and the constant flow type. One supposidly counteracts the defects of the other to give a constant mixture at varying suctions.

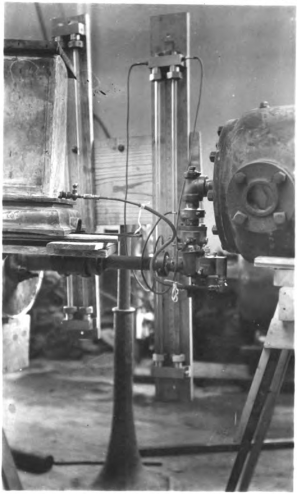
Our apparatus was set up in a train in order as follows.

The air was taken in at room temperature, which was kept as near constant as possible thru a standard two inch orifice into a large orifice tank.

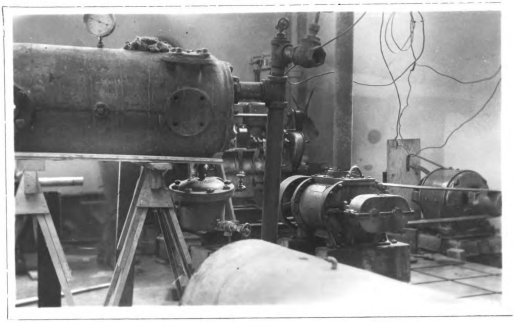


Emerging from the orifice tank with a straight pipe connected to the pipe, was the carbureter air duct.





The fuel gasoline was supplied from a reservoir tank on a small set of platform scales. There was provided a stop cock on the tank from which there was a copper tube connection to the gasoline inlet of the carbureter. A fitting was made to match the manifold connection of the carbureter and to this fitting a pipe led to the baffle tank. The baffle tank was constructed of heavy cast iron and contained four baffles for reducing the velocity and changing the direction of flow of the vapor.



At the end of the baffle tank farthest from the carbureter was located a residue collecting tank used to drain off the gasoline entrapped in the baffle tank. From the baffle tank at the same end as the residue collector was a pipe connection going to a positive rotary blower. In this pipe connecting the baffle tank and the blower was a pipe connection to which a hose connection was fitted. At this point water was injected into the train which eliminated the fire risk of the gasious exhaust and also tended to seal the blower. A large relief or throttling valve was placed in the pipe line between the water connection and the blower to keep the pressure on the carbureter constant during a run and to change the vacuum for different adjustments of the carbureters. The exit pipe from the blower terminated outside the laboratory by way of a window. The power used to run the blower was a five horsepower motor.

The following temperatures and pressures were taken: The temperature and pressure inside the orifice tank, the temperature before and after the carbureter, also the pressure drop in the carbureter, and the pressure in the baffle tank. For the pressures on the orifice tank a draft gage was used. On the baffle tank a dial pressure gage was used. This gage was not very accurate but good enough for the pressure at this point. A differential manometer with water was used for the pressure drop over the carbureter. Temperatures were obtained by thermometers. These thermometers were accurate, and the divisions were large with a small numerical range.

There is one important adverse criticism to this set-up, it being that the baffle tank should have been inclined so that the entrapped gasoline would have flowed to the residue collector quickly eliminating any error due to the gasoline taking too much time to gravitate to the residue collector.

The following is a procedure of a test. The throttle valve was opened, the motor started and blower set in operation. The water was turned on so that dripping was noticeable at the exhaust. The throttle was adjusted to give about a 20" vacuum thru carbureter. The machine was allowed to run this way for several minutes. The reservoir tank was filled with gasoline, the cock was opened on the reservoir tank, and gasoline allowed to flow thru set-up several minutes before the test was begun, to allow settled running conditions and reduction and constancy of temperatures and pressures. Then the scales were balanced and the poise set less than the balancing point. When the scales balanced, time was recorded, residue chamber closed and following readings taken; gross fuel weight, temperatures and pressure at carbureter, temperature and pressure on orifice and pressure tanks. Then for six three-minute intervals temperatures and pressures were recorded. During this time the residue was drained off twice into a container. By looking into the baffle tank thru the glass ports a fog or mist could be plainly seen varying in density in proportion to the throttle opening. When the time was completed for a test run the gasoline was shut off, all temperatures and pressures taken, the reservoir with remaining fuel and the residue weighed.

Then for the next run in the case of the Marvel was to change the carbureter throttle valve. There were four openings from full open to nearly closed. After these four throttle openings were completed, a new adjustment of the carbureter was made. With the Marvel, adjustments were made to the needle valve and to the slow speed air adjustment. In the case of the Zenith only the slow speed air adjustment was altered. With both carburetors, four throttle positions were used for each adjustment of the respective carburetors.


KEEP
AWAY

Running Log of Carbureter Tests
Marvel, Model W.

Run	Throttle Valve Opening.	Orifice Tank Vac. Pressure.	Orifice Tank Temp.	Pressure Drop Thru Carburetor.	Temp. Air at Carburetor.	Temp. Vapor at Exit of Carburetor.	Vac. in Baffle Tank	Wt. of Fuel Used. Gross	Residue Collected. Gross
No.	"H_2O	"H_2O	°F.	"H_2O	°C.	°C.	"Hg.	Lbs.	Lbs.
5	1	1.6	64.6	29.0	18.3	11.0	3.5	25.80	4.1
	1	1.6	64.6	29.0	18.2	9.2	2.5	----	---
	1	1.6	65.2	29.9	18.5	9.1	2.5	----	---
	1	1.6	66.0	29.8	18.8	9.3	2.5	----	---
	1	1.6	66.2	29.8	18.9	9.4	2.5	----	---
	1	1.5	66.7	29.8	19.1	9.6	2.5	----	---
	1	1.6	66.8	29.9	19.3	9.9	2.5	19.90	---
6	2	1.5	65.0	29.5	18.4	10.0	3.0	22.00	4.65
	2	1.5	64.8	29.6	18.3	8.3	3.0	---	---
	2	1.5	65.0	29.8	18.4	8.2	3.0	---	---
	2	1.4	64.9	29.7	18.4	8.1	3.0	---	---
	2	1.5	64.7	29.5	18.3	8.1	3.0	---	---
	2	1.5	64.4	29.8	18.2	8.0	3.0	---	---
	2	1.4	64.8	29.5	18.4	8.1	3.0	25.25	---

Atmospheric Pressure on Differential Manometer, 18.5 H_2O.
Needle Valve, ¼ turn open, Air Adjustment, 1 1/2 open.
Wgt. Residue Container, 0.72#. Wgt. Fuel Container, is 4.45#.
Time of test for each throttle opening, 10 minutes.
Gage on baffle tank reads 1"Hg. too high.

Running Log of Carburetor Tests.
Marvel - Model E.

Run	Throttle Valve Opening.	Orifice Tank Vac. Pressure.	Orifice Tank Temp.	Pressure Drop Thru Carburetor.	Temp. Air at Carburetor.	Temp. of Vapor at Exit of Carburetor.	Vac. in Baffle Tank	Wgt. of Fuel Used Gross	Residue Collected. Gross
No.	No.	"H_2O	°F.	"H_2O	°C.	°C.	"Hg.	lbs.	lbs.
7	3	0.8	67.8	29.0	19.8	12.0	2.5	19.2	2.6
	3	0.8	65.7	29.6	19.0	10.7	2.5	---	---
	3	0.9	65.5	29.6	18.9	10.5	2.5	---	---
	3	0.9	65.7	29.6	19.0	10.6	2.5	---	---
	3	0.8	65.8	29.6	19.0	10.7	2.5	---	---
	3	0.8	65.6	29.5	18.8	10.7	2.5	---	---
	3	0.9	66.2	29.5	19.0	10.9	2.5	15.9	---
8	4	0.2	66.4	29.5	19.1	12.1	2.2	18.05	1.5
	4	0.2	66.5	29.4	19.1	11.6	2.2	----	---
	4	0.2	66.1	29.5	19.0	11.4	2.2	----	---
	4	0.2	65.9	29.5	19.0	11.3	2.2	----	---
	4	0.2	65.6	29.5	19.0	11.2	2.2	----	---
	4	0.2	65.6	29.5	18.9	11.2	2.2	----	---
	4	0.2	65.5	29.7	18.8	10.2	2.2	16.05	---

Running Log of Carburetor Tests.
Marvel - Model E.

Run	Throttle Valve Opening.	Orifice Tank Vac. Pressure.	Orifice Tank Temp.	Pressure Drop Thru Carburetor.	Temp. Air at Carburetor.	Temp. of Vapor at Exit of Carburetor.	Vac. in Baffle Tank	Wgt. of Fuel Used Gross	Residue Collected. Gross
No.	No.	"H_2O	°F.	"H_2O	°C.	°C.	"Hg.	Lbs.	Lbs.
9	1	1.6	69.6	29.5	20.8	13.1	2.5	[illegible]0.20	1.50
	1	1.6	69.6	29.5	20.9	14.1	2.5	----	---
	1	1.6	70.1	29.5	21.2	14.4	2.5	----	---
	1	1.7	69.9	29.6	21.1	14.3	2.5	----	---
	1	1.7	70.2	29.6	21.5	14.8	2.5	----	---
	1	1.6	70.6	29.6	21.5	14.3	2.5	----	---
	1	1.6	70.6	29.6	21.5	14.4	2.5	27.65	---
10	2	1.4	69.8	29.8	21.6	12.8	2.5	27.00	2.45
	2	1.4	69.9	29.5	21.5	12.4	2.5	----	---
	2	1.4	70.6	29.5	21.6	12.8	2.5	----	---
	2	1.4	70.4	29.6	21.5	12.8	2.5	----	---
	2	1.4	70.6	29.6	21.6	12.8	2.5	----	---
	2	1.4	70.8	29.6	21.7	12.9	2.5	----	---
	2	1.5	70.7	29.8	21.7	12.9	2.5	23.50	---

Needle Valve, 1/2 turn open.
Air adjustment, 1.5 turn open.
Atmospheric pressure on differential manometer, 18.25 H_2O.

Running Log of Carbureter Tests.
Marvel - Model [illegible].

Run	Throttle Valve Opening.	Orifice Tank Vac. Pressure.	Orifice Tank Temp.	Pressure Drop Thru Carburetor.	Temp. Air at Carburetor.	Temp. of Vapor at Exit of Carburetor.	Vac. in Baffle Tank	Wt. of Fuel Used Gross	Residue Collected. Gross
No.	No.	"H_2O	°F	"H_2O	°C.	°C.	"Hg.	Lbs.	Lbs.
11	3	0.8	70.2	29.5	21.6	14.2	2.5	22.50	1.75
	3	0.8	69.9	29.6	21.4	13.9	2.5	----	---
	3	0.8	69.4	29.8	21.2	13.6	2.5	----	---
	3	0.7	69.3	29.4	21.1	13.5	2.5	----	----
	3	0.7	69.4	29.[illegible]	21.1	13.5	2.5	----	---
	3	0.8	69.3	29.8	21.0	13.4	2.5	----	---
	3	0.8	68.8	29.7	20.8	13.2	2.5	20.05	---
12	4	0.2	69.0	29.5	20.8	15.5	2.5	19.65	1.03
	4	0.2	69.4	29.0	20.5	15.5	2.5	----	---
	4	0.2	68.5	29.5	20.6	15.8	2.5	----	---
	4	0.2	68.8	29.5	20.7	16.0	2.5	----	---
	4	0.2	68.8	29.5	20.7	16.2	2.5	----	---
	4	0.2	68.8	29.6	20.7	16.2	2.5	----	---
	4	0.2	68.8	29.5	20.7	16.2	2.5	19.10	---

Running Log of Carburetor Tests.
Zenith - Model L5

Run	Throttle Valve Opening.	Orifice Tank Vac. Pressure.	Orifice Tank Temp.	Pressure Drop Thru Carburetor.	Temp. Air at Carburetor.	Temp. of Vapor at Exit of Carburetor.	Vac. in Baffle Tank	Wgt. of Fuel Used Gross	Residue Collected. Gross
No.	No.	"H_2O	°F.	"H_2O	°C.	°C.	"Hg.	Lbs.	Lbs.
13	1	2.8	83.9	29.8	28.9	17.7	3	27.00	3.60
	1	2.8	84.2	29.7	29.1	17.7	3	----	---
	1	2.8	84.2	29.9	29.1	17.7	3	----	---
	1	2.8	84.1	29.8	29.0	17.6	3	----	---
	1	2.8	84.0	29.8	29.1	17.6	3	----	---
	1	2.8	84.0	29.7	29.1	17.7	3	----	----
	1	2.9	84.2	30.0	29.2	19.8	3	20.15	---
14	2	2.1	84.0	29.5	29.0	18.6	3	25.00	2.00
	2	2.1	82.9	29.5	29.1	17.6	3	----	---
	2	2.0	84.0	29.5	29.0	17.5	3	----	---
	2	2.0	84.1	29.5	28.7	17.5	3	----	---
	2	2.0	83.3	29.5	28.6	17.3	3	----	---
	2	2.0	82.2	29.7	28.5	16.9	3	----	---
	2	2.0	82.1	29.8	28.3	16.9	3	19.20	---

Wgt. of fuel supply tank, 2.7"
Wgt. of residue container 0.8"
Low speed air adjustment, 1/8 turn open (Mect. Adj.)
Atmospheric pressure on differential manometer, 20 "H_2O

Running Log of Carbureter Tests.
Zenith - Model L5.

Run	Throttle Valve Opening.	Orifice Tank		Pressure Drop Thru Carbureter.	Temp. Air at Carbureter.	Temp. of Vapor at Exit of Carbureter.	Vac. in Baffle Tank	Wt. of Fuel Used	Residue Collected.
		Vac. Pressure.	Temp.					Gross	Gross
No.	No.	"H_2O	°F.	"H_2O	°C.	°C.	"Hg.	Lbs.	Lbs.
15	3	0.8	84.0	29.5	29.0	18.2	2.5	24.00	2.60
	3	0.8	84.2	29.5	29.1	17.9	2.5	----	---
	3	0.8	83.6	29.5	29.0	17.8	2.5	----	---
	3	0.8	83.2	29.5	28.7	17.6	2.5	----	---
	3	0.8	82.7	29.5	28.6	17.4	2.5	----	---
	3	0.8	82.8	29.7	28.5	17.4	2.5	----	---
	3	0.8	83.2	29.8	28.7	17.5	2.5	20.10	---
16	4	0.1	82.8	30.5	28.5	22.5	2.2	20.00	1.65
	4	0.1	82.7	30.5	28.5	18.6	2.2	----	---
	4	0.1	82.9	30.5	28.6	17.9	2.2	----	---
	4	0.1	82.8	30.5	28.7	17.7	2.2	----	---
	4	0.1	82.8	30.5	28.7	17.5	2.2	----	---
	4	0.1	82.7	30.5	28.5	17.4	2.2	----	---
	4	0.1	82.6	30.5	28.5	17.4	2.2	18.10	---

Running Log of Carbureter Tests.
Zenith - Model L5.

Run	Throttle Valve Opening.	Orifice Tank: Vac. Pressure	Orifice Tank: Temp.	Pressure Drop Thru Carburetor.	Temp. of Vapor at Outlet of Carburetor.	Temp. Air at Carburetor.	Vac. in Baffle Tank	Wgt. of Fuel Used Gross	Residue Collected. Gross
No.	No.	"H_2O	°F.	"H_2O	°C.	°C.	"Hg.	Lbs.	Lbs.
17	1	2.7	82.2	29.5	28.3	17.9	3	14.00	3.20
	1	2.7	82.2	29.5	28.3	17.3	3		
	1	2.8	82.5	29.7	28.4	17.5	3	----	---
	1	2.7	82.5	29.8	28.4	17.3	3	----	---
	1	2.8	82.5	29.2	28.3	17.2	3	----	---
	1	2.6	82.5	29.5	28.3	17.2	3	----	---
	1	2.6	82.6	29.7	28.5	17.4	3	16.45	---
18	2	2.1	82.5	29.5	28.3	17.5	3	15.50	3.20
	2	2.1	82.6	29.5	28.5	17.3	3		
	2	2.1	82.7	29.6	28.5	17.2	3	----	---
	2	2.1	82.8	29.6	28.5	17.[illegible]	3	----	---
	2	2.0	83.4	29.5	28.7	17.5	3	----	---
	2	2.0	83.[illegible]	29.5	28.7	17.5	3	----	---
	2	2.0	82.9	29.4	28.5	17.4	3	9.65	---

Slow speed adjustment, 5/8 turn open.

Running Log of Carbureter Tests.
Zenith - Model L5.

Run	Throttle Valve Opening.	Orifice Tank Vac. Pressure.	Orifice Tank Temp.	Pressure Drop Thru Carburetor.	Temp. Air at Carburetor.	Temp. of Vapor at Exit of Carburetor.	Vac. in Baffle Tank	Wgt. of Fuel Used Gross	Residue Collected. Gross
No.	No.	"H_2O	°F.	"H_2O	°C.	°C.	"Hg.	Lbs.	Lbs.
19	3	0.8	83.0	30.0	28.5	19.0	2.5	14.00	2.70
	3	0.8	82.6	29.8	28.4	17.9	2.5	----	---
	3	0.8	82.3	30.0	28.3	17.5	2.5	----	---
	3	0.8	82.0	29.7	28.2	17.5	2.5	----	---
	3	0.8	81.9	29.9	28.0	17.4	2.5	----	---
	3	0.8	81.6	30.0	27.9	17.3	2.5	----	---
	3	0.8	81.6	29.5	27.9	17.2	2.5	9.80	---
20	4	0.1	81.3	29.5	27.8	17.8	2.2	9.40	1.80
	4	0.1	81.2	29.5	27.7	17.3	2.2	----	---
	4	0.1	81.2	29.3	27.7	17.1	2.2	----	---
	4	0.1	81.2	29.7	27.7	17.0	2.2	----	---
	4	0.1	82.0	29.8	27.8	17.2	2.2	----	---
	4	0.1	82.6	29.8	28.0	17.4	2.2	----	---
	4	0.1	83.1	29.0	28.2	17.5	2.2	7.45	---

Running Log of Carbureter Tests.
Zenith - Model L5.

Run	Throttle Valve Opening.	Orifice Tank Vac. Pressure.	Orifice Tank Temp.	Pressure Drop Thru Carbureter.	Temp. Air at Carbureter.	Temp. Vapor at Exit of Carbureter.	Vac. in Baffle Tank	Wgt. of Fuel Used Gross	Residue Collected. Gross
No.	No.	"H_2O	°F.	"H_2O	°C.	°C.	"Hg.	Lbs.	Lbs.
21	1	2.75	75.0	29.3	23.6	16.8	3	22.00	8.55
	1	2.8	75.5	29.5	23.9	13.8	3	----	---
	1	2.8	75.8	29.5	24.2	13.8	3	----	---
	1	2.8	76.2	29.5	24.4	13.8	3	----	---
	1	2.8	76.5	29.5	24.6	14.0	3	----	---
	1	2.8	76.5	29.5	24.8	14.1	3	----	---
	1	2.8	76.8	29.2	24.9	14.[illegible]	3	10.25	---
22	2	2.2	77.2	30.0	25.2	14.6	3	18.40	3.30
	2	2.2	77.7	29.9	25.3	14.6	3	----	---
	2	2.2	77.8	29.8	25.4	14.5	3	----	---
	2	2.2	77.9	29.7	25.5	14.6	3	----	---
	2	2.2	78.2	29.7	25.6	14.7	3	----	---
	2	2.2	78.2	29.7	25.7	14.8	3	----	---
	2	2.2	77.8	29.7	25.8	14.8	3	12.55	---

Slow speed adjustment 2 turns open.
Atmospheric pressure on differential manometer, 19.4"H_2O.

Running Log of Carbureter Tests.

Zenith - Model L5.

Run	Throttle Valve Opening.	Orifice Tank Vac. Pressure.	Orifice Tank Temp.	Pressure Drop Thru Carburetor.	Temp. Air at Carburetor.	Temp. Vapor at Exit of Carburetor.	Vac. in Baffle Tank	Wt. of Fuel Used Gross	Residue Collected. Gross
No.	No.	"H_2O	°F.	"H_2O	°C.	°C.	Lbs.	Lbs.	Lbs.
23	3	1.0	78.2	29.5	25.9	16.0	2.5	16.50	2.50
	3	0.9	78.3	26.0	26.0	15.6	2.5	----	---
	3	0.9	78.5	26.0	26.0	15.4	2.5	----	---
	3	0.9	78.7	26.0	26.0	15.4	2.5	----	---
	3	0.8	78.8	26.0	26.1	15.4	2.5	----	---
	3	0.8	78.4	26.0	26.0	15.7	2.5	13.10	---
	3	--	---	---	---	--	--	----	---
24	4	0.1	78.9	29.5	26.1	16.0	2.2	12.50	2.45
	4	0.2	79.0	29.5	26.1	15.8	2.2	---	---
	4	0.1	79.0	29.5	26.3	15.8	2.2	---	---
	4	0.2	79.0	29.5	26.4	15.7	2.2	---	---
	4	0.1	79.2	29.6	26.3	15.7	2.2	----	---
	4	0.2	79.2	29.5	26.4	15.8	2.2	----	----
	4	0.1	79.2	29.5	26.4	15.8	2.2	10.55	---

Time of test for run number 3, sixteen minutes.

Tabulated Data and Results
Marvel - Model E.

Run	Throttle Valve Opening.	Orifice Tank Vac. Pressure	Orifice Tank Temp.	Pressure Drop Thru Carburetor.	Temp. Air at Carburetor.	Temp. Vapor at Exit of Carburetor.	Vac. in Baffle Tank	Wgt. of Fuel Used Net	Residue Collected. Net
No.	No.	"H_2O	°F.	"H_2O	°F.	°F.	"H_2O	Lbs.	Lbs.
5	1	1.59	65.7	21.0	65.6	49.4	36.2	5.9	3.4
6	2	1.43	64.8	22.3	65.0	47.2	40.7	6.7	3.9
7	3	0.85	65.9	22.5	66.2	51.8	32.5	3.3	1.9
8	4	0.20	65.9	22.5	66.2	54.6	27.1	3.0	0.8

Needle Valve 3/4 turn open
Air adjustment 1 1/2 turns open
Time of tests 18 minutes

9	1	1.6	70.5	22.6	70.2	57.5	33.9	2.6	1.78
10	2	1.4	70.4	23.0	70.7	55.0	33.9	3.7	1.73
11	3	0.77	69.5	22.6	70.1	56.5	34.0	2.5	1.03
12	4	0.2	68.7	22.5	69.3	60.6	33.9	0.6	0.31

Needle Valve 1/2 turn open
Air adjustment 1 1/2 turns open
Time of tests 18 minutes

Tabulated Data and Results
Marvel - Model T.

Run No.	Fuel Exhausted and lost Lbs.	Air used per min. cu.ft.	Fuel /100 cu. ft. air "	Fuel /100 cu. ft. air ozs.	Temp. Drop in Carburetor. °F	Fuel Vaporized %
5	2.5	66.0	.496	7.95	16.3	43.0
6	2.8	63.0	.595	9.50	18.8	40.0
7	1.4	48.0	.382	4.58	14.4	43.0
8	2.2	23.4	.713	1.14	11.6	72.0

Needle Valve ¾ turn open
Air adjustment 1 1/2 turns open
Time of tests 18 minutes

9	1.8	68.0	.208	3.33	12.7	69.0
10	1.9	63.0	.326	5.22	15.7	53.0
11	1.4	47.0	.290	4.64	13.6	58.0
12	0.3	23.4	.131	2.11	8.7	44.0

Needle Valve 1/2 turn open
Air adjustment 1 1/2 turns open
Time of test 18 minutes

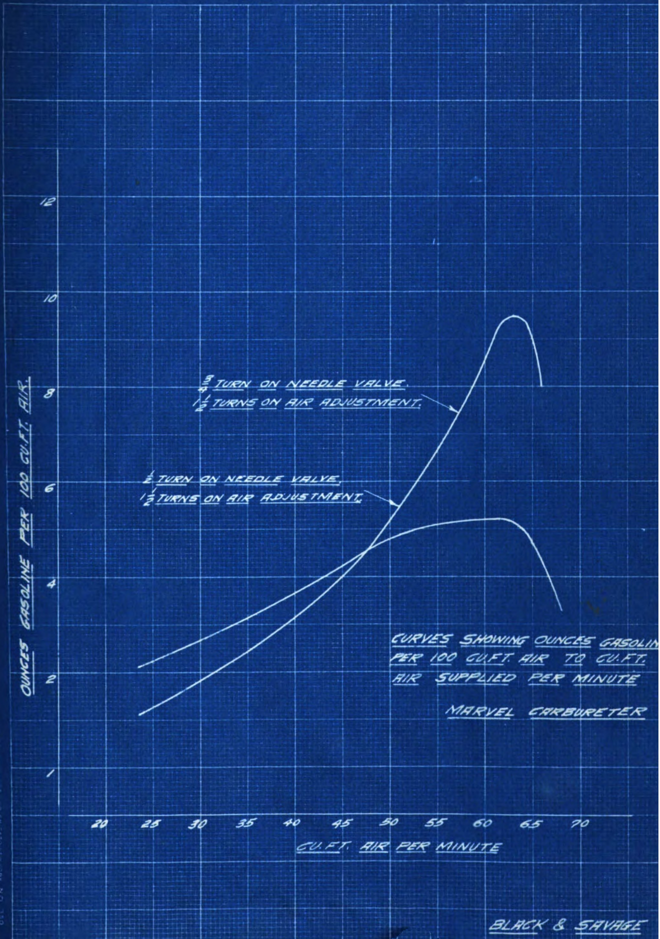
Tabulated Data and Results.
Zenith - L5

Run	Throttle Valve Opening.	Orifice Tank		Pressure Drop Thru Carburetor.	Temp. Air at Carburetor.	Temp. Vapor at Exit of Carburetor.	Vac. in Baffle Tank	Wt. of Fuel Used Net	Residue Collected. Net
		Vac. Pressure.	Temp.						
No.	No.	"H_2O	°F	"H_2O	°F.	°F	"H_2O	Lbs.	Lbs.
13	1	2.8	84.1	19.9	84.3	64.4	40.7	6.85	2.88
14	2	2.0	83.4	19.0	84.0	63.5	40.7	5.80	1.28
15	3	0.8	83.4	19.1	83.8	63.8	34.0	3.90	1.88
16	4	0.1	85.6	21.0	85.5	65.2	29.0	1.90	0.93
Slow Speed Adjustment 1/8 turn open									
17	1	2.7	82.5	19.0	83.1	62.5	40.5	7.55	2.40
18	2	1.1	82.9	19.0	83.3	63.3	40.7	5.85	2.43
19	3	0.8	82.1	19.5	82.9	63.0	34.0	4.20	1.90
20	5	0.1	81.8	19.5	82.0	63.5	29.0	1.90	1.00
Slow Speed Adjustment 5/8 turn open									
21	4	2.8	76.0	18.8	75.8	58.1	40.7	11.75	7.75
22	4	2.2	77.8	19.5	78.1	68.5	40.7	5.85	2.50
23	4	0.87	78.5	20.5	78.8	60.1	34.0	3.40	1.70
24	4	0.15	79.1	20.2	79.3	60.4	29.0	1.95	1.65

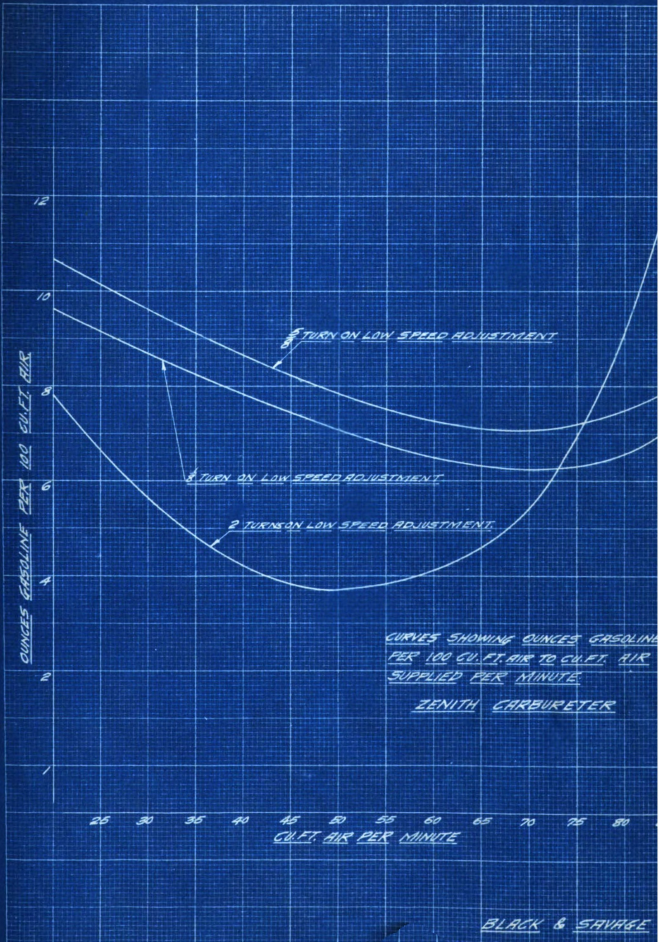
Slow Speed Adjustment 2 turns open

Tabulated Data and Results
Zenith Model - L5.

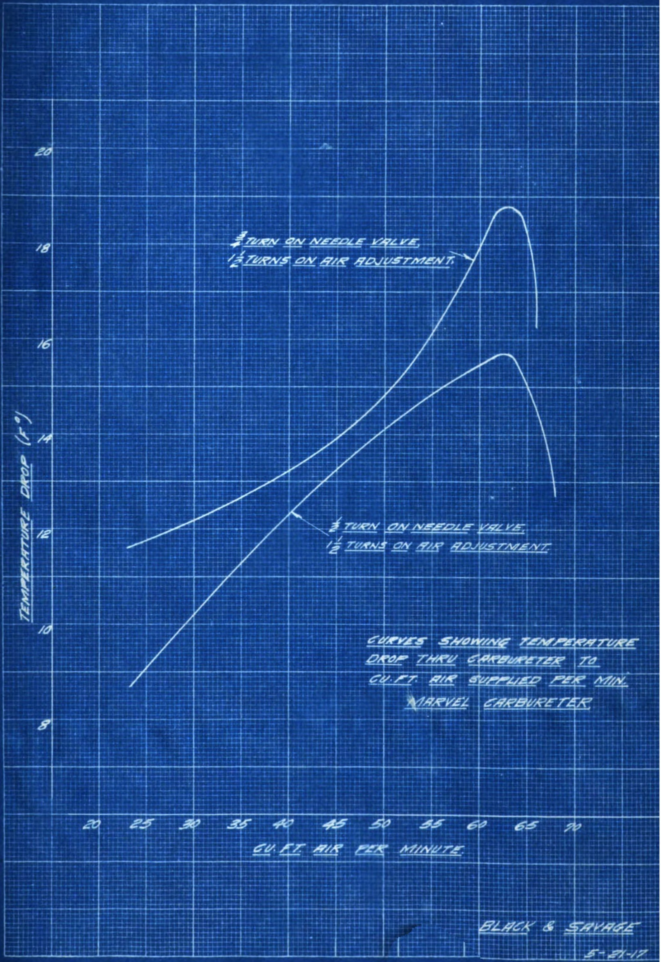
Run No.	Fuel Exhausted. and lost Lbs.	Air used per min. cu.ft.	Fuel /100 cu. ft. air #	Fuel /100 cu. ft. air ozs.	Temp. Drop in Carburetor. °F.	Fuel Vaporized. %
13	3.97	85.0	.448	7.17	19.9	58.0
14	4.52	75.0	.388	6.20	20.5	78.0
15	2.02	47.0	.460	7.37	20.0	52.0
16	0.97	17.1	.617	9.88	17.3	51.0
Slow Speed Adjustment 1/8 turn						
17	5.15	85.0	.495	7.92	20.6	68.0
18	3.42	73.0	.445	7.12	20.0	59.0
19	2.30	47.0	.507	8.12	19.9	55.0
20	0.95	17.1	.665	10.60	18.7	49.0
Slow Speed Adjustment 5/8 turn open						
21	4.00	85.0	.768	12.30	17.7	54.0
22	3.35	75.0	.433	6.93	19.6	57.0
23	1.70	49.0	.231	3.71	18.7	50.0
24	0.30	16.3	.541	8.76	18.4	15.0
Slow Speed Adjustment [illegible] turns open						



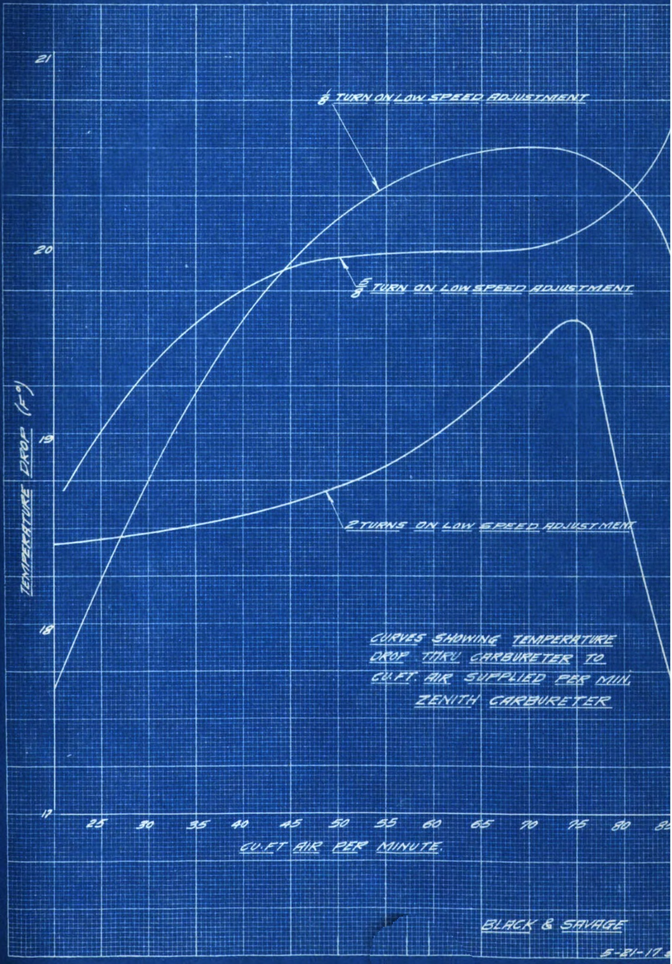
12
10
8
6
4
2
1
OUNCES GASOLINE PER 100 CU.FT. AIR.
3/4 TURN ON NEEDLE VALVE.
1 1/2 TURNS ON AIR ADJUSTMENT.
1/2 TURN ON NEEDLE VALVE.
1 1/2 TURNS ON AIR ADJUSTMENT.
CURVES SHOWING OUNCES GASOLIN
PER 100 CU.FT. AIR TO CU.FT.
AIR SUPPLIED PER MINUTE
MARVEL CARBURETER
20 25 30 35 40 45 50 55 60 65 70
CU.FT. AIR PER MINUTE
BLACK & SAVAGE



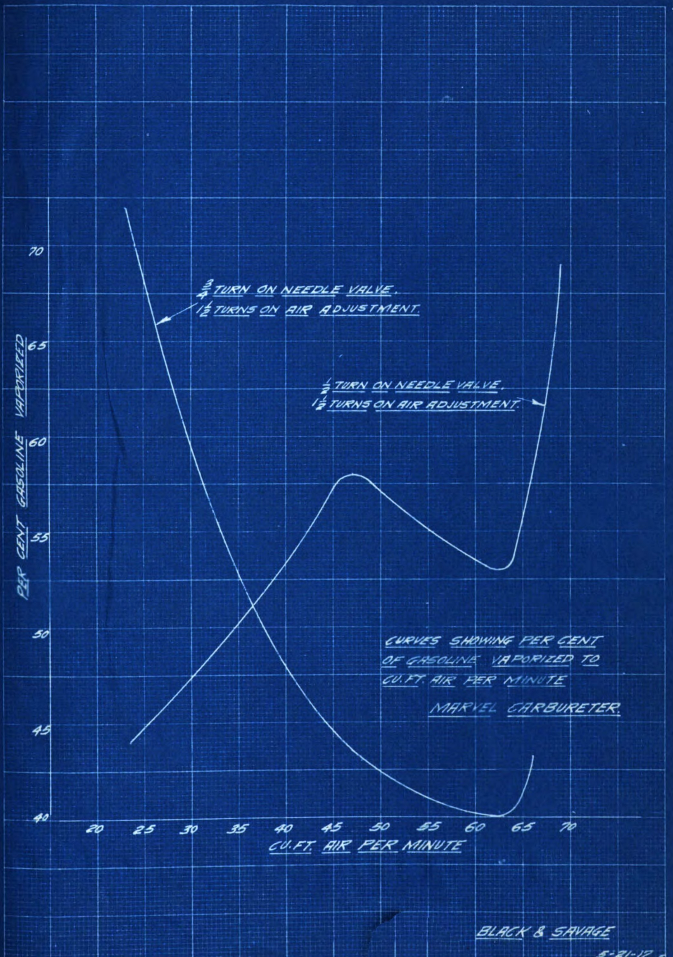
12
10
8
6
4
2
1
OUNCES GASOLINE PER 100 CU. FT. AIR
5/8 TURN ON LOW SPEED ADJUSTMENT
1/8 TURN ON LOW SPEED ADJUSTMENT
2 TURNS ON LOW SPEED ADJUSTMENT.
CURVES SHOWING OUNCES GASOLINE
PER 100 CU. FT. AIR TO CU. FT. AIR
SUPPLIED PER MINUTE.
ZENITH CARBURETER
25 30 35 40 45 50 55 60 65 70 75 80
CU. FT. AIR PER MINUTE
BLACK & SAVAGE



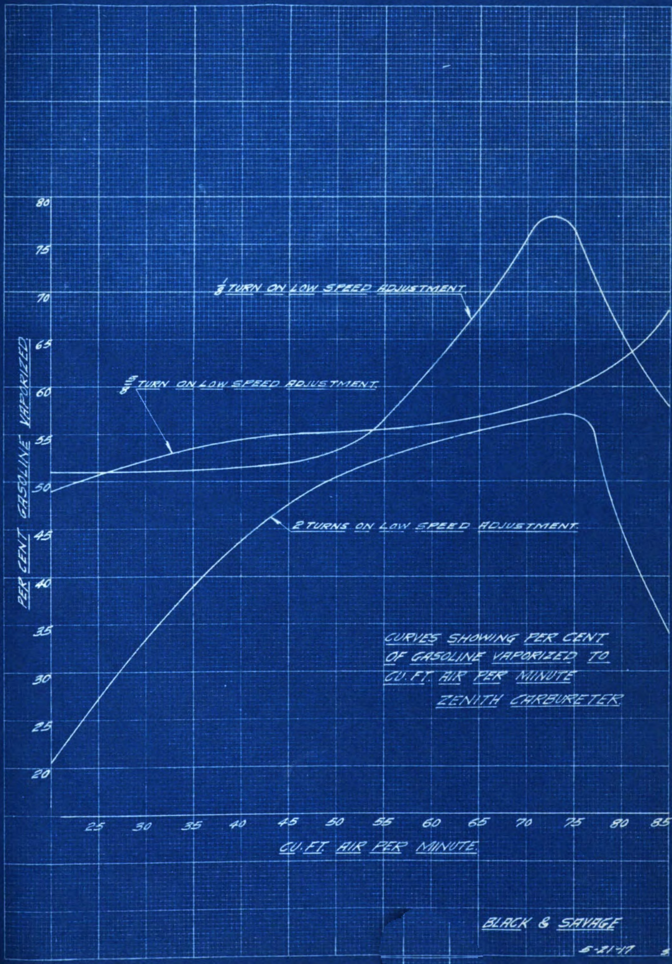
20
18
16
14
12
10
8
TEMPERATURE DROP (F°)
3/4 TURN ON NEEDLE VALVE.
1 1/2 TURNS ON AIR ADJUSTMENT.
1/2 TURN ON NEEDLE VALVE.
1 1/2 TURNS ON AIR ADJUSTMENT.
CURVES SHOWING TEMPERATURE
DROP THRU CARBURETER TO
CU. FT. AIR SUPPLIED PER MIN.
MARVEL CARBURETER.
20 25 30 35 40 45 50 55 60 65 70
CU. FT. AIR PER MINUTE.
BLACK & SAVAGE
5-21-17



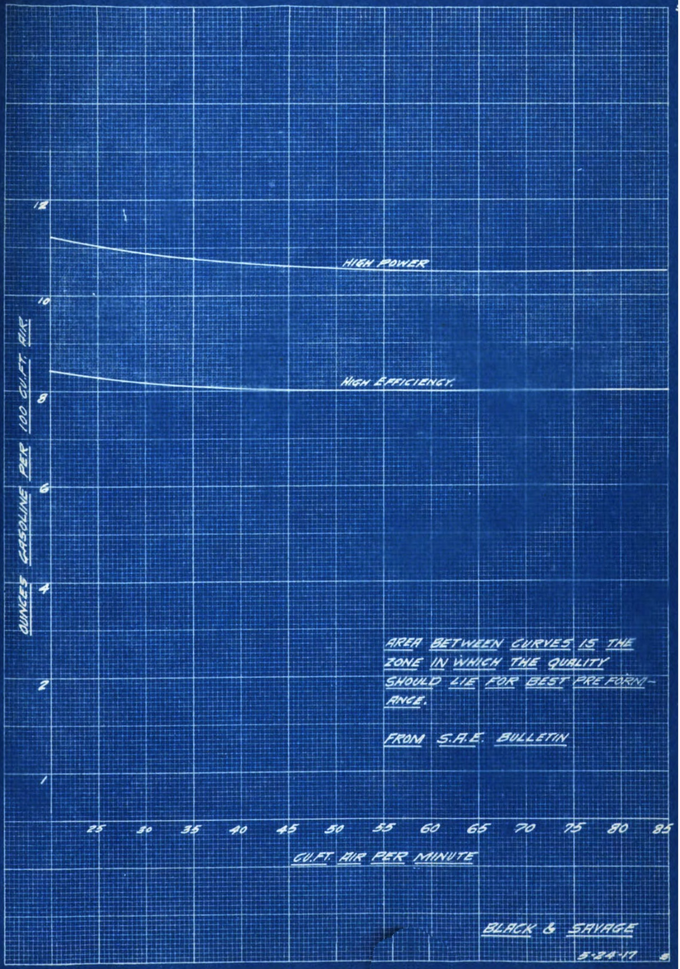
1/8 TURN ON LOW SPEED ADJUSTMENT
5/8 TURN ON LOW SPEED ADJUSTMENT
2 TURNS ON LOW SPEED ADJUSTMENT
TEMPERATURE DROP (F°)
21
20
19
18
17
25 30 35 40 45 50 55 60 65 70 75 80
CU. FT AIR PER MINUTE.
CURVES SHOWING TEMPERATURE DROP THRU CARBURETER TO CU.FT. AIR SUPPLIED PER MIN.
ZENITH CARBURETER
BLACK & SAVAGE



3/4 TURN ON NEEDLE VALVE.
1 1/2 TURNS ON AIR ADJUSTMENT.
1/2 TURN ON NEEDLE VALVE.
1 1/2 TURNS ON AIR ADJUSTMENT.
PER CENT GASOLINE VAPORIZED
70
65
60
55
50
45
40
20
25
30
35
40
45
50
55
60
65
70
CU. FT. AIR PER MINUTE
CURVES SHOWING PER CENT
OF GASOLINE VAPORIZED TO
CU. FT. AIR PER MINUTE
MARVEL CARBURETER.
BLACK & SAVAGE
5-21-17



PER CENT GASOLINE VAPORIZED
80
75
70
65
60
55
50
45
40
35
30
25
20
1/8 TURN ON LOW SPEED ADJUSTMENT
5/8 TURN ON LOW SPEED ADJUSTMENT
2 TURNS ON LOW SPEED ADJUSTMENT
CURVES SHOWING PER CENT
OF GASOLINE VAPORIZED TO
CU. FT. AIR PER MINUTE
ZENITH CARBURETER
25
30
35
40
45
50
55
60
65
70
75
80
85
CU. FT. AIR PER MINUTE
BLACK & SAVAGE
5-21-17



HIGH POWER
HIGH EFFICIENCY.
OUNCES GASOLINE PER 100 CU.FT. AIR.
12
10
8
6
4
2
1
25
30
35
40
45
50
55
60
65
70
75
80
85
CU.FT. AIR PER MINUTE
AREA BETWEEN CURVES IS THE ZONE IN WHICH THE QUALITY SHOULD LIE FOR BEST PREFORM-ANCE.
FROM S.A.E. BULLETIN
BLACK & SAVAGE
5-24-17