BUNTING & DOLE

Comparative Test of Alcohol, Gasoline, and Kerosene in a Meitz and Weiss Oil Engine

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED Comparative Test of Alcohol, Gasoline, and Kerosene in a Meitz and Weiss Oil Engine

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

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Instructor in Charge.

APPROVED: G. A. Goodenough

HEAD OF DEPARTMENT OF Mechanical Engineering

CONTENTS.

COMPARATIVE TEST OF MEITZ & WEISS OIL ENGINE ON ALCOHOL, GASOLINE AND KEROSINE.

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INTRODUCTION .

In Europe during the last ten years the high price of petroleum oils used as fuel in internal-combustion engines has led to extended efforts to find other suitable economical fuels. Among these, alcohol has received much attention, and a number of engines especially designed for this fuel have been manufactured and used in Germany.

Recently a widespread interest has developed in this country concerning the possibilities of alcohol as fuel . This matter is important to the users of small and medium sized power units, because alcohol is manufactured from various products of the soil, and therefore has a source of supply that is practically inexhaustible.

The question of a possible substitute for the petroleum fuels will become of increasing importance as time goes on. The supply of crude oil to be obtained in the U.S. must ultimately diminish and the history of the past indicates that a constant increase in price of kerosene and gasolene may be expected. On the other hand it is not unreasonable to hope that with improvements in manufacture or methods of denaturizing, the cost of alcohol may fall in regard to cost. Alcohol may occupy a position of constantly increasing advantage in comparison with the petroleum oils.

OBJECT OF THE INVESTIGATION.

The object of this investigation may be put under two heads:

I.- To determine whether the Meitz and Weiss kerosene and oil engine is better adapted to the use of alcohol, gasolene, or kerosene as fuel. This involved the determination of the processes necessary to make the engine run on alcohol and gasolene, also the measurement of the relative power developed by the engine while using these fuels, as compared with the power developed while using the fuel for which it was designed, and the relative consumption of the different fuels per brake horse power.

2.- To determine so far as the limited time and data permit the relative cost of operating this engine on the different fuels at full, three fourths, and one half load.

PROPERTIES OF FUELS USED.

Since all liguid fuels available for commercial use are complicated mixtures of many different chemical substances, they are always liable to vary in their composition, and accordingly in their properties.

Gasolene and kerosene are most easily examined by their specific gravities, but since each is a mixture of numerous lighter and heavier oils, a definite constant density is not a guarantee, that the composition of the same grade of oil may not vary sufficiently to effect the action of the fuel in the engine.

Commercially pure grain or ethyl alcohol is

sensibly pure except for the water that may be mixed with it. In this country alcohol is classified according to its strength by stating the percentage of absolutely pure alcohol, by volume, which exists in the mixture of alcohol and water. Thus 90 % alcohol means that 90 % by volume of the mixture is alcohol and the rest water. Since the volume of alcohol and water contracts on mixing, the volume of the water alone would be more than 10 % of the volume of the mixture. Since lighter than water, the stronger the alcohol is, the smaller its specific gravity would be, and 90 % alcohol contains less than 90 % alcohol by weight.

In France as in this country, alcohol is classified as to strength by the percentage by volume, in Germany by the percentage by weight. This fact should be noted in comparing results in the two countries.

In statistics relating to alcohol, issued by the U.S. Commissioner of Internal Revenue, quantities are stated in "proof" gallons. A"proof" gallon contains 50 % alcohol by volume, the remainder of the mixture being water; hence, a quantity of alcohol when stated in "proof" gallons is expressed by a number just twice as large as it would be stated in gallons of 100 % alcohol.

According to the regulations of the Commissioner of Internal Revenue, denatured alcohol may be prepared as follows,- To 100 volumes of ethyl or grain alcohol of a strength not less than 90 % there must be added either 10 volumes of mwthyl or wood alcohol, and ½ of 1 volume of benzine or 2 volumes of methyl alcohol and ½ of one volume of pyridin bases. The substances added to the grain alcohol will probably not be of uniform quantity, hence there will be some variability

in the properties of the denatured alcohol which will affect its use as fuel. The following figures are fair averages or approximate values and serve to show the relative values of the different fuels:

Relative Weight of Different Fuels.

Substance.	Specific Gr.	Lbs. per gal.
Gasolene	0.71	5.9
Kerosene	0.80	6.7
95 % ethyl alcohol	0.82	6.8
90 % ethyl alcohol	0.83	6.9

The two most important properties of a liquid fuel which determine its availability or adaptability for use in an engine are its heat of combustion and its volatility.

HEAT OF COMBUSTION.

The heat of combustion of fuels is determined experimentally by burning a known weight of fuel in a calorimeter and measuring the number of British thermal units absorbed by a known quantity of water surrounding the calorimeter.

The heat of combustion of the various petroleum oils varies between 19,000 and 21,000 B.T.U. per pound and 20,000 is often used as an average. The experimental value for pure alcohol is about 12,700 B.T.U. per pound.

All liquid fuel contains a considerable proportion of hydrogen, which when burned forms water. When the fuel is burned in a calorimeter the steam formed is condensed by the cold water

surrounding the calorimeter and contributes a considerable amount of heat to the total amount absorbed by the cold water. When a fuel is burned in an internal-combustion engine, the products of combustion always leave the engine cylinder at a temperature much above the boiling point of water; hence the engine is unable to make use of the latent heat of condensation of the steam formed, although this latent heat is included in that measured by the calorimeter. On this account it is customary in comparing fuels used in explosion engines to calculate what is known as the low heating value of the fuel, that is the heat of combustion as measured in the calorimeter minus the heat added due to the condensing of the steam formed by combustion of the hydrogen and the hydro-carbons present in the fuel. The amount of hydrogen in the fuel determines the amount of water that will be formed on combustion. As the gases leave the cylinder at a temperature far above that at which this latent heat of steam is available the engine should not be charged up with it in the thermal efficiency. This low heating value may be calculated when an ultimate analysis of the fuel is obtainable and is used in practice to get the true thermal efficiency.

DESCRIPTION OF APPARATUS.

The apparatus consisted of a standard 12 H.P. Mietz & Weiss kerosene engine, equipped with fuel weighing, water measuring , and power absorbing apparatus. The data below gives the details of the engine.

ENGINE DATA .

I.-	Name of engine	MEITZ & WEISS
2.-	Manufactured by	August Meitz, Iron, Foundry and Machine Works, I28-I38 Mott st.,N.Y.
3,-	Number of cycles	Two
4.-	Kind of Fuel	Alcohol, Gasoline, Kerosene.
5.-	Heat of Combustion	Alcohol , I00II B.T.U. per lb. Gasoline , I8,940 B.T.U. per lb. Kerosene , I9,I00 B.T.U. per lb.
6.-	Rated Horse Power	I2 H.P.
7.-	Floor space occupied	4' - 4" x 6' - 4"
8.-	Number of cylinders	One
9.-	Bore of Cylinder	9"
I0.-	Stroke of piston	I0"
II.-	Volume of cylinder	756.67 cu. in.
I2.-	Clearance	I20.5 cu. in.
I3.-	Diameter of fly wheels	4' - 4"
I4.-	Rated Revolutions per Minute	350 rev. per min.
I5.-	Kind of governing	Variable stroke fuel pump, controlled by shaft governor.
I6.-	Kind of ignition	Hot Bulb.
I7.-	Cooling	Water cooled, steam injected into cylinder.
I8.-	Approximate Weight	3900 lbs.

The engine used in these tests was a I2 H.P. Meitz and Weiss oil engine. It was a single cylinder horizontal engine of the two cycle type with hot bulb ignition. The fuel was injected into the cylinder, on compression by means of a plunger pump, the stroke of which was controlled by the fly wheel governor, thus controlling the revolutions per minute of the engine. When the Rev. per min. became greater than the normal rating the stroke of the pump was shortened, less fuel was injected into the cylinder, and the force of the explosion was proportionately less.

The engine is cooled by means of a water jacket. The heat of combustion generates steam in this jacket which is collected in the steam dome, shown in the photograph. From there it goes into the cylinder through a port which opens just after the air port and closes just ahead of it as can be seen by referring to sketch shown.

The weight of water used by the engine was measured by means of a cast iron cylinder having a gage glass,graduated in lbs.

The cylinder, wrist pin and crank pin bearings are oiled by means of a suction oiler at the side of the cylinder.

The fuel container was placed on a platform scale and was connected to the fuel pump by means of a flexible rubber tube. By means of the platform scale the exact weight of fuel used on each test was measured. The load was applied by means of a Prong brake and the power develcped by the engine measured by means of a platform scale at the end of the arm on the brake. The brake and the scales can be seen in the photograph on p.

Two indicators were used, one a Crosby gas engine

indicator with a piston of one fourth sq. in. area. A I20 lb. spring was used in this indicator thus giving 240 lb. as the scale of this spring. This indicator was used to take indicator cards of the pressure in the cylinder. The other indicator was a Thompson steam engine indicator using a ten lb. spring. This was used to obtain a card of the pressures in the crank case.

Compression plates were fastened to the cylinder head during the alcohol tests as alcohol requires a very much higher compression than gasoline and kerosene.

The hot bulb was originally heated by means of a small blast lamp operated on gasolene, but as this did not prove very effective, a bunsen burner arrangement was used. The hot bulb was enclosed by a cast iron plate bolted onto the cylinder head. In this plate was a shutter which could be closed when the bulb was heated so as to keep the heat in and the bulb would remain hot while the engine was running. By this means all cost of ignition was eliminated as soon as the engine was once started.

The cylinder head was removable, being bolted directly to cylinder by stud bolts and thereby closing off the end of the water jacket. No little trouble was encountered with the gasket between cylinder and head leaking, when using the high compression required by alcohol. But after much time and experimenting it was found that a gasket made of paper and shellaced proved to be the best combination and held very well.

METHOD OF CONDUCTING TESTS.

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In conducting these tests it is imperative that certain data be obtained. Both the brake horse power and the indicated horse power must be known; the amount of fuel, its cost heating power, and ultimate analysis; also the temperature of the exhaust and the temperature and quantity of water delivered to water jacket were taken.

The brake horse power was measured by means of a friction brake on a pully attached to the fly wheel; the indicated horse power was obtained from indicator cards taken on a gas engine indicator; the amount of fuel was obtained by weighing the fuel at start and end of run; and the heating value and ultimate analysis were obtained by chemical analysis.

Many things were tried in an attempt to make the engine operate on alcohol, in fact, it seemed for a while that it would be impossible to make the engine operate at all on full load. At times the engine would be working satisfactorily when for no apparent reason it would commence slowing down and stop if left to itself. This slowing down was accompanied by knocking in the cylinder. Sometimes if the load were removed it would pick up again and sometimes nothing apparently could be done to keep it going. The cause of this stopping was not discovered definitely but was possibly due to water in the fuel which caused it to miss firing, or dirt which clogged the valves leading to or from the injection pump and caused miss firing, or the cylinder became too hot so that the piston stuck in the cylinder. In all cases with alcohol the steam injection was left connected so that steam entered the cylinder.

In the $\frac{3}{4}$ load and $\frac{1}{2}$ load tests on alcohol there was not nearly so much trouble encountered and they were disposed of very satisfactorily.

In the case of gasolene not nearly so much trouble was encountered, possibly due to the fact that the high compression required by the alcohol was not needed and the normal compression of about 98 lb. was used. When using the gasolene and kerosene as fuel the engine was found to operate very much better by disconnecting the steam dome and allowing a large amount of cooling water to flow around the cylinder, but not allowing any to enter the cylinder in the form of steam as before. There was no knocking when running on these fuels and there was no tendency to stop as when running on alcohol.

During the many experiments to discover what was the cause of the stopping so unexpectedly it was found that the fuel injection came rather late, in fact, so late that instead of occurring when the piston was nearly on head end center and the air compressed, it was injected before the exhaust was closed so that most of the charge or explosive force of the mixture was lost out of the exhaust and went into the muffler instead of doing work in the cylinder. The time of explosion of the fuel was made to occur earlier by means of a variable extention put on the pump plunger. This extention was adjusted while the engine was running and was placed at the point which seemed to give the best running conditions without any pre-ignition or muffler explosions. It consisted of a sleeve put on over the end of the plunger having set screws in it which held it in place.

Then also the cards taken during these periods of knocking just as the engine was slowing down, seemed to indicate pre-ignition, some of the charges would explode very heavily while others would not explode at all.

A large part of the time was spent experimenting to find the reasons why the engine would not run, in fact, more time was spent this way than was required for the actual running of the tests. A large number of indicator cards of varying slopes and sizes were obtained, some of which are of very irregular outline. This is possibly due to the inertia of the pencil mechanism of the indicator and the excessively high pressures developed by the explosion of part of the previous charges that did not ignite, due also to the fact that mixture varies in 2 cycle engines. Muffler explosions were very common.

When running, one man kept the load constant. It was also this man's duty to take the indicator cards and the r.p.m. of the engine. The other man took readings of the exhaust temperature, fuel used and removed the indicator cards after they were taken by the first man. The second man acted also as recorder making a record of all the data taken on duplicate carbon copy and preserving the indicator cards.

No trouble was encountered in keeping the bulb hot when running on alcohol, in fact, it became so hot that the shutter was left constantly open, while with gasolene and kerosene it was usually left closed so as to keep it red hot.

METHOD OF CALCULATING RESULTS.

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In calculating the results the indicator cards from both the cylinder and the crank case were integrated and their mean effective pressures obtained. The m. e. p. of the crank case being substracted from that of the cylinder. The true scale of the spring was found by calibrating cold, finding the correct scale when cold by plotting the values so obtained and then subtracting 6 % from this value as a correction for the temperature at which it was working when the engine was running. This cold calibration was assumed to be the correct scale of the spring at that temperature and the 6 % correction factor was obtained from data from previous experiments. The indicator base power was obtained from the formula,

$$I.H.P. = \frac{PLAN}{33,000}$$, and the brake Horse power from formula,

$$B.H.P. = \frac{2\pi R N W}{33,000}$$, where P = m.e.p. in lbs. per sq. in.,

L = stroke in feet, A = area in sq. in., N = r.p.m., and W.= wt. on brake scales, R = rev. per min.

Mechanical efficiency calculated from the formula, mech. eff. = $\frac{B.H.P.}{I.H.P.}$. Thermal efficiency from the total quantity of heat supplied to engine from fuel used divided by the heat obtained as work, based on low heat value.

CONCLUSION.

It would seem from data obtained and curves plotted that for economical operation as regards fuel consumption and cost of fuel that alcohol at the present price could not compete successfully with either gasolene or kerosene. However the mechanical efficiency of the alcohol was about 20 % greater than that of kerosene, while gasolene was even higher than the alcohol.

There is no doubt with an engine designed especially for alcohol and with a lower cost of the fuel itself, but what alcohol could compete successfully with either gasolene or kerosene.

As very nearly the same value of the I.h.p. at $\frac{3}{4}$ and $\frac{1}{2}$ load were obtained, it would seem to indicate that not every charge of oil was exploded at $\frac{1}{2}$ load, or that oil was not injected at every revolution. As there was no absolutely accurate way of determining this it was assumed that an explosion accurred at each revolution.

Table # 1 Alcohol.

12 H.P. Mietz & Weiss Oil Engine

Length of Run min.	R.P.M.	M.E.P. in cylinder	M.E.P. in Crnkcase	M.E.P. net.	I.h.p.	B.h.p.	Temp. of Exh.	Wt. lbs of Fuel per B.h.p. hr	cents Cost of Fuel per B.h.p. hr	Mech. Eff.	Therm. Eff.
90	333	29.60	1.78	27.82	14.9	10.11	449	1.97	.142	68.0	13.3
60	339	24.00	1.64	22.36	12.17	7.72	439	2.35	.169	63.5	10.8
60	343	23.25	1.66	21.59	11.9	5.21	412	3.09	.225	43.8	6.6

Analysis.

Specific Gravity @ 20° C. .8179 Heating Value. 10,865

Carbon. 38.8 % Net Heating Value. 10,011

Hydrogen. 8.4 % Oxygen. 42.8%

Water 10.0 %

Cost of Fuel per gallon 49 cents.

Table #2 Gasolene.

12 H.P. Mietz & Weiss Oil Engine.

Length of Run min.	R.P.M.	M.E.P. in Cylinder	M.E.P. in Cr'nkcase	M.E.P. net.	I.h.p.	B.h.p	Temp. of Exh.	Wt. of Fuel (lb.) per Bh.p.hr	Cost of Fuel per Bh.p.hr. (cts.)	Mech Eff.	Therm. Eff.
67	346	25.25	1.73	23.52	13.09	10.51	573	1.14	.019	80.5	11.8
60	348	21.05	1.68	19.37	10.82	7.92	528	1.07	.018	73.2	12.6
60	348	21.05	1.72	19.33	10.81	5.28	472	1.31	.022	48.9	10.3

Analysis.

Specific Gravity @ 20°C.	.730	Heating Value.	20,183
Carbon	85.5 %	Net Heating Value.	18,940
Hydrogen.	12.5 %	H_2O, O, & N	2.0 %

Cost of Fuel per gallon 10½ cents.

Table # 3 Kerosene.

12 H.P. Mietz & Weiss Oil Engine.

Length of Run min.	R.P.M.	M.E.P. in Cylinder	M.E.P. in Crnkcase	M.E.P. net.	I.h.p.	B.h.p.	Temp. of Exh.	Wt. lb of Fuel per Bhp.hr	cts. Cost of Fuel per B.h.p. hr.	Mech. Eff.	Therm. Eff.
60	349	31.35	1.69	29.66	16.67	10.60	507	.872	.0097	63.8	15.3
60	349	28.42	1.76	26.66	15.00	7.96	457	1.020	.0113	53.1	13.1
60	351	28.00	1.82	26.18	14.75	5.34	403	1.290	.0143	36.2	10.3

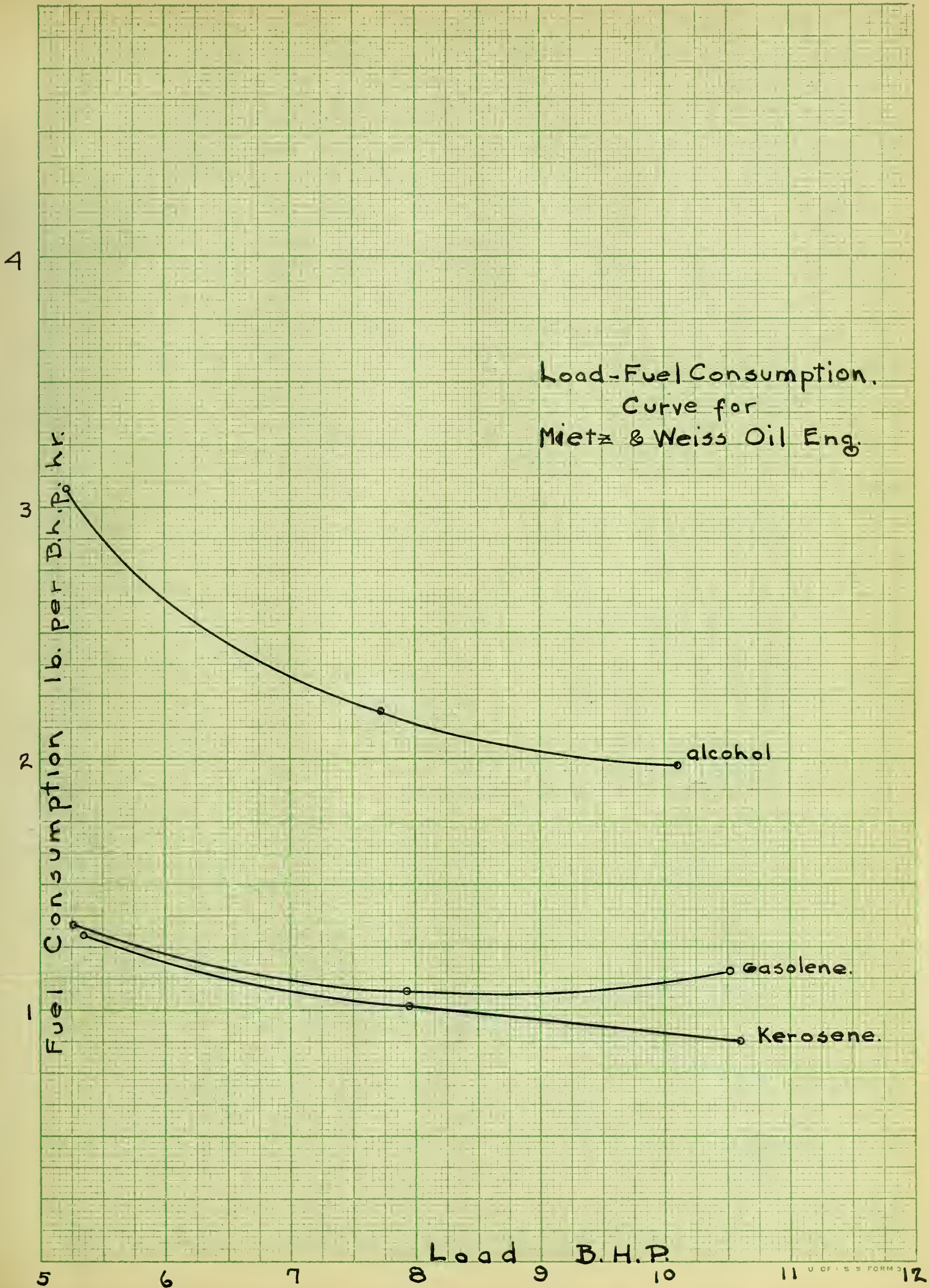
Analysis

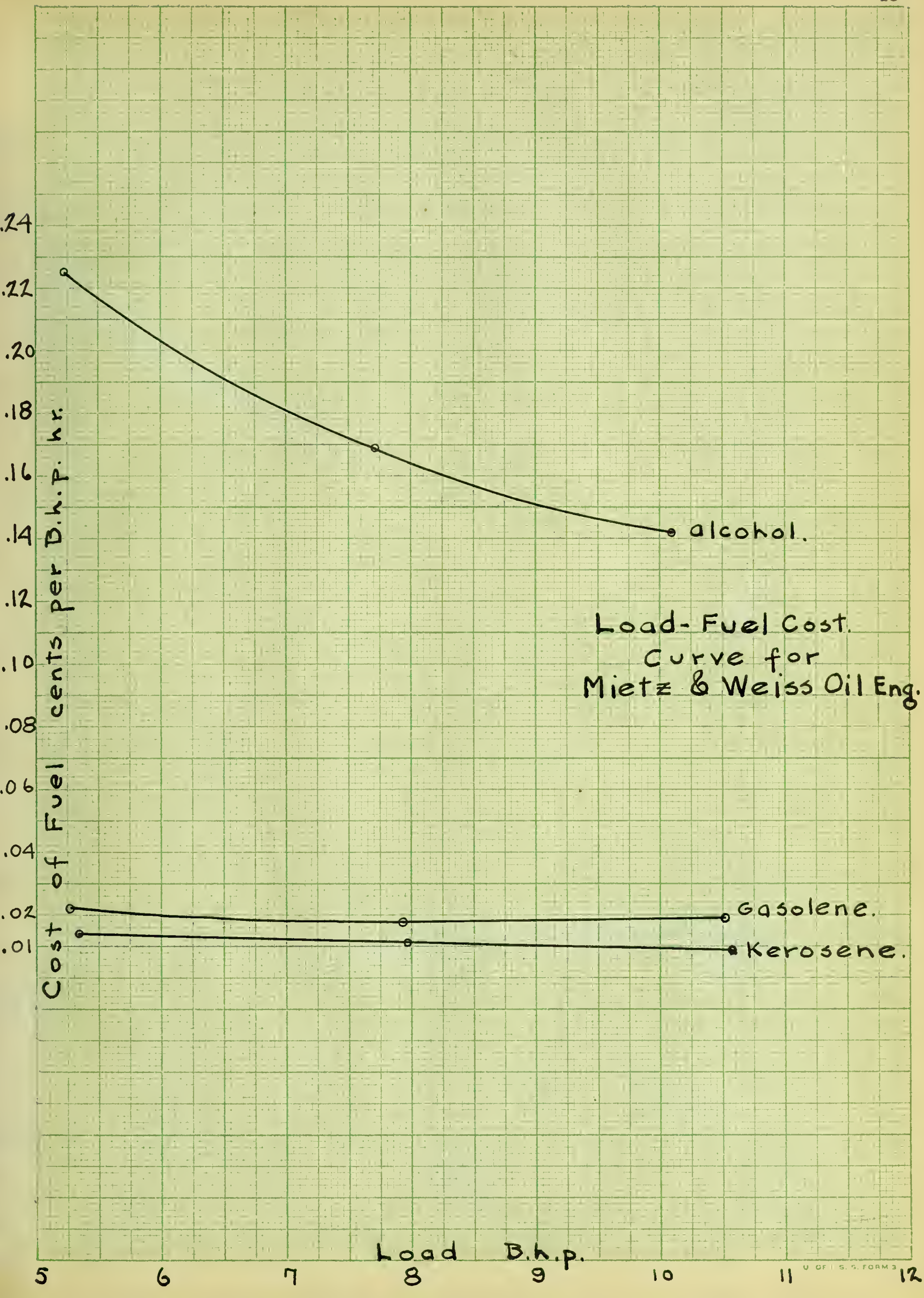
Specific Gravity @ 20°C. .8108 — Heating Value. 19,100

Carbon. - Ultimate analysis not made. — Net Heating Value. - assumed same as high value

Hydrogen. - — H_2O, O, & N

Cost of Fuel per gallon 7½ cents.


Load-Fuel Consumption.
Curve for
Mietz & Weiss Oil Eng.
Fuel Consumption lb. per B.H.P. hr.
Load B.H.P.
alcohol
Gasolene.
Kerosene.
4
3
2
1
5
6
7
8
9
10
11
12


Load-Fuel Cost.
Curve for
Mietz & Weiss Oil Eng.
alcohol.
Gasolene.
Kerosene.
Cost of Fuel cents per B.h.p. hr.
Load B.h.p.
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
.01
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6
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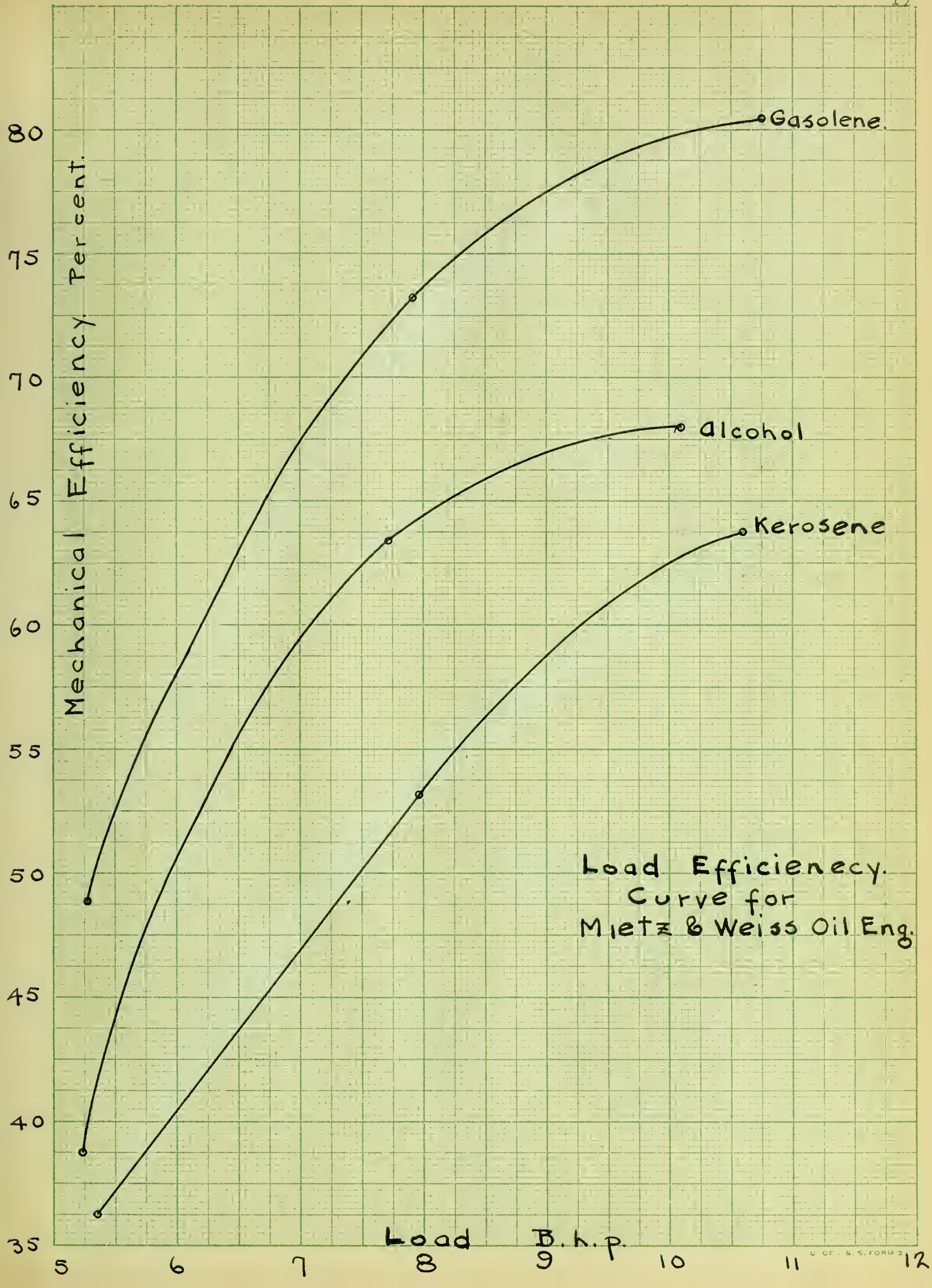
12


Gasolene.
Alcohol
Kerosene
Mechanical Efficiency Per cent.
Load B.h.p.
Load Efficienecy.
Curve for
Mietz & Weiss Oil Eng.
80
75
70
65
60
55
50
45
40
35
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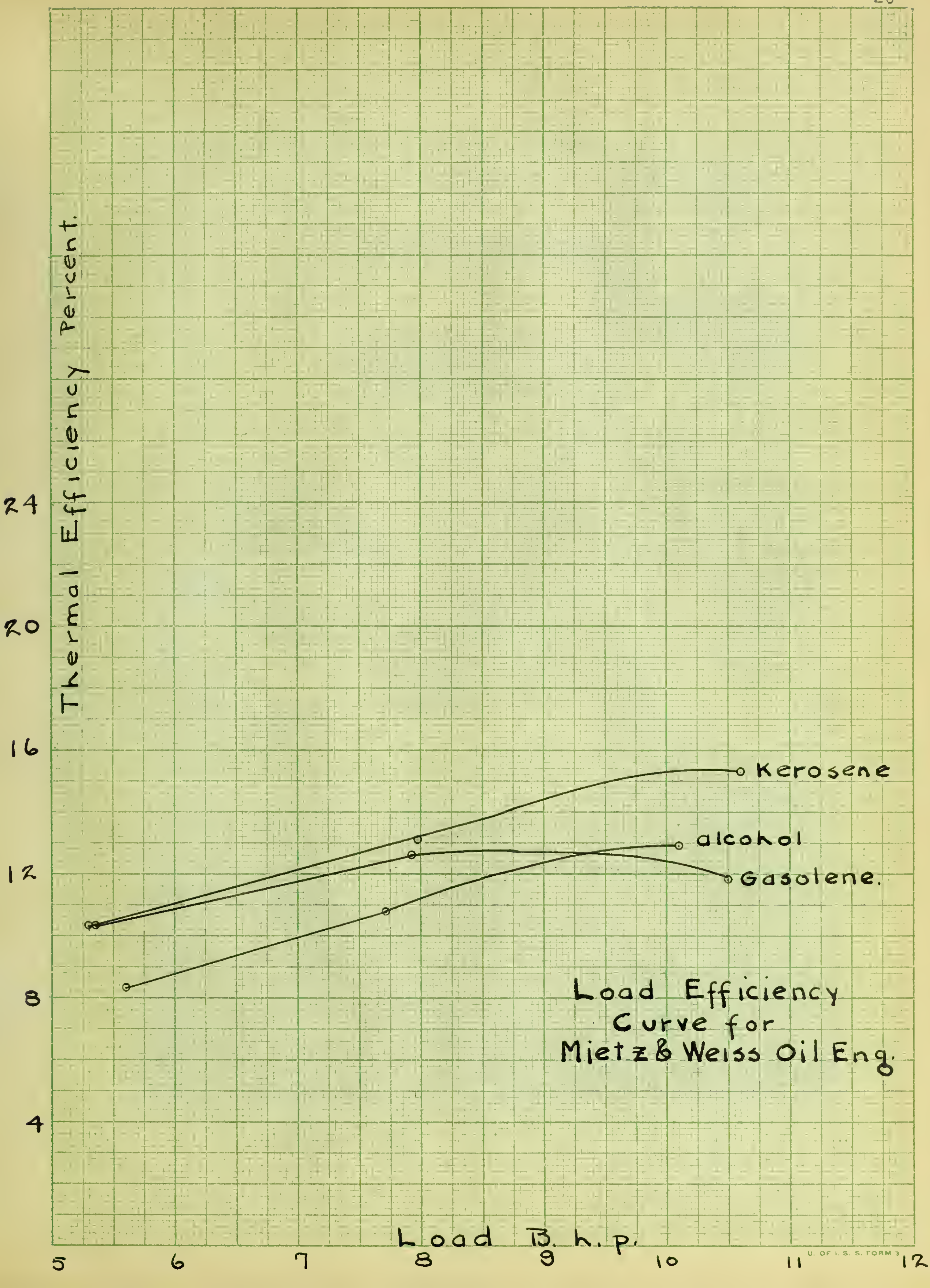
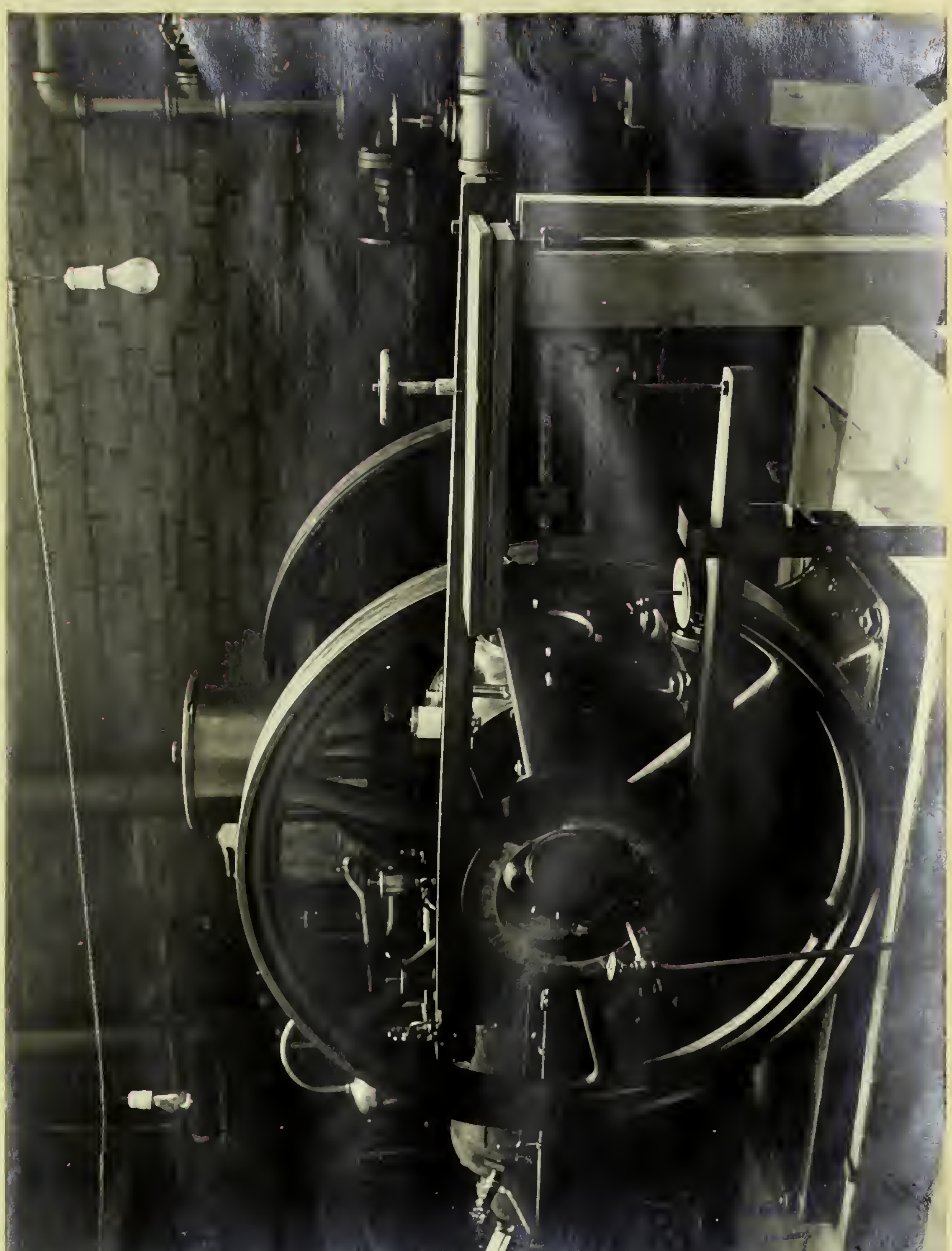
12


Thermal Efficiency Percent.
24
20
16
12
8
4
Kerosene
alcohol
Gasolene.
Load Efficiency
Curve for
Mietz & Weiss Oil Eng.
Load B. h. p.
5
6
7
8
9
10
11
12
U. OF I. S. S. FORM 3



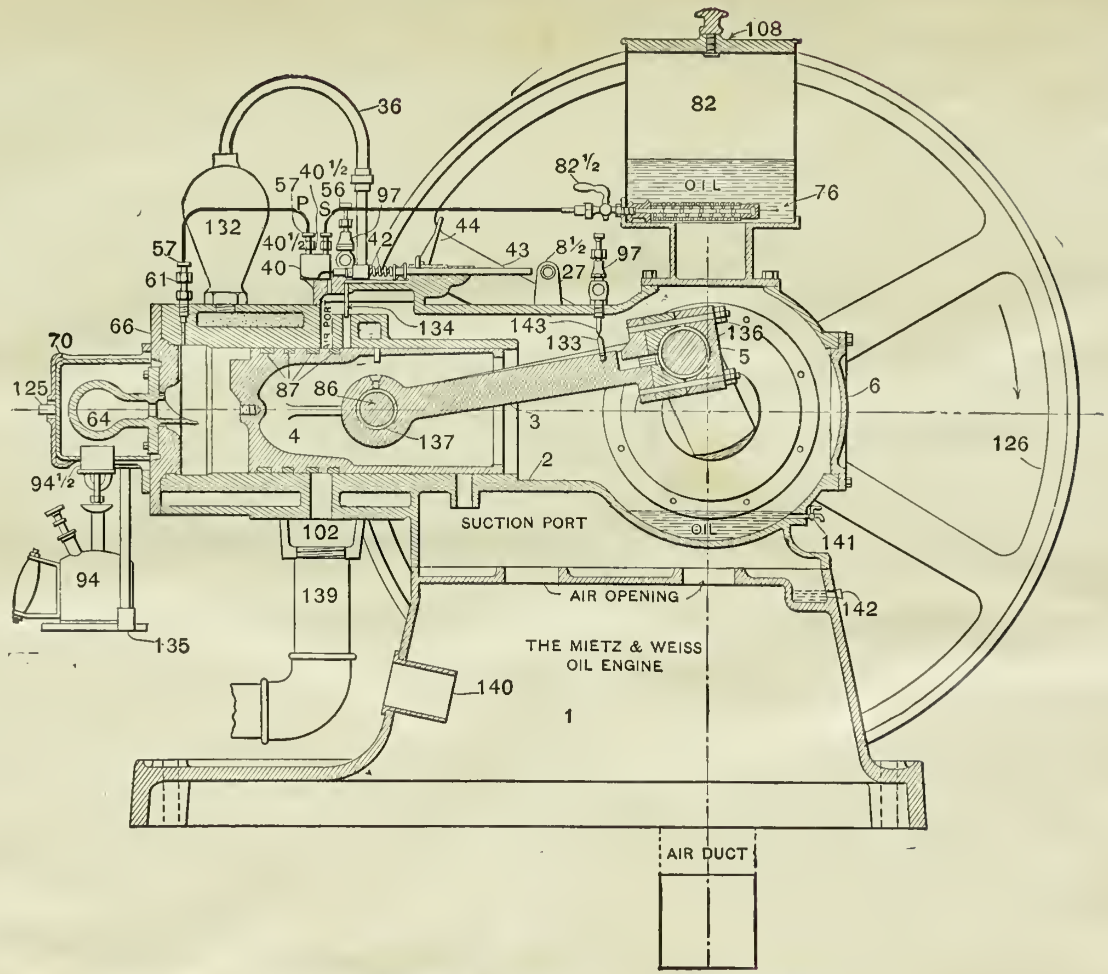


Fig. 2.—Section of the Mietz & Weiss Oil Engine.

7

Representative Indicator Cards.

Alcohol

240# Spring

Full load

3/4 load

1/2 load

GASOLINE

240 # Spring.

Full load

3/4 load

1/2 load

KEROSENE

240# Spring.

Full load.

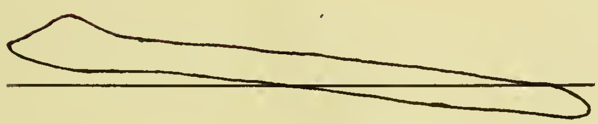
3/4 load

1/2 load

CRANK CASE CARDS

10# spring.

ALCOHOL



GASOLINE

KEROSENE