"COMPARATIVE TESTS OF FUELS FOR INTERNAL COMBUSTION ENGINES"

By

Fred B. McKinnell
Elmer Johnson

Since the advent of the gasoline engine, the price of gasoline has constantly increased until now it is higher than that of kerosene. It is practically for this reason that these comparative tests were carried on, to decide whether an engine designed for gasoline could be run on kerosene fuel, and also to make a measurement of the relative maximum powers of the engine when using kerosene and the fuel for which it was originally designed.

Properties of Liquid Fuels

It must be remembered that all liquid fuels available for commercial use are complicated mixtures of many different chemical substances, and hence are always liable to more or less change in their chemical composition and accordingly in their properties.

Gasoline 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 may not change sufficiently to affect the action of the fuel in the engine. The following figures are fair averages or approximate values and serve to show the relative values of different fuels.

Substance	Spec. Grav.	Lbs. per gal.
	.71	5.90
	.73	6.06
Gasoline	.75	6.22
	.77	6.38
	.80	6.70
	.83	6.88
Kerosene	.85	7.06
	.88	7.30

Here the presence of any solid dissolved in these oils tends to increase the specific gravity.

The two most important properties of a liquid fuel which determines its availability or adaptability for use in an engine, are its heat of combustion and its volatility. The useful work which can be obtained by burning a definite amount of any fuel is in general, approximately proportional to the amount of heat generated by the combustion of the fuel. In this amount of heat the various fuels differ greatly. Moreover a liquid fuel must be converted into a gas or vapor before it can be burned in an explosion engine. Hence the ease or difficulty of vaporizing the fuel has a great effect in determining the form and complexity of the vaporizing apparatus, and also has considerable influence upon the economy of the engine and the general difficulties that may be encountered in its satisfactory operation. Especially is this true in case an improper mixture of fuel vapor and air is used.

Gasoline is easily vaporized at ordinary temperatures and hence needs no artificial means of vaporizing it. Usually it is admitted directly into the air entering the engine through the carburetor, which regulates the proportion of fuel and sprays it uniformly through the mass of air, so that as the liquid spray turns into vapor it will produce a homogenous mixture of air and vapor. Kerosene requires a high heat to vaporize it completely, since its boiling point is higher than that of gasoline, and hence it is almost necessary to use a vaporizer of a hot plate type. In this case the proportion of fuel is regulated by the amount of fuel forced against the hot plate.

As with all substances which liquify at ordinary temperatures, there is a definite limit to the amount of kerosene vapor which can exist in a cubic foot of space at a given temperature. Assuming the laws for perfect gases to hold at any given constant temperature, the weight of kerosene vapor present in a cubic foot of space is proportional to its vapor pressure, and may be measured or represented by the vapor pressure. This may be illustrated by imagining a cylinder provided with a tight piston and containing kerosene vapor at a pressure corresponding to 10 m. m. of mercury and kept constantly, throughout the experiment, at a temperature of 70° F. If now, the vapor is compressed by the piston until its volume is reduced one half, the vapor pressure will rise to 20, there being of course twice as much vapor per cubic foot of space occupied as there was originally. If the volume is again halved, the pressure will rise to 40. But if the compression is continued until the vapor pressure rises to 110 m. m., a change takes place in the action. The pressure will not rise above 110 if the temperature is kept at 70° F. If the piston is moved a greater amount so as to reduce the volume still more, part of the kerosene vapor will be condensed into liquid, but the vapor pressure will remain the same and the amount of vapor per cubic foot of space will remain constant.

Hence there is a definite maximum amount of kerosene vapor which can exist in a cubic foot of space at a given temperature. Space in such a condition is said to be saturated with kerosene vapor and the corresponding vapor pressure is called the vapor pressure of saturated kerosene vapor at the given temperature. It is important to remember that the space may contain any smaller amount with a correspondingly lower vapor pressure, but cannot contain a greater amount than the quantity corresponding to the saturated state.

The vapor pressure of saturation increases rapidly with the temperature, and the value as determined by experiment are:

Temp.	Water	Gasoline	Kerosene	Alcohol
32° F	5	99	52	30
41° F	7	115	63	40
70° F	20	186	110	101

When different gases or vapors exist simultaneously in the same space, if they have no chemical action on each other, each one acts by itself as though no other gas were present.

In order that kerosene may change from a liquid to a vapor, it must receive a large amount of heat either from the air with which it mixes or from the metal parts of the carburetor with which it comes in contact. The hotter these parts, the more quickly the kerosene can absorb the requisite amount of heat. But if the air is too hot there is danger that the mixture and some of the vapor produced, may be too rick in kerosene, and some of the vapor must remain unburned. Still if the air be moist, or the kerosene contain some water, or the time allowed for vaporization be too short, the temperature of the air must be higher than 180° to form the best explosive mixture.

Air at any temperature will take up some kerosene vapor, and the higher the temperature, the quicker it will take up the amount necessary for the best explosive mixture. In the case of incomplete vaporization, some of the fuel may be carried along as a spray, which may or may not be vaporized in the cylinder on the compression stroke. If not it will certainly be vaporized after the explosion of the rest. It would seem desirable, therefore, to heat considerably the air supplied to a kerosene carburetor. But too much heating of the air will bring about a bad effect on the engine because it will make the charge hotter at the end of compression, and thus decrease the weight of the charge in the cylinder. The horse-power of the engine, other things being equal, will be decreased in direct proportion as the density of the charge is lowered by the heating, so that heating of the air before carbureting, is good for complete vaporization, but bad if carried too far in its effect on power reduction.

Apparatus Used

The engine used was a horizontal single cylinder Witte engine, made by the Witte Iron Works of Kansas City, Mo. The engine is rated at 10 H. P. at 250 revolutions per minute. The action is four cycle, and the cylinder is 2 7-1/4" bore by 14" stroke, water cooled. The compression is 50# per square inch. The carburetor is attached directly to the end of the cylinder. The fuel supply receptacle is of the constant level over-flow type, supplied by a pump which is operated by a cam, and arranged so that it can be operated by hand. The spray orifice is controlled by a needle valve, having a numbered head and a pointer. The admission of the next charge is effected by the governor operating the inlet valve, which permits a flow of air to be drawn past the spray orifice, and charge itself with the vaporized gasoline which entered in the form of a spray. The charge is taken on into the cylinder preparatory to the compression stroke.

The inlet and exhaust valve together with the air valve are all placed in the carburetor. The first two are mechanically operated, the inlet valve being operated directly by the governor. The air inlet valve is operated directly by the suction of the engine.

The ignitor used is of the "hammer break" type and five batteries furnished the current. A prony brake was used to find the B.H.P. The I.H.P. was obtained by using a Crosby gas engine indicator with a piston, of 1/4 sq. in. area, in which a 150# spring was used. Metallic surface cards and brass points were used on the indicator.

The engine was fitted to use liquid fuels and the vessel for holding the same consisted of a tank from which the engine supply was pumped. On one side of the tank was placed a glass gage, similar to a water gage on a steam boiler, and this was arranged so that the height of the fuel could be marked by means of a pointer, and after using out the amount needed for the test, and the overflow poured back, the number of gallons required to raise it to its original height, is the amount consumed.

Three tests were made of each fuel, the duration of each test being 2 hours, 3 hours, and 5 hours. The readings were taken at intervals of ten minutes. The revolutions were counted by means of a Crosby speed counter, actuated by a part of the mechanism of the engine. The explosions were counted during the same interval that the revolutions were taken, a stop watch being used for this purpose.

The cylinder was cooled by water drawn directly from the mains and the temperature controlled by regulating the supply by means of a globe valve.

The first three runs of the first test were made on gasoline, the specific gravity of which was 63. This being Kansas Coop. oil. Very good results were obtained and no trouble encountered during the test. In the second hour run the B.H.P. averaged 6.595 and the efficiency .7287. The oil used was 1.396 gal. per hour, or .2075 gal. per B.H.P. per hour. The second run being a 3 hour test, the B.H.P. was not quite as high, being 5.908 and the efficiency .7507. The oil used was 1.590 gal. per hour, or .2674 gal. per B.H.P. per hour. The third run was for 5 hours; the B.H.P. was 6.037 and the efficiency .6678. The oil used per hour 1.2 gal. or .1987 gal. per B.H.P. per hour. This was a smaller fuel consumption for the 5 hour run, together with a smaller efficiency.

The second test, also composed of 3 runs similar to the first test, was made on gasoline, the specific gravity of which was only 54. This was also Kansas Coop. oil. Of the 2 hour run the average B.H.P. was only 5.747 and the efficiency .7818. The oil consumed per hour was 1.376 gal. or .2394 gal. per B.H.P. per hour. In the 3 hour run the average B.H.P. was 5.267 and the efficiency .7866 and the oil consumed per hour was 1.412 gal. or .2680 gal. per B.H.P. per hour. In the five hour run the average B.H.P. was 5.571 and the efficiency .6808. The oil consumed was 1.447 gal. per hour or .2597 gal. per B.H.P. per hour.

The third test was composed of many attempts to use kerosene and ended in an utter failure. All the kerosenes in stock were tried, consisting of the following:

Kerosene	Spec. Grav.	Flash	Fire
Water white	40	123	147
Radiant oil	43.8	120	145
Prime white	41.5	125	150

There seemed to be no difference in the results from using any of these oils. The first and greatest fault was that the explosion waves prevailed and our efforts to obviate them proved a failure. At first it was thought possible that an imperfect spark might be partially to blame but after putting in new ignition points the results were no better. Compression plates of varying thickness, and giving compressions varying from 55 lbs. to 95 lbs. were used, but the explosion waves still prevailed. Hot and cold cylinders were tried but with no better success. The entering air was then drawn in at a high temperature by admitting the air, around the exhaust pipe, and the results were no better than when the cool was used.

The explosive waves subjected the engine to violent shocks, which made it rock and vibrate violently.

GASOLINE.

G-1.
No. 6.

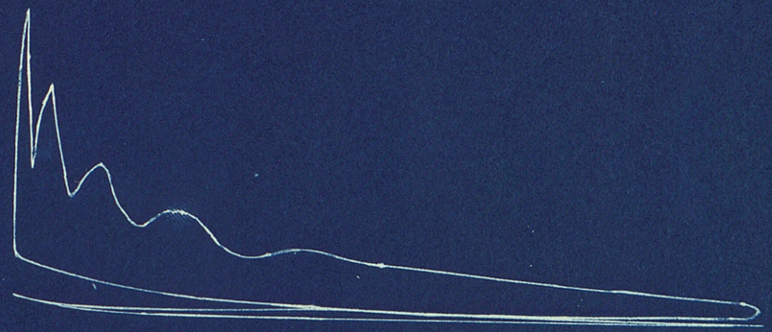
G-2.
No. 9.

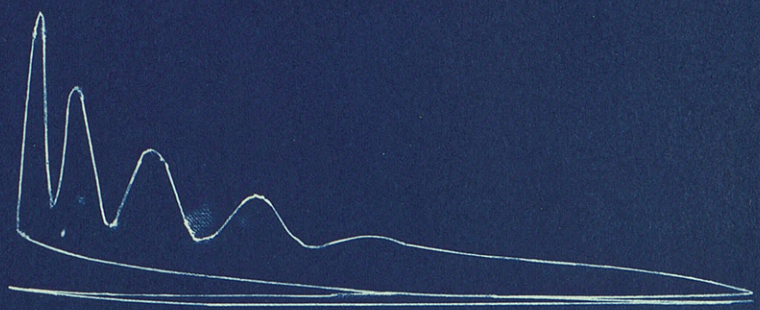
GASOLINE.

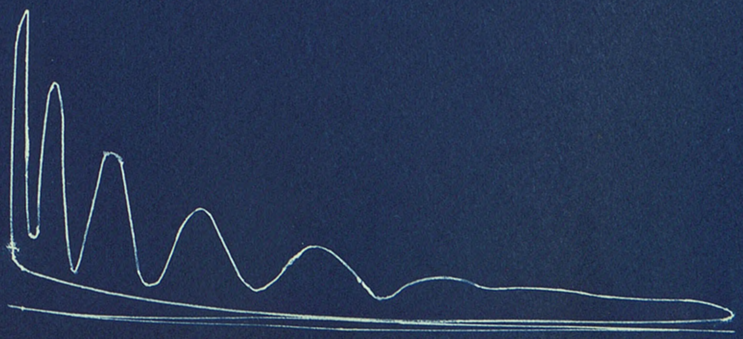
G.-1.
No. 9.

G.-2.
No. 8.

CARDS SHOWING EFFECT OF EXPLOSION WAVES DEVELOPED WHEN USING KEROSENE AS FUEL.







DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

TEST MADE AT

ON

DATE

BAROMETER IN LBS.

LOG OF GASOLINE ENGINE TRIAL.

CONSTANTS OF ENGINE.

Diam. of cylinder....... 7.25 in. Area of piston...... 41.28 sq. in.

Length of stroke........ 1.166 ft. Engine constant..... .0001459

Brake constant...... .0001

OBSERVERS:

F. B. McKINNELL.

ELMER JOHNSON.

No. Card.	Time.	R. P. M.	Brake Load	B. H. P.	Explosions per ...... Mins.	Explosions per Minute.	M. E. P.	I. H. P.	Eff.	Remarks.
1	3 10	255	20#	5.100		123	41.11	7.370	.6920	GASOLINE.
2	20	310	"	6.200		120	45.90	8.038	.7699	
3	30	313	"	6.260		115	50.40	8.459	.7290	SPECIFIC GRAVITY. .63
4	40	311	"	6.220		110	44.21	7.094	.8772	
5	50	302	"	6.040		111	46.90	7.5.98	.7950	
6	4 00	309	"	6.180		119	41.00	7.1.16	.8688	2.793 GAL. OIL USED.
7	10	300	"	6.000		108	47.40	74.68	.8034	1.396 " " " PER HR
8	20	285	"	5.710		104	43.50	6.5.95	.8658	.2075 " " " PER BK HP
9	30	257	"	5.150		117	46.00	7.248	.7104	
10	40	262	"	5.240		114	44.70	74.32	.7034	
11	50	270	"	5.400		124	38.60	6.981	.7738	
12	5 00	282	"	5.640		126	40.60	74.60	.7560	
	Maximum.	313		6260		126	5040	8.459	8772	
	Minimum,	255		5100		104	3860	6.595	6920	
	Total,	34.56		79140		1391	53032	88860	87447	
	Average,	288		6.595		115.8	44.19	7.405	.7287	

State kind of gasoline in each case

Department of Mechanical Engineering, K. S. A. C.

Log of Gasoline Engine Trial.

Test Made At ____________

On ____________

Date ____________

Barometer ________ In ________ Lbs.

Constants of Engine.

Diam. of cylinder....... 7.25 in.
Length of stroke........ 1.166 ft.
Area of piston..... 41.28 sq. in.
Engine constant..... .001459
Brake constant....... .0010

Observers:

F. B. McKinnell.
Elmer Johnson.

No. Card.	Time.	R. P. M.	Brake Load	B. H. P.	Explosions per ...... Mins.	Explosions per Minute.	M. E. P.	I. H. P.	Eff.	Remarks.
1	2 30	292	20#	5840		112	45.22	7.392	.7900	Gasoline
2	40	299	"	5980		116	48.04	8.149	.7351	
3	50	293	"	5860		117	45.59	7.779	.7538	Sp. Gr. .68
4	3 00	298	"	5960		109	55.58	8.831	.6730	
5	10	305	"	6100		106	54.75	8.462	.7209	4.771 Gal Oil Used
6	20	297	"	5940		98	63.09	9.018	.6593	1.590 " " Per Hr.
7	30	300	"	6000		99	58.56	8.452	.7089	.2674 Gal Oil Used Per Bk HP Hr.
8	40	284	"	5680		113	45.70	7.535	.7520	
9	50	290	"	5800		110	49.87	8.010	.7241	
10	4 00	299	"	5980		121	44.54	7.860	.7611	
11	10	300	"	6000		104	46.59	7.070	.8485	
12	20	298	"	5960		119	37.50	6.509	.9154	
13	30	298	"	5960		98	61.14	8.746	.6821	
14	40	299	"	5980		110	4500	7.219	.8290	
15	50	270	"	5400		116	51.28	8.681	.6254	
16	5 00	295	"	5900		100	57.26	8.354	.7061	
17	10	300	"	6000		119	39.67	6383	.8710	
18	20	300	"	6000		121	43.22	7634	.7862	
	30									
	Maximum.	305		610		121	63.09	9.018	.9154	
	Minimum,	270		540		98	37.50	6.509	.6254	
	Total,	5317		10634		1988	892.60	142574	135127	
	Average,	298.7		5.908		110.4	49.58	79208	.7507	

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

Test Made At ____________

On ____________

Date ____________

Barometer ________ In ________ Lbs.

LOG OF GASOLINE ENGINE TRIAL.

CONSTANTS OF ENGINE.

Diam. of cylinder 7.25 in. Area of piston 41.28 sq. in.

Length of stroke 1.166 ft. Engine constant .001459

Brake constant .0010

OBSERVERS:

F. B. McKinnell

Elmer Johnson.

No. Card.	Time.	R. P. M.	Brake Load	B. H. P.	Explosions per ...... Mins.	Explosions per Minute.	M. E. P.	I. H. P.	Eff.	Remarks.
										GASOLINE.
1	8 50	300	20#	6,000		130	43.88	8,328	.7204	Sp. Gr. .68
2	9 00	311	"	6,220		128	42.91	8.018	.7751	
3	10	306	"	6,120		126	42.96	7,892	.7754	6.00 Gal. Oil Used.
4	20	290	"	5,800		140	42.00	8,584	.6755	1.20 " " " Per Hr.
5	30	300	"	6,000		129	42.91	7,835	.7657	.1987 Gal. Oil Used Per. Bk. H.P. Hr.
6	40	288	"	5,760		118	44.06	9,596	.6000	
7	50	258	"	5,160		110	50.13	8,030	.6301	
8	10 00	290	"	5,800		117	43.67	7,459	.7760	
9	10	320	"	6,400		115	57.24	9,566	.6711	
10	20	306	"	6,120		126	42.90	8,910	.6857	
11	30	313	"	6,260		110	44.81	7,137	.8797	
12	40	280	"	5,600		134	45.39	8,803	.6361	
13	50	290	"	5,800		139	45.11	8.132	.7241	
14	11 00	280	"	5,600		135	46.66	9,066	.6177	
15	10	312	"	6,240		135	46.76	9,109	.6853	
16	20	300	"	6,000		115	50.00	8,395	.7148	
17	30	274	"	5,480		134	44.32	8,660	.6328	
18	40	300	"	6,000		114	48.38	8,175	.7339	
19	50	271	"	5,420		133	40.63	7,961	.6809	
20	12 00	317	"	6,340		120	43.27	7,580	.8364	
21	10	279	"	5,580		119	45.00	7,838	.7119	
22	20	320	"	6,400		134	40.34	7,877	.8125	
23	30	311	"	6,220		129	41.59	7,821	.7953	
24	40	301	"	6020		129	59.38	8,964	.6718	
25	50	318	"	6360		122	53.48	9,618	.6613	
26	1 00	286	"	5720		115	52.01	8,732	.6551	
27	10	296	"	5920		145	42.45	8,831	.6710	
28	20	318	"	6360		109	46.78	7,444	.8544	
29	30	261	"	5220		114	44.62	7,426	.7029	
30	40	301	"	6020		113	46.12	7,594	.7927	
	Maximum.	320		6400		145	5938	9618	8797	
	Minimum,	238		5220		109	4034	7137	6177	
	Total,	17757		181120		3618	137776	249581	200355	
	Average,	291		6.037		120	4590	8.031	.6678	

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

TEST MADE AT

ON

DATE

BAROMETER IN LBS.

LOG OF GASOLINE ENGINE TRIAL.

CONSTANTS OF ENGINE.

Diam. of cylinder 7.25 in. Area of piston 41.28 sq. in.

Length of stroke 1.165 ft. Engine constant .001459

Brake constant .0010

OBSERVERS: GA

F. B. McKINNELL.

ELMER JOHNSON.

No. Card.	Time.	R. P. M.	Brake Load	B. H. P.	Explosions per ... Mins.	Explosions per Minute.	M. E. P.	I. H. P.	Eff.	Remarks.
1	2 20	298	20#	5.960		115	45.75	7.873	.8060	
2	30	287	"	5.740		113	47.30	7.793	.7381	GASOLINE
3	40	288	"	5.760		110	45.75	7.341	.7848	
4	50	282	"	5.640		113	43.85	7.230	.7800	SP. GR. .54
5	3 00	280	"	5.610		116	42.82	7.250	.7741	
6	10	283	"	5.660		109	46.50	7.495	.7560	2.753 GAL OIL USED.
7	20	289	"	5.780		112	45.36	7.611	.75[illegible]	1.376 " " " PER HR.
8	30	286	"	5.720		115	42.80	7.181	.7963	.2394 GAL OIL USED PER BK. HP. HR.
9	40	290	"	5.800		112	42.58	7.010	.8265	
10	50	280	"	5.610		110	44.80	7.190	.7801	
11	4 00	292	"	5.840		110	47.70	7.583	.7698	
12	10	292	"	5.840		115	42.50	7.130	.8190	
	Maximum,	298		5960		116	47.70	7.793	.8265	
	Minimum,	280		5360		110	42.50	7.010	.7381	
	Total,	3447		6896		1350	53771	88.487	93807	
	Average,	287		5.747		112.5	4480	7.374	.7818	

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

TEST MADE AT

ON

DATE

BAROMETER ________ IN ________ LBS.

LOG OF GASOLINE ENGINE TRIAL.

CONSTANTS OF ENGINE.

Diam. of cylinder....... 7,25 in.
Length of stroke........ 1,166 ft.
Area of piston...... 41,28 sq. in.
Engine constant..... .0001459
Brake constant...... .0000

OBSERVERS:

F. B. McKINNELL.
ELMER JOHNSON.

No. Card.	Time.	R. P. M.	Brake Load	B. H. P.	Explosions per ...... Mins.	Explosions per Minute.	M. E. P.	I. H. P.	Eff.	Remarks.
1	2—00	280	20#	5,600		115	45,51	7,641	.7310	GASOLINE.
2	10	290	"	5,800		117	44,80	7,658	.7567	
3	20	298	"	5,960		114	44,52	7,435	.8020	Sp. Gr. .54
4	30	290	"	5,800		112	46,25	7,567	.7666	
5	40	295	"	5,900		119	45,52	7,910	.7459	
6	50	292	"	5,840		118	42,75	7,355	.7919	4,236 GAL OIL USED
7	3—00	288	"	5,760		115	42,85	7,190	.8010	1,412 " " " PER HR.
8	10	297	"	5,940		118	42,75	7,432	.7995	.2680 GAL OIL USED PER BK. H.P. HR.
9	20	298	"	5,960		114	44,75	7,453	.8000	
10	30	282	"	5,640		115	41,20	6,918	.8160	
11	40	285	"	5,700		120	41,20	7,215	.7909	
12	50	284	"	5,680		119	39,75	6,904	.8234	
13	4—00	292	"	5,840		109	44,73	7,136	.8190	
14	10	298	"	5,960		116	45,09	7,655	.7789	
15	20	279	"	5,580		118	40,66	7,028	.7950	
16	30	279	"	5,580		113	44,75	7,381	.7561	
17	40	280	"	5,600		116	42,65	7,216	.7878	
18	50	284	"	5680		111	43.62	7,030	.8080	
	Maximum,	298		5960		120	4625		.8234	
	Minimum,	279		5580		109	3975		.7310	
	Total,	4992		103820		2079	78335		141597	
	Average,	221,6		5267		115,5	4352		.7866	

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

TEST MADE AT

ON

DATE

BAROMETER IN LBS.

LOG OF GASOLINE ENGINE TRIAL.

CONSTANTS OF ENGINE.

Diam. of cylinder....... 7.25 in. Area of piston....... 41.28 sq. in.

Length of stroke........ 1.166 ft. Engine constant....... .001459

Brake constant....... .0010

OBSERVERS:

F. B. McKinnell

Elmer Johnson.

No. Card.	Time.	R. P. M.	Brake Load	B. H. P.	Explosions per .... Mins.	Explosions per Minute.	M. E. P.	I. H. P.	Eff.	Remarks.
										GASOLINE
1	9.00	290	20#	5.800		129	44.92	8.442	.6872	
2	20	292	"	5.840		138	45.20	9.068	.6441	Sp Gr. .54
3	30	293	"	5.860		123	40.49	7.809	.7532	
4	40	295	"	5.900		124	45.30	8.191	.7203	7.239 Gal. Oil Used.
5	50	296	"	5.920		132	43.78	8.438	.7017	1.447 " " " Per Hr.
6	10.00	296	"	5.920		129	47.79	8.884	.6664	.2597 Gal Oil Used Per Bk. HP. Hr.
7	10	288	"	5.760		127	44.24	8.403	.6855	
8	20	292	"	5.840		130	46.21	8.770	.6659	
9	30	298	"	5.960		129	45.85	8.635	.6903	
10	40	296	"	5.920		132	43.40	8.264	.7164	
11	50	298	"	5.960		134	43.80	8.579	.6948	
12	11.00	282	"	5.640		139	46.35	9.406	.5997	
13	10	255	"	5.100		125	46.05	8.406	.6067	
14	20	260	"	5.200		127	44.90	8.325	.6247	
15	30	268	"	5.360		131	45.90	6.778	.7908	
16	40	278	"	5.560		124	42.34	7.650	.7260	
17	50	290	"	5.800		138	43.50	8.954	.6478	
18	12.00	265	"	5.300		117	44.26	7.560	.7011	
19	10	287	"	5.740		130	45.82	8.696	.6601	
20	20	275	"	5.500		133	42.80	8.310	.6618	
21	30	275	"	5.500		133	46.21	8.974	.6129	
22	40	272	"	5.440		126	45.11	8.298	.6240	
23	50	264	"	5.280		132	41.61	8.020	.6584	
24	1.00	264	"	5.280		126	42.57	7.831	.6743	
25	10	257	"	5.140		123	41.40	7.434	.6914	
26	20	245	"	4.900		118	42.75	7.394	.6627	
27	30	285	"	5.700		126	42.45	7.809	.7299	
28	40	280	"	5.600		124	43.20	7.820	.7162	
29	50	278	"	5.560		129	44.25	8.319	.6684	
30	2.00	278	"	5.560		130	44.25	8.398	.6620	
	Maximum,	296		5.960		139	47.78	7406	7908	
	Minimum,	245		4.900		117	40.49	7394	5997	
	Total,	8392		167.140		3858	1323.60	267.855	20.4246	
	Average,	279.4		5.571		128.6	40.12	8.925	.6808	