COMPARATIVE THERMAL EFFICIENCY TESTS OF ALCOHOL AND KEROSENE USED AS FUEL ON THE MIETZ AND WEISS OIL COMBUSTION ENGINE

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

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ENTITLED COMPARATIVE THERMAL EFFICIENCY TESTS OF ALCOHOL AND KEROSENE USED AS FUEL ON THE MIETZ AND WEISS OIL COMBUSTION ENGINE

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

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COMPARATIVE THERMAL EFFICIENCY TESTS OF ALCOHOL AND KEROSENE USED AS FUEL IN THE MIETZ AND WEISS OIL COMBUSTION ENGINE.

I
PRELIMINARY REMARKS.

The thermal efficiency tests of a Mietz and Weiss oil engine were performed in the Mechanical Engineering Laboratory of the University of Illinois. A series of tests, using kerosene and alcohol as fuel, were run at various loads and under similar conditions in order to make a fair comparison between the value of kerosene and alcohol as fuel for power purposes. To serve as a check on the accuracy of the data obtained duplicate tests were run for each load and for each fuel.

II
DESCRIPTION AND OPERATION OF ENGINE.

The engine used in the test is of the two cycle type and is made by the Mietz Iron Foundry and Machine Works,

New York. It is rated at twelve horse power at three hundred twenty revolutions per minute and is governed by means of a fly wheel governor. The size of the cylinder is nine by ten inches. The engine is equipped with two fly wheels fifty inches in diameter and four and one half inch faces which permits them to be belted directly to high-speed machinery, such as electric generators. The engine can be operated by kerosene, alcohol, fuel oil, crude oil, gasoline and distillate.

General views of the engine are shown on pages 22 and 23 and a cross section, with a list of details, is shown on page 24.

The operation of the engine is as follows:

Air enters the interior of the base through the opening, marked 140 in the sketch on page 24, and is drawn from there into the closed crank chamber through the suction port in the lower part of the cylinder. On the forward stroke of the piston (towards the crank chamber, first stroke) this air is compressed and a port, marked air port, which is operated by the piston, allows it to pass, together with the steam generated in the water jacket, to the combustion space of the cylinder. At the same time the exhaust port, 102, being overrun and operated by the piston, discharges the products of combustion. The fuel is injected into the cylinder by a small pump, 42, 43, 44, which is actuated by the fly wheel governor, and there mixed with air and steam, so that on the completion of the compression stroke, second stroke, the mixture of air,

oil vapor and steam is automatically fired, the expansion driving the piston forward and by its connecting rod delivers power to the crank shaft. The ignition of the engine is effected by compression and is entirely automatic. The kerosene burner, 94, is used for several minutes to heat the bulb, 64, before starting the machine.

The unusual feature of this engine consists in the cooling water arrangement. Instead of circulating the cooling water as is ordinarily done, it is allowed to evaporate in the jacket, the water level being kept constant by means of a float valve. This float valve is located in a box attached to the side of the engine near the head end. The vapor formed collects in the steam dome, 132 sketch on page 24, and is by means of the bent pipe led to the intake port of the cylinder.

III
APPARATUS.

The dynamometer used for measuring the brake horse power was the ordinary Prony brake, as shown in the sketch on page 24. The brake pulley was kept cool by a stream of water playing upon the inside.

Two scales were used, one, of the Buffalo platform type, for measuring the brake pressure in pounds and one for weighing the oil. The fuel supply was not drawn from the engine tank but from a can resting on the smaller scale, as

shown in the photograph on page 22.

Two Crosby inside spring indicators were used to obtain indicator cards on the head and crank ends of the cylinder. The indicator mounted on the head end was of the gas engine type with a sixty pound spring and the one on the crank end of the steam engine type with a ten pound spring. A reduction of piston travel was obtained by means of an eccentric placed on the crank shaft between one of the fly wheels and its bearing.

The speed of rotation was found by means of a speed counter and watch.

The water supply, which was taken from the tank located on the front of the engine, was measured in inches as recorded by the gage glass attached to the tank and afterwards reduced to pounds by obtaining the weight of a column of water of known length.

Fahrenheit thermometers of ranges zero to two hundred twenty and zero to six hundred were used to obtain the temperatures of the surrounding air and of the exhaust gases respectively. The photograph on page 22 shows the location of the exhaust gas thermometer in the exhaust pipe immediately outside of the engine.

The Hempel Gas Analysis apparatus was used in analyzing the exhaust gases.

In order to secure accurate results calibrations were made of the following apparatus: thermometers, scales, and indicator springs.

IV

MANNER OF CONDUCTING TESTS.

It was decided to run a series of tests at zero, a quarter, half, three quarters, and full load for one hour periods each. An overload test was unsuccessful when using kerosene as fuel. Under the same running conditions it was found the engine could not carry over half load when using alcohol.

In order to have the engine in good running condition at the time of starting each test a preliminary run of twenty to thirty minutes was made. The series of readings was begun as soon as the cards taken and the temperature readings showed a constant state of affairs.

The following readings were taken every five minutes:

Temperature of the exhaust gas at the engine.

Temperature of surrounding air.

Revolutions per minute.

Initial and final readings only, were taken of the water consumption in inches and of the fuel supply in pounds. The brake load on the scales was kept constant by adjusting the friction on the brake pulley.

Indicator cards were taken on both crank and head end every five minutes. Sample cards are shown on page 17 to 21.

Gas samples were obtained on tests number 3, 5, and 8 by inserting a split tube into the exhaust pipe and

drawing a sample into a gas collecting bottle. These samples were to be used in calculating the amount of air used during the test.

A sample of each fuel was carefully analysed to obtain its chemical composition and heating value, these results to be used in conjunction with the exhaust gas analysis mentioned above.

V

CALCULATIONS.

Corrections for temperatures were made from the calibration curves and the true scales of indicator springs were calculated from the calibration cards.

The volume of exhaust gas and the weight of air per pound of fuel were calculated as follows:

Fuel - kerosene:- Test 5.

Analysis of fuel - By weight.

C = 87.6 %

H = 12.1

O+N+S = .2

H_2O = .1

Analysis of exhaust gas - By volume.

CO_2 = 5.8 %

O = 14.4

CO = .6

CH_4 = 1.3

N = 77.9

Specific weights of exhaust gas constituents at 62° F. and 30" Hg.

CO_2 = .1161

CO = .0726

O = .0841

CH_4 = .0428

N = .0740

The weights of these constituents in the exhaust gas are.

CO_2 = .1161 × .058 = .0064

O = .0841 × .144 = .01212

CO = .0726 × .006 = .00043

CH_4 = .0428 × .013 = .00055

N = .0740 × .779 = .05756

.07734 pounds in one cubic foot of exhaust gas.

The percent by weight of each constituent in the exhaust gas is given by the formula:

$$\frac{\text{(Specific weight of each constituent)(\% of each constituent)}}{\text{(Specific weight of exhaust gas)}}$$

Therefore:

CO_2 = .0064 / .07734 = 8.3 % by weight.

O = .01212/ .07734 = 15.72

CO = .00043/ .07734 = .56

CH_4 = .00055/ .07734 = .71

N = .0575 / .07734 = 74.54

99.83 % by weight.

Kerosene used per hour = 8.725 pounds.

Therefore the weight of C used per hour =

8.725 × .876 = 7.64 pounds,

The weight of C per pound of exhaust gas is given by the formula:

(lb. of C in 1 lb. CO_2)(% CO_2 in 1 lb. exh. gas) + (lb. C in 1 lb. CO)(% CO in lb. exh. gas) + (lb. C in lb. CH_4)(% CH_4 in 1 lb. exh. gas) / 100.

$$\frac{.272 \times 8.3 + .43 \times .56 + .75 \times .71}{100} = .0304$$

Therefore the percentage of C in one pound of CO_2 =

.272 × .083/ .0304 = 74.2 %

Therefore the actual weight of C appearing in CO_2 per hour is (% C in 1 lb. CO_2)(lb. C used per hour)

= .742 × 7.64 = 5.66 lb.

The ratio of O to C in CO_2 = 2 2/3 to 1

Therefore the weight of CO_2 gas = 3 2/3 × 5.66

= 20.8 pounds per hour.

The volume of this CO_2 gas = weight / specific wt.

= 20.8 / .1161 = 179 cu. ft.

The volume of exhaust gas therefore

= (vol. CO_2)/(% CO_2 in exh. gas)

= 179 / .058 = 3090 cubic feet.

The weight of this exhaust gas = vol. × specific wt.

= 3090 × .07734 = 239.2 lb. per hour.

The weight of N in the gas is (wt. gas) (% of N)

= 239.2 × .7454 = 178. lb. N.

The weight of air required is (wt. N)/(% N in air)

= 178 / .77 = 232 lb. air required.

The weight of air required per pound of fuel is

= 232 / 8.725 = 26.6 lb.

In order to calculate the thermal efficiency the lower heating value of the fuel was needed and was calculated as follows:

Higher heating value of kerosene is 20100 B.T.U.

Average air temperature is 75.6^0

B.T.U. required to evaporate 1 lb. H_2O under the given conditions is (212 - 75.6)+ 966.1 = 1102.5

1102.5 × .001 = 1.1 B.T.U. required to evaporate the H_2O in 1 lb. of fuel.

CH_4 in exhaust gas = .71 % by weight.

239.2 lb. gas × .0071 = 1.7 lb. CH_4 in exhaust gas.

$C + H_4 = CH_4$

12 + 4 = 16

12/16 + 4/16 = 16/16 or the weight of H = 1/4 the weight of the CH_4.

Therefore the weight of H in CH_4 = 1.7/4 = .425 lb.

8.725 × .121 = 1.055 lb. H used per hour in the fuel.

1.055 - .425 = .63 lb. H uniting per hour to form water.

.63/8.725 = .0725 lb. H per pound of fuel uniting to form water.

$H_2 + O = H_2O$

2 + 16 = 18.

2/18 + 16/18 = 18/18 or the ratio of O to H in H_2O is 8 to 1.

Therefore .0725 × 9 = .6525 lb. H_2O formed per pound of fuel.

Therefore the B.T.U. required to evaporate this water is 1102.5 × .6525 = 717.5 B.T.U.

718.6 = 718.6 B.T.U. lost evaporating H_2O

Therefore 20100 - 718.6 = 19380 B.T.U., the lower heating value of the fuel.

To determine the pressure on the scale at the end of the brake arm, the following formula was used.

B.H.P. = 2 × 3.1416 × R×N×P / 33000. where

R = length of brake arm in feet.

N = revolutions per minute.

P = pressure in lb. required on the scales.

Considering the full load or 12 B.H.P. the formula gives:

12 = 2 × 3.1416 × 4.05 × 340. × P / 33000.

or P = 46.5 pounds.

The B.H.P. for each set of readings was calculated using the R.P.M. obtained from the speed indicator.

The following calculations were made for the set of readings at full load, for kerosene.

B.H.P. = 2 × 3.1416 × 4.05 × 337 × 45.6/33000.

= 12.02 B.H.P.

The indicated horse power or I.H.P. is

I.H.P. = PLAN/33000. where

P = Mean effective pressure.

L = Length of stroke in feet.

A = Area of piston in square inches.

N = Revolutions per minute.

Substituting the proper values in the above formula,

I.H.P. = 26.65 × .833 × 63.6 × 337/33000

= 14.4 I.H.P.

The mechanical and thermal efficiencies are as follows:

Mechanical efficiency = B.H.P./I.H.P. =

12.02/14.4 = 83.5 %

Thermal efficiency = B.T.U. output/B.T.U.input

= 12.02×2545/((19380 × 8.723)+(34.8 × 966))

= 15.1 %.

Weight of oil per B.H.P. per hour =

8.725/12.02 = .725 lb. = .107 gallons.

The heat balance was calculated as follows:

I B.T.U. used per hour = 20100 × 8.725 = 175000.

II B.T.U. lost in the formation and evaporation of water in the engine cylinder as calculated on pages 10 and 11 is

$$719 \times 8.725 = 6275. \text{ B.T.U.}$$

III B.T.U. lost in exhaust gases:

Temperature of gases 438.

Weight of gases 239.2 lb.

1. Sensible heat lost in gases is

= (wt. of gas) × (specific heat) × (temperature of gas above the air)

$$= 239.2 \times .26 \times (438 - 80) = 22300.$$

2. Heat lost in water jacket = (wt. of water used) × ((heat of liquid + latent heat of steam) + (specific heat of superheated steam) × (degrees of superheat))

$$= 34.8 \times (150 + 966 + ((433 - 212)\times.6))$$

$$= 43600$$

3. Heat equivalent of work = I.H.P. × 2545 B.T.U.

$$= 14.4 \times 2545 = 36600.$$

4. Heat of combustion in CO in exhaust gases = (vol. of gas) × (% CO in gas) × (heating value)

$$= 3090 \times .006 \times 319 = 5910$$

5. Heat of combustion in CH_4 in exhaust gases =

$$= 3090 \times .013 \times 1010 = 40600$$

Total heat accounted for = 155285 B.T.U.

175000 - 155285 = 19715 B.T.U. unaccounted for.

19715 / 175000 = 11.3 % lost by radiation etc.

VI

DISCUSSION, CURVES AND CONCLUSIONS.

Attempts were made to carry an overload on the engine when using kerosene but they proved unsuccessful. With a few pounds pressure in excess of full load on the scale the engine would run normally for a quarter of an hour when the speed would diminish perceptibly and an excess of fuel be pumped into the cylinder. The engine would gradually slow down to the accompaniment of occasional loud explosions in the exhaust pipe. Even at full load the engine had difficulty in maintaining its rated speed.

Upon substituting wood alcohol for kerosene difficulty was experienced in starting the engine. Several vain attempts at starting the machine were made but it failed to attain normal speed at any time; a few sharp explosions would take place and the piston make a few strokes, which gradually diminished. To overcome this trouble a start was made with kerosene and a change over to alcohol made after the normal running speed had been reached. This was due to the inability of the cylinder to properly vaporize the alcohol. With alcohol, however, only one half load could be carried, running under the same conditions as was done with kerosene, as the engine behaved in a similar manner as that mentioned above where an overload attempt was made with kerosene. With the steam pipe open to the atmosphere it was found that the engine could carry just full load with alcohol, but as soon as water was run

through the cylinder jacket, thus cooling off the engine, a slowing down would occur followed by a final stop. The water had to be at a temperature higher than 170 degrees in order to keep the cylinder warm enough for combustion purposes. The same experiment was tried with kerosene with the result that fifty percent overload could be carried. In this case the water had to be under 70 F in order to prevent back firing, the upper limit being found by gradually throttling the water supply and measuring the temperature just as the back firing commenced. According to the above results alcohol requires a hot cylinder and kerosene a moderately cool cylinder for the best operating conditions. No readings were taken with the engine running under these conditions.

The final results of the test are shown by curves 1, 2, 3, and 4. The points on these curves were plotted from average values of each test.

Curve No. 1 shows the relation between the mechanical efficiency and the brake horse power, and from an inspection it shows that the maximum efficiency was obtained when developing between nine and ten brake horse power. Curve No. 2 shows the relation between the thermal efficiency and the brake horse power. The thermal efficiency increases with the brake horse power, as would naturally be expected. Curve No. 3 shows the relation between the kerosene consumed in pounds per brake horse power hour and the brake horse power, and clearly indicates how the consumption per brake horse power hour decreases with an increase in the load. Curve No. 4 is

similar to No. 3, alcohol being substituted for kerosene.

CARD NO. 8. HEAD END

SPRING NO. 60. M.E.P.-2.68. LBS.

LOAD-0. APRIL-3,09.

FUEL-KEROSENE.

CARD NO. 10. HEAD END

SPRING NO. 60. M.E.P. 9.50. LBS.

LOAD-$1/4$. APRIL-3, 09.

FUEL-KEROSENE.

CARD NO. 12. HEAD END.

SPRING NO 60. M. E. P. 17.4 LBS.

LOAD - 1/2. APRIL-17-09.

FUEL - KEROSENE.

CARD NO. 11. HEAD END

SPRING NO. 60. M. E. P. 21.8 LBS.

LOAD - 3/4. APRIL-17-09.

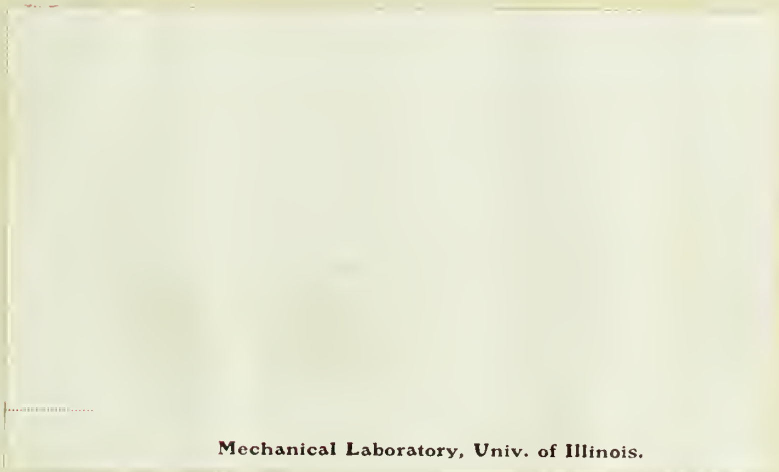
FUEL - KEROSENE.

CARD NO. I. HEAD END.

SPRING NO. 60. M. E. P. 26.8 LBS.

LOAD · FULL. APRIL · 17, -09.

FUEL · KEROSENE



ALL LOADS CRANK END

SPRING NO. 10. M. E. P. · 1.70. LBS.

FUEL · KEROSENE.

CARD NO. 4. HEAD END
SPRING NO. 60. M. E. P. 4.76 LBS.
LOAD O. MAY 1, 09.
FUEL - ALCOHOL.

CARD NO. 10. HEAD END.
SPRING NO. 60. M. E. P. 12.30 LBS.
LOAD - 1/4. MAY 1, 09.
FUEL - ALCOHOL.

CARD NO. 11. HEAD END.

SPRING NO. 60. M. E. P. 20.10 LBS.

LOAD. 1/2. MAY 1, 09.

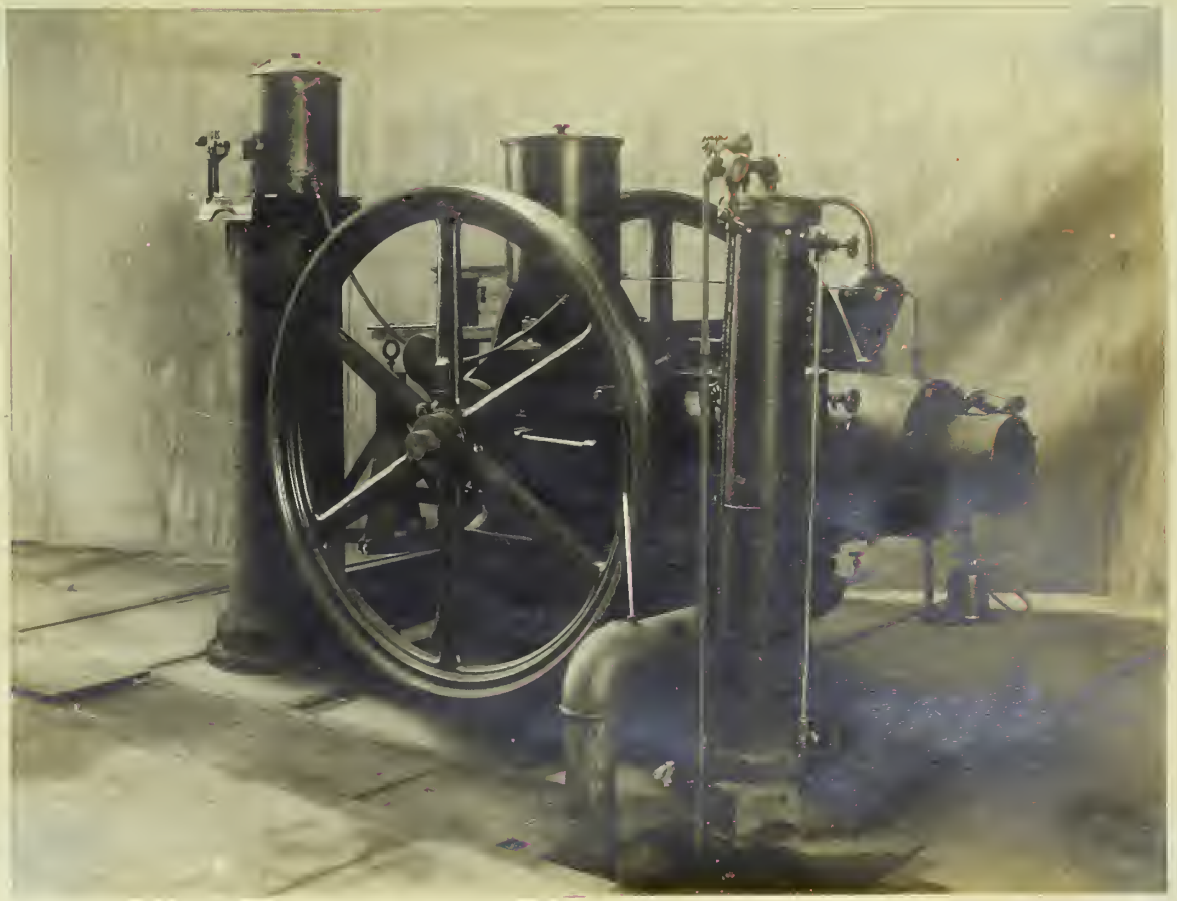
FUEL. ALCOHOL.

Mechanical Laboratory, Univ. of Illinois.

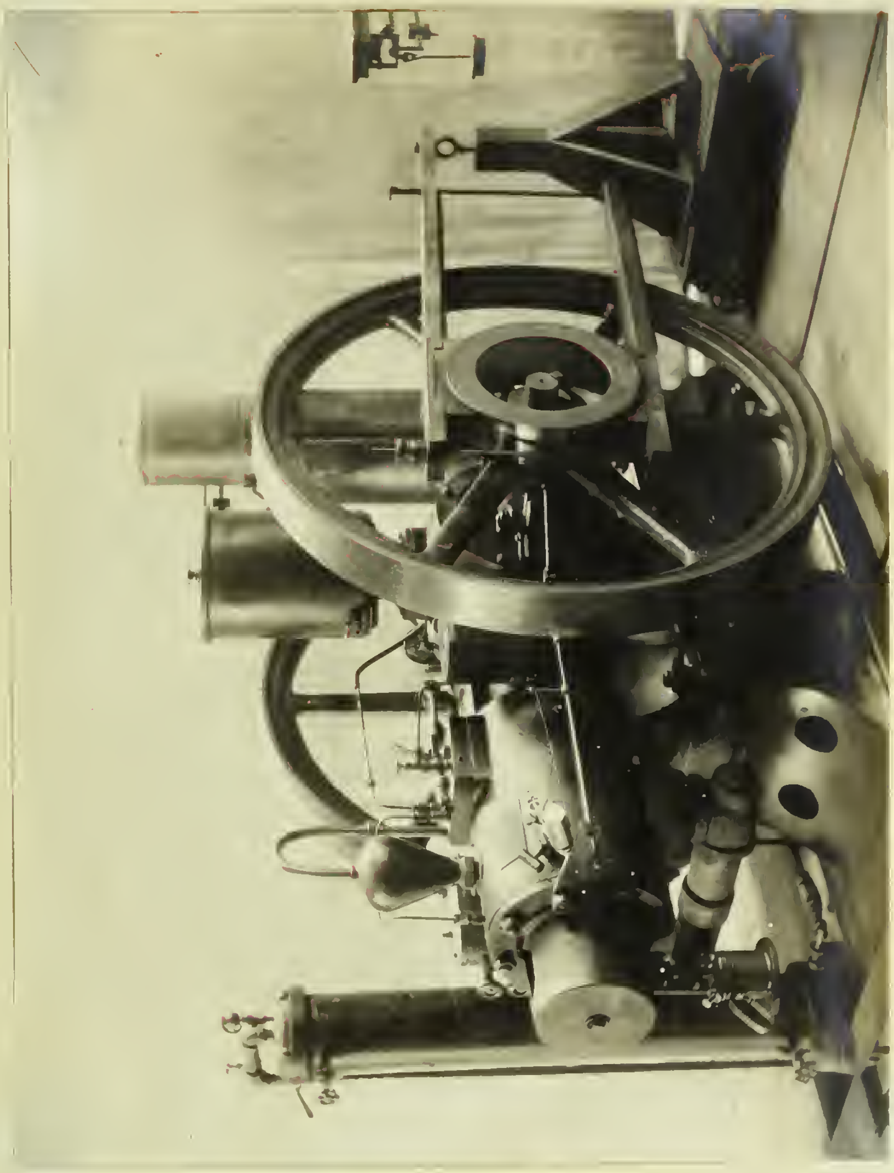
ALL LOADS. CRANK END

SPRING NO. 10. M. E. P. 1.70. LBS.

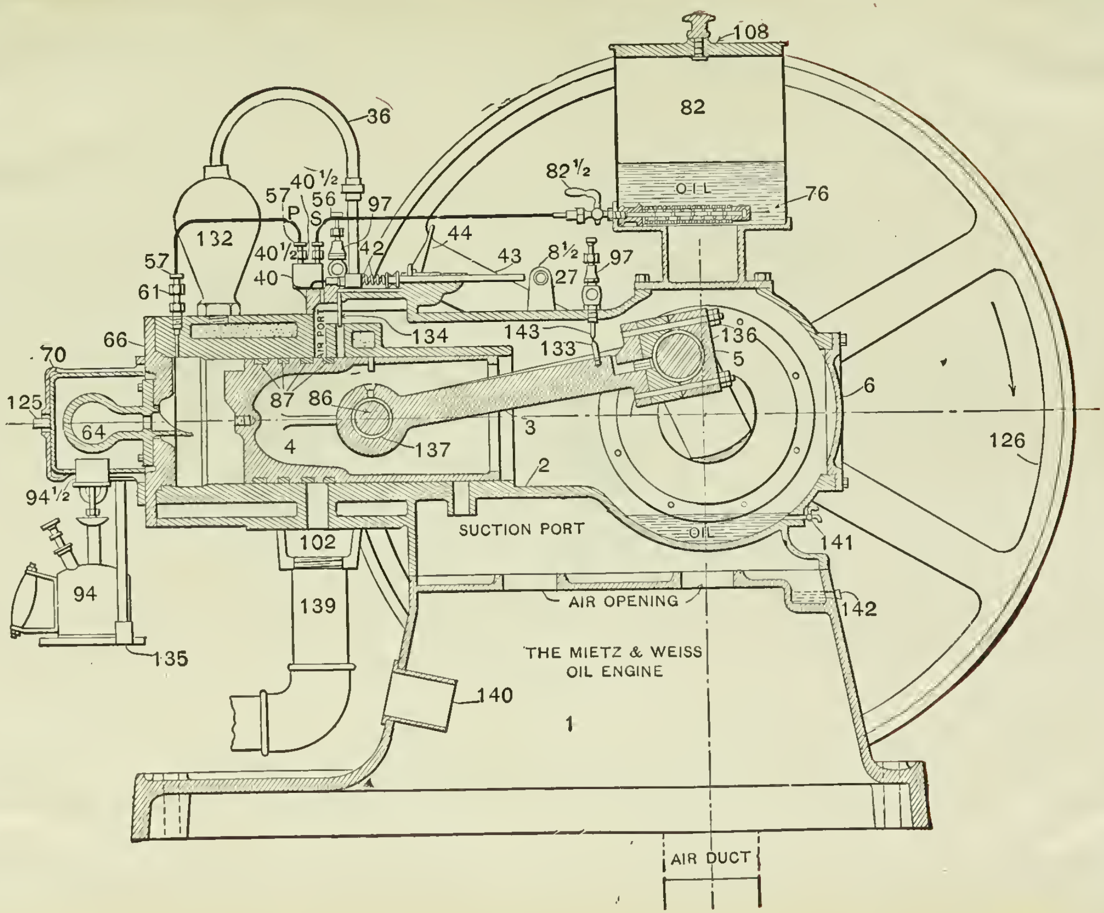
FUEL-ALCOHOL.



12·H. P. MIETZ AND WEISS OIL COMBUSTION ENGINE



12-H.P. MIETZ AND WEISS OIL COMBUSTION ENGINE.



CROSS SECTION OF MIETZ AND WEISS OIL ENGINE.

CLASSIFICATION OF ENGINE PARTS.

1. Base.

2. Cylinder.

3. Connecting rod.

4. Piston.

5. Connecting rod crank boxes.

6. Crank chamber head.

8 1/2. Rocker arm roller.

27. Rocker arm.

36. Steam pipe.

40. Oil pump.

40 1/2. S. Suction valve.

P. Pressure valve.

42. Oil pump plunger.

43. Oil pump guide.

44. Oil pump handle and screw.

56. Oil pump suction pipe.

57. Oil pump discharge.

61. Injection nozzle.

64. Igniter ball.

66. Igniter ball flange.

70. Air mantle with damper.

76. Oil tank filter.

82. Oil tank.

82 1/2 Oil tank cock.

86. Piston pin.

87. Piston rings.

94. Starting lamp.

94 1/2 Starting lamp burner.

97. Lubricating sight feed.

102. Exhaust port.

126. Fly wheel.

132. Steam dome.

133. Connecting rod oil tip.

135. Lamp bracket.

136. Crank pin bushing.

137. Connecting rod piston pin bushing.

139. Exhaust pipe.

140. Air hole.

141. Base cock.

143. Lubricating tip.

TEST NO. I.

APRIL 3, 1909.

NO	TIME	TEMPERATURE AIR °F	TEMPERATURE EXHST. °F	R.P.M.	OIL LBS.	WATER IN.	M.E.P. HEAD	M.E.P. CRANK	M.E.P. DIFF.
1	12:30	72	280	348	37.75	4.75	1.82	1.70	0.12
2	:35	73	288	348			4.68	1.70	3.98
3	:40	69	290	347			5.00	1.69	3.31
4	:45	72	292	346			2.76	1.69	1.07
5	:50	74	292	347			1.74	1.69	0.05
6	:55	73	290	348			5.08	1.73	3.35
7	1:00	73	286	347			3.80	1.75	2.05
8	:05	72	282	347			2.68	1.68	1.00
9	:10	71	280	347			3.24	1.68	1.56
10	:15	72	281	346			4.82	1.69	3.13
11	:20	75	280	347			6.34	1.69	4.65
12	:25	70	280	345			0.88	1.69	0.81
13	:30	73	280	347	33.75	14.8			
AV.		72.	284				3.56	1.68.	1.88.
DIFF.					4.00	10.05			

FUEL - KEROSENE. LOAD - O.

B.H.P. - O. MECH. EFF. - O.

I.H.P. - 1.045. THERM. EFF. - O.

GAL. OF FUEL PER HR. - 0.59.

TEST NO 2.

APRIL 3, 1909.

NO	TIME	TEMPERATURE		R.P.M.	OIL	WATER	M. E. P		
		AIR °F	EXHST. °F		LBS.	IN.	HEAD	CRANK	DIFF.
1	1 :50	77.	342	345	31.93	2.4	7.10	1.70	5.40
2	:55	75	346	344			8.64	1.75	6.89
3	2 :00	74.	340	347			11.00	1.69	9.31
4	:05	74	338	345			10.34	1.69	8.65
5	:10	74	338	344			9.50	1.70	7.80
6	:15	74	341	344			12.68	1.70	10.98
7	:20	75	342	347			15.80	1.70	14.10
8	:25	74	341	347			13.46	1.70	11.76
9	:30	75	344	345			8.64	1.72	6.92
10	:35	75	347	344			9.50	1.71	7.79
11	:40	75	348	346			15.86	1.68	14.18
12	:45	71	350	345			9.50	1.68	7.82
13	:50	73	349	346	26.56	17.75			
AV.		74.2	344	345			11.00	1.70	9.30
DIFF.					5.37.	15.35			

FUEL - KEROSENE. LOAD - 1/4.

B.H.P - 3.11. MECH. EFF. - 60.7 %.

I. H. P. - 5.125 THERM. EFF. - 6.63 %.

GAL. OF FUEL PER B.H.P PER HR. - 0.254.

TEST NO. 3.

APRIL 17, 1909.

NO.	TIME	TEMPERATURE AIR °F	EXHST. °F	R.P.M.	OIL LBS.	WATER IN.	M. E. P. HEAD	CRANK	DIFF.
1	2:15	78.	378	343	34.31	6.0	14.20	1.74	12.46
2	:20	78	378	344			14.20	1.74	12.46
3	25	78	377	342			15.50	1.68	13.82
4	30	79	376	343			14.20	1.61	12.59
5	35	79	375	343			15.80	1.61	14.19
6	40	79	376	343		15.75 1.30	14.20	1.68	12.52
7	45	79	376	343			15.50	1.74	13.76
8	50	79	378	342			15.80	1.74	14.06
9	55	79	374	343			19.00	1.61	17.39
10	3:00	79	375	344			15.10	1.55	13.55
11	05	79	376	343			15.80	1.55	14.25
12	10	79	375	344			17.40	1.61	15.79
13	15	79	374	344	27.38	13.35			
AV.		79	376	343			15.50	1.65	13.85
DIFF.					6.93.	21.80			

FUEL - KEROSENE. LOAD - 1/2.

B. H. P. - 6.18 MECH. EFF. - 81.5 %.

I. H. P. - 7.6 THERM. EFF. - 10.10 %.

GAL. OF FUEL PER B.H.P. PER HR - 0.165.

TEST NO. 4.

APRIL 17, 1909.

NO.	TIME	TEMPERATURE		R.P.M.	OIL.	WATER	M. E. P		
		AIR °F	EXHST. °F		LBS.	IN.	HEAD	CRANK	DIFF.
1	3:15	70	427	340	28.70	1.75	20.60	1.70	18.90
2	:20	71	424	340			20.60	1.68	18.92
3	:25	69	427	339			20.60	1.68	18.92
4	:30	70	429	339			22.20	1.72	20.48
5	:35	69	430	339			20.60	1.70	18.90
6	:40	71	434	339			20.60	1.72	18.88
7	:45	73	434	338			19.00	1.71	17.29
8	:50	74	436	338			19.00	1.68	17.32
9	:55	77	440	339			21.00	1.68	19.32
10	4:00	74	445	337			19.00	1.71	17.29
11	:05	73	442	338			21.80	1.70	20.10
12	:10	71	438	339			21.80	1.70	20.10
13	:15	74	434	340	20.75	31.4			
AV.		72	434	339			20.34	1.70	18.64
DIFF.					7.95	29.65			

FUEL - KEROSENE. LOAD - 3/4.

B.H.P. - 9.12. MECH. EFF. - 90.3 %.

I.H.P. - 10.1. THERMAL EFF. - 12.65 %.

GAL. OF FUEL PER B.H.P. PER HR. - 0.128.

TEST NO 5

APRIL 17, 1909.

NO.	TIME	TEMPERATURE		R.P.M.	OIL	WATER	M. E. P.		
		AIR °F	EXHST. °F		LBS.	IN	HEAD	CRANK	DIFF.
1	3:40	80	436	340	24.0	3.4	26.80	1.74	25.06
2	:45	80	440	338			29.20	1.74	27.46
3	:50	81.	438	335			27.60	1.79	25.81
4	:55	80	444	337			31.60	1.79	29.81
5	4:00	81	446	337		16.20 0.30	25.60	1.79	23.81
6	:05	81	448	337			29.20	1.75	27.45
7	:10	81	454	338			29.80	1.69	28.11
8	:15	81	452	337			27.60	1.84	25.76
9	:20	81	450	337		18.20 4.25	28.40	1.84	26.56
10	:25	81	454	336			30.00	1.84	28.16
11	:30	81	453	335			28.60	1.56	27.04
12	:35	81	455	336			26.60	1.69	24.91
13	:40	81	454	337	15.275	8.6			
AV.		80.8	448	337			28.40	1.75	26.65
DIFF.					8.725.	35.05			

FUEL - KEROSENE. LOAD - FULL.

B.H.P. - 12.02. MECH. EFF. - 83.5%.

I.H.P. - 14.4. THERM. EFF. - 15.1%.

GAL. OF FUEL PER B.H.P. PER HR - 0.107.

TEST NO 6.

MAY 1, 1909.

NO.	TIME	TEMPERATURE AIR °F	TEMPERATURE EXHST °F	R. P. M.	ALCOH. LBS.	WATER IN.	M. E. P. HEAD	M. E. P. CRANK	M. E. P. DIFF.
1	3:30	64	273	343	23.68	3.0	6.34	1.60	4.74
2	:35	64	274	345			4.82		3.22
3	:40	64	270	347			4.76		3.16
4	:45	64	266	346			4.76		3.15
5	:50	64	266	346			4.76		3.16
6	:55	64	266	346			6.34		4.74
7	4:00	64	268	345			4.82		3.22
8	:05	64	269	346			4.76		3.16
9	:10	64	272	347			4.76		3.16
10	:15	64	269	346			4.76		3.16
11	:20	63	266	346			3.30		1.70
12	:25	62	268	347			4.76		3.16
13	:30	63	265	346.	16.75	7.75			
AV.		63.7	268	346			4.90	1.60	3.30.
DIFF.					6.93	4.75			

FUEL-ALCOHOL.　　LOAD - O.

B. H. P. -O.　　MECH. EFF -O

I. H. P. -1.83.　　THERMAL. EFF.-O.

GAL. OF FUEL PER HR. - 1.02.

TEST NO.7

MAY 1, 1909.

NO	TIME	TEMPERATURE AIR °F	TEMPERATURE EXHST. °F	R.P.M.	ALCOH. LBS.	WATER IN.	M. E. P. HEAD	M. E. P. CRANK	M. E. P. DIFF.
1	2:15	63	332	342	35.88	1.0	7.86	1.25	6.61
2	:20	64	340	341			12.94	1.74	11.20
3	:25	64	336	342			14.60	1.86	12.74
4	:30	64	331	342			14.60	1.39	13.21
5	:35	63	332	342			16.10	1.66	14.44
6	:40	63	329	342			13.56	1.49	12.07
7	:45	62	323	340			12.68	1.49	11.19
8	:50	62	328	341			11.42	1.49	9.93
9	:55	63	324	342			12.68	1.65	11.03
10	3:00	63	323	341			12.30	1.49	10.81
11	:05	64	324	341			10.52	1.66	8.86
12	:10	64	324	341			10.54	1.45	9.09
13	:15	64	322	342	25.625	11.0			
AV.		63.3	328	341			12.48	1.55	10.93
DIFF.					10.255	10.0			

FUEL-ALCOHOL. LOAD - 1/4.

B.H.P. - 3.08. MECH. EFF. - 51.5 %.

I.H.P. - 5.98. THERM. EFF. - 6.68 %.

GAL. OF FUEL PER B.H.P. PER HR - 0.49.

TEST NO. 8

MAY 1, 1909.

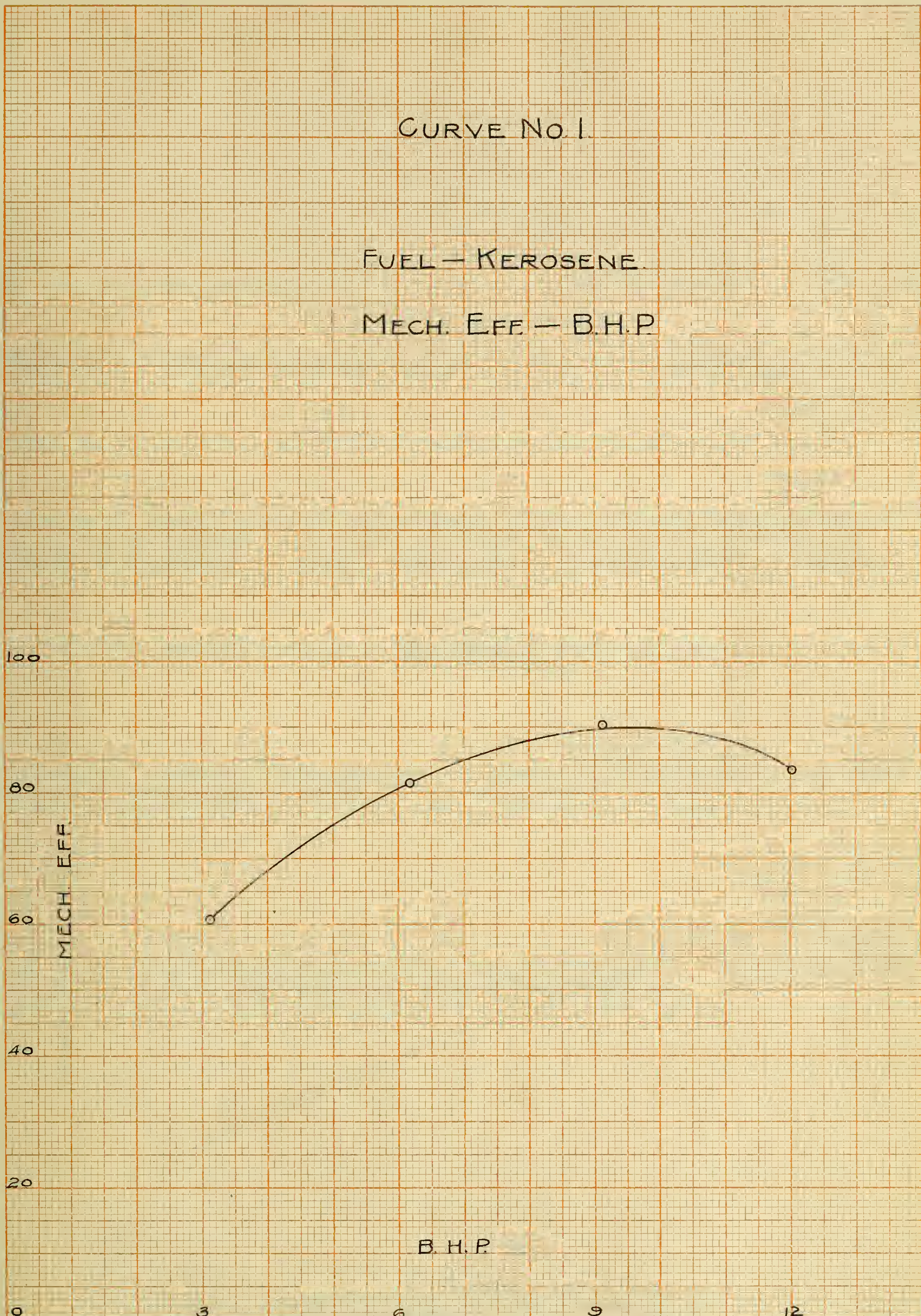
NO.	TIME.	TEMPERATURE AIR °F	TEMPERATURE EXHST. °F	R.P.M.	ALCOH. LBS.	WATER IN.	M. E. P. HEAD	M. E. P. CRANK	M. E. P. DIFF.
1	4:00	83	394	336	26.125	1.0	19.00	1.59	17.41
2	:05	84	392	337			17.74	1.59	16.14
3	:10	85	393	336			19.00	1.59	17.41
4	:15	84	404	334			20.30	1.59	18.71
5	:20	83	397	336			19.00	1.59	17.41
6	:25	84	397	336			19.00	1.59	17.41
7	:30	84	402	337			20.10	1.59	18.51
8	:35	84	396	335			19.40	1.59	16.81
9	:40	84	398	335			17.74	1.59	16.14
10	:45	84	394	336			17.74	1.59	16.14
11	:50	84	402	335			17.74	1.59	16.14
12	:55	84	398	335					
13	5:00	84	398	336	13.375	20.1			
AV.		84	398	336			18.78	1.59	17.19
DIFF					12.75	19.1			

FUEL - ALCOHOL. LOAD - 1/2.

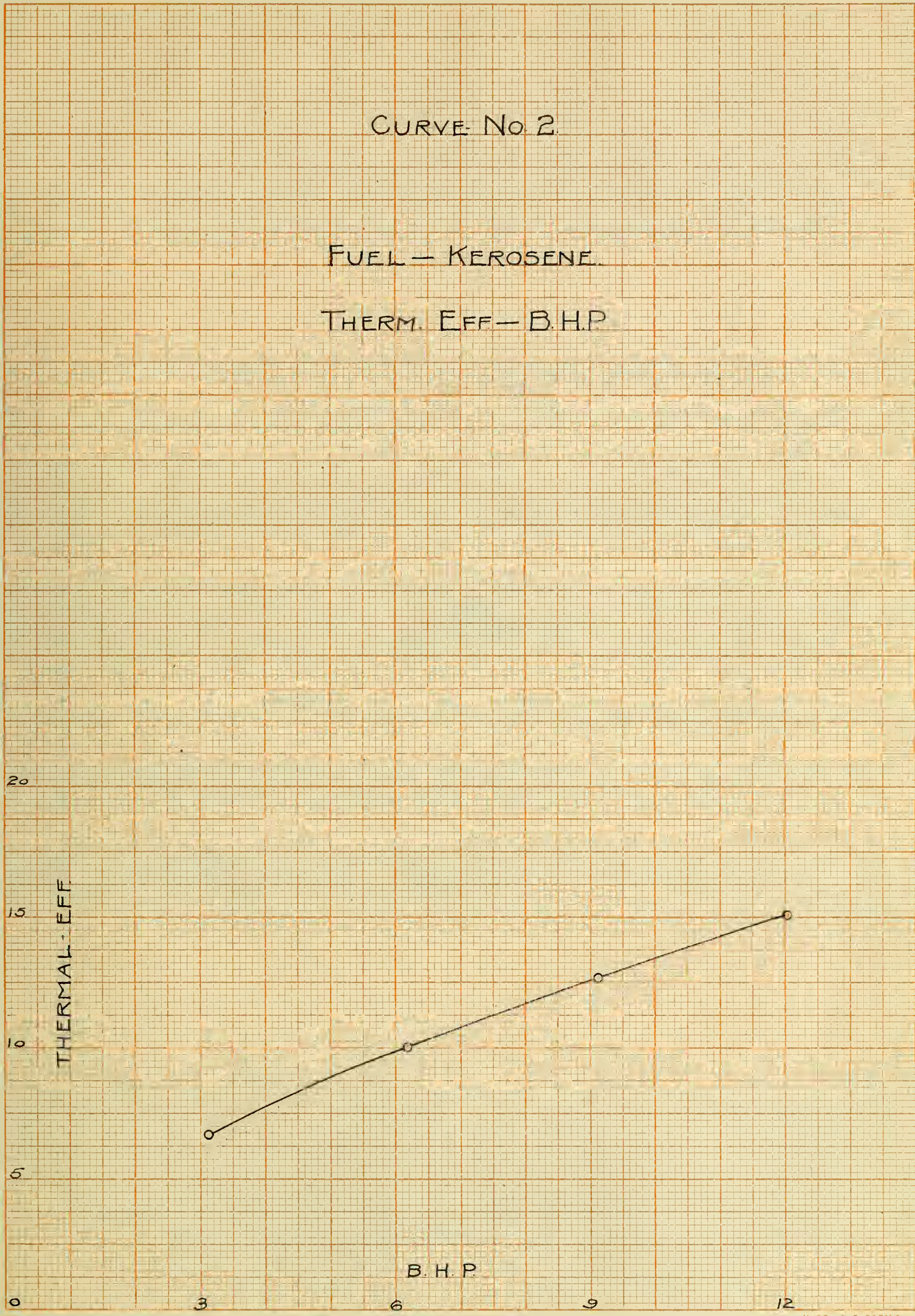
B. H. P. - 6.06. MECH. EFF. - 65.5 %.

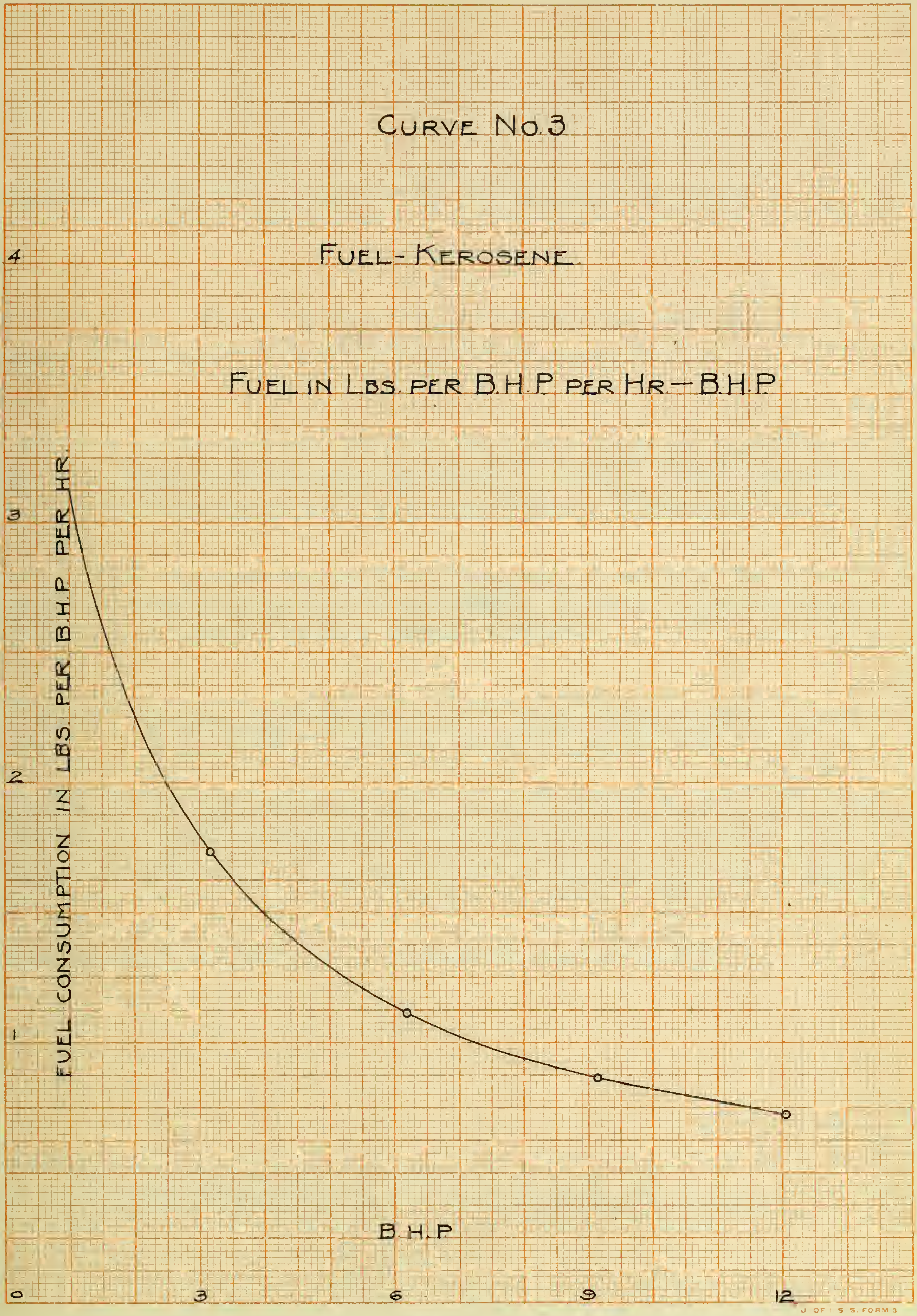
I. H. P. - 9.25. THERM. EFF. - 10.15 %.

GAL. OF FUEL PER B.H.P. PER HR. - 0.31.



U. OF I. S. S. FORM 3

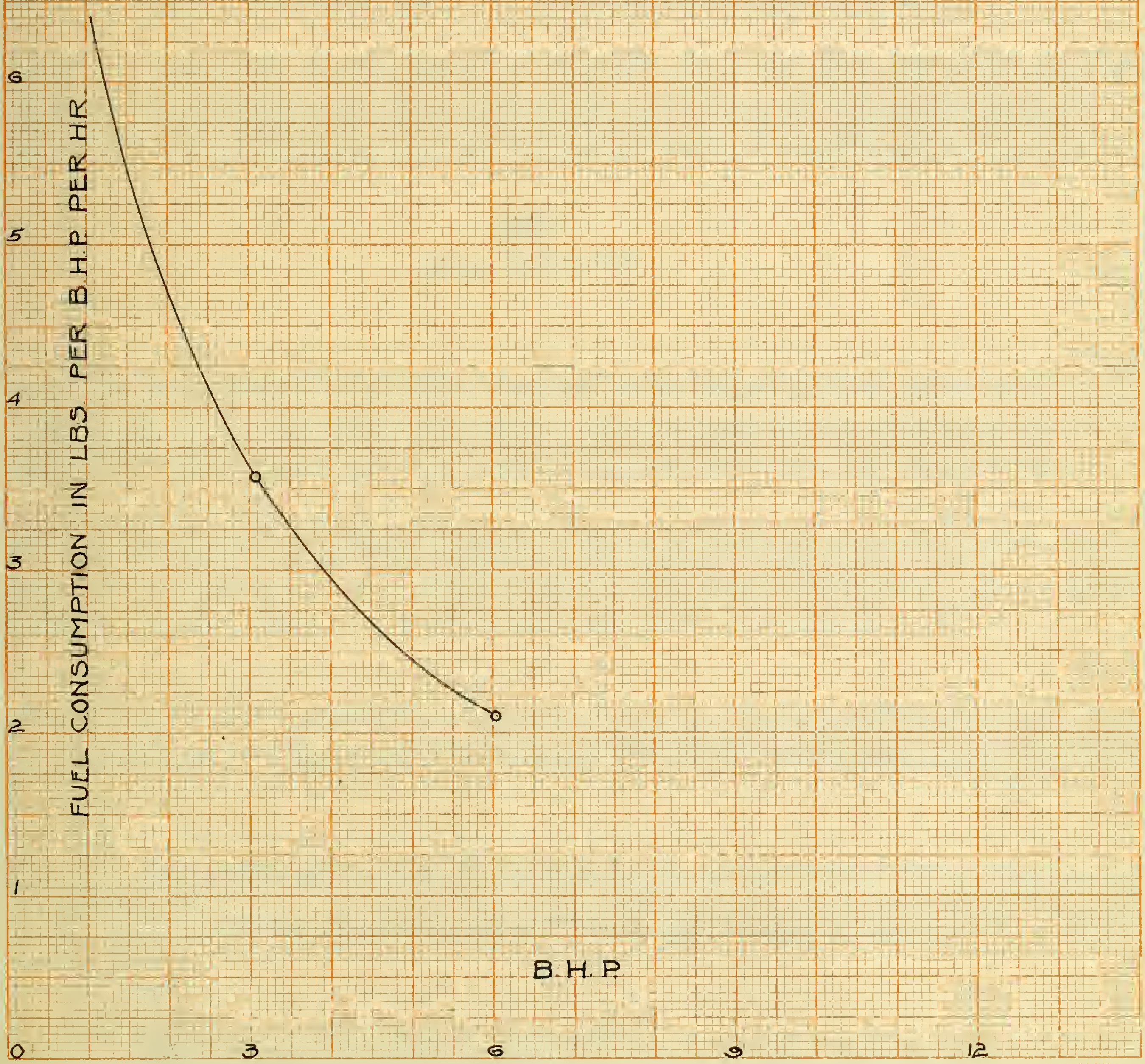

CURVE No 2.
FUEL — KEROSENE.
THERM. EFF — B.H.P.
THERMAL. EFF.
B. H. P.
20
15
10
5
0
3
6
9
12


CURVE NO. 3
FUEL - KEROSENE
FUEL IN LBS. PER B.H.P. PER HR. — B.H.P.
FUEL CONSUMPTION IN LBS. PER B.H.P. PER HR.
B.H.P.
0
1
2
3
4
3
6
9
12

CURVE NO. 4

FUEL - ALCOHOL

FUEL IN LBS. PER B.H.P. PER HR. — B.H.P.



U. OF I. S. S. FORM 3