AN INVESTIGATION

of the

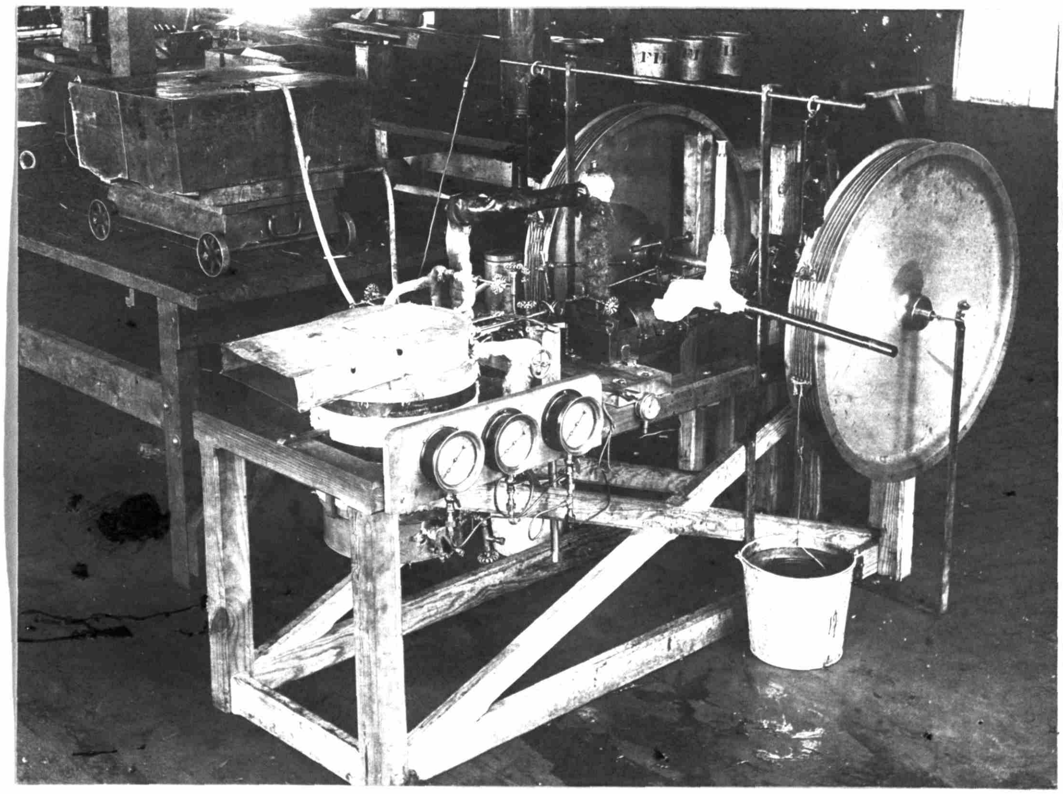
EFFICIENCY OF THE STANLEY AUTOMOBILE ENGINE AND BOILER

WITH SPECIAL REFERENCE TO THE USE OF SUPERHEATED STEAM

J. W. Crowell.

F O R E W O R D .

The writer wishes here to acknowledge his indebtedness to Mr. Francis E. Stanley for his very great assistance. Mr. Stanley not only furnished the entire equipment for the tests, but, by his interest and advice, did much to further the work.



LIST OF ILLUSTRATIONS.

Fig. No.		Page.
Frontispiece.	Photograph of Apparatus .	
1.	Plan view of engine	4.
2.	Side view of engine	4.
3.	Top view of burner plate	4.
4.	Bottom view of burner plate	4.
5.	Burner casting	4.
6.	General view of apparatus	6.
7.	Plan view of apparatus	7.
8.	Double superheating system	64.
9.	Single superheating "	64.
10.	Special superheating system	64.

C O N T E N T S .

	Page.
CHAPTER I.	
Object of Thesis.	1.
CHAPTER II.	
Description of Apparatus.	2.
CHAPTER III.	
Details of Tests.	9.
CHAPTER IV.	
Account of Tests.	15.
CHAPTER V.	
Results of Tests.	58.

CHAPTER I.

Object of Thesis.

In the operation of an automobile on the road it is very difficult to investigate the efficiency of its mechanism, as it is impossible to accurately determine the power developed. In order to form definite ideas in regard to the economy and power of the Stanley automobile engine and boiler under various conditions, a special apparatus was built, embodying all the essential working parts of a carriage, but affording means for the accurate measurement of the power developed, and for securing other necessary data.

The apparatus was so constructed that the power measured would correspond to the power delivered to the rim of the wheel under actual conditions, the same friction losses being introduced. This enabled direct comparisons to be made.

The point of greatest interest to be studied, was the influence upon the efficiency of superheating the steam. In addition, the effects of varying the load, the speed and the point of cut-off of the engine were to be considered.

CHAPTER II.

Description of Apparatus.

Before showing the arrangement of the testing apparatus, a brief description of the motive parts of the automobile manufactured by the Stanley Motor Carriage Company of Newton, will be given.

The engine has two double acting cylinders, with a common steam chest. The stroke is $3\frac{1}{2}$", and the bore $2\frac{1}{2}$". It has ordinary slide valves, and a Stevenson link motion, which in full gear gives a cut-off at about $\frac{5}{8}$ stroke. The pistons each have two broad packing rings. The crank shaft, crank pin, eccentric shafts and cross head are all fitted with ball bearings. Fig 1, page 4 gives a plan view of engine, Fig. 2, a side view.

The boiler is of the vertical fire tube type with copper shell and tubes. The shell is wound with two layers of steel wire. No rivets are used in the construction, the heads being held to the shell by electrically welded steel rings shrunk on. There are 295, $\frac{1}{2}$" copper tubes, giving a heating surface of 37 sq. ft. The boiler is well lagged with asbestos. The superheating of the steam is accomplished by throttling and by passing the steam through the boiler tubes and through steel tubes in the fire box.

The ordinary equipment is shown in Fig. 8, (Page 64), the course of the steam being indicated by arrows.

The burner consists of a cast iron shell, slotted, for the outlet of the gases.. Fig. 3 shows a top view, and Fig. 4 a bottom view of the plate. The arrangement of the vaporizer and casing is shown in Fig. 5. The gasoline for the main burner passes through the pipe 1, (Fig. 5) and, leaving the jet 2, enters the mixing tube 3. The pilot light has an independent vaporizing tube, 4, and jet 5.

The water level in the boiler is shown by a special indicator, thus doing away with a water glass, and allowing the use of very high boiler pressures. The indicator consists of an enlarged water column, in which is placed a cylindrical brass float, attached to a light chain running over a sector carried by a rod passing through the wall of the chamber. The leakage of steam is prevented by a small, nicely ground conical bearing, which offers but slight resistance to the rotation of the rod. On the outside end of the rod is a wheel carrying a cord on which is suspended a lead counterweight. The brass cylinder, partly balanced by the counterweight, floats on the water, and by the position of the outside wheel the level can be followed very closely.

The testing apparatus consisted of an engine and boiler, with the pump and other fixtures set up in a heavy wooden frame. Fig. 6 (Page 6) gives a general idea of the arrangement, and

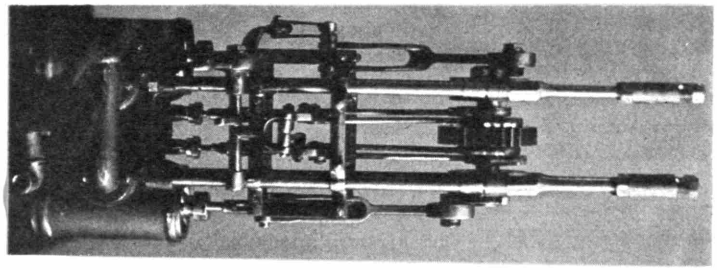


Fig. 1

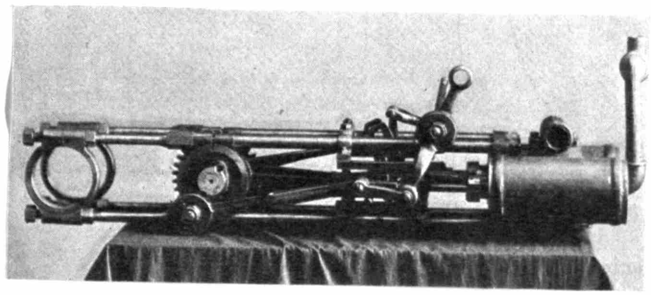


Fig. 2

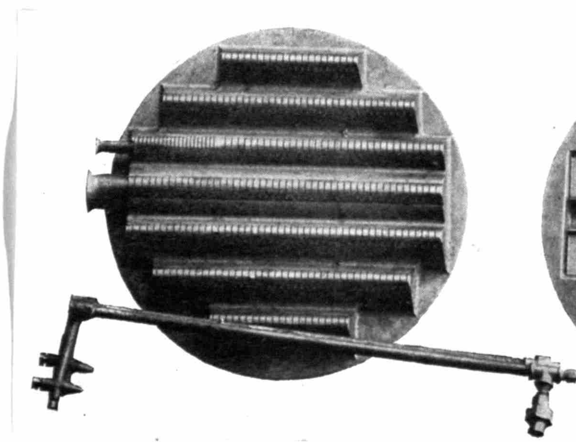


Fig. 3

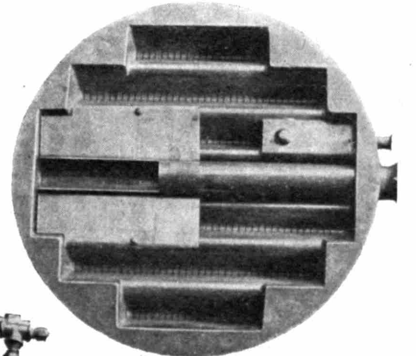


Fig. 4

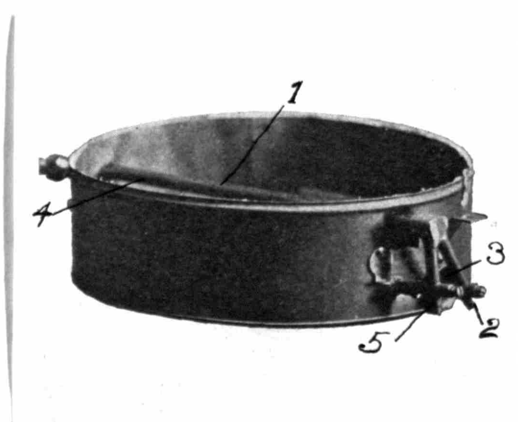


Fig. 5

Fig. 7 shows a plan view of the essential parts. The engine, 1, (Fig. 7 Page 7) is geared directly to the shaft 2, carrying the brake wheels 3 and 4. The water pump 5, and the gasoline pump 6, are both operated through the rocker 7, the connecting rod 8, and lever 9. The water pump is supplied from the tank A (Fig. 6) and when the valve 10 (Fig. 7) is closed, delivers the water to the boiler 11, through the pipe 12. If the by-pass valve 10 is open, the water is allowed to return to the supply tank through the pipe 13.

The gasoline pump draws from the tank b. (Fig. 6) through the pipe 14 (Fig. 7) and delivers into the pipe 15. In order to provide an air cushion, the pressure tank 16 is connected to the system at 17. The pressure is controlled by an automatic by-pass valve 18, which allows the gasoline to return to the supply tank through the pipe 19, when the required pressure is reached. When the by-pass is closed, the gasoline passes up through the valve 20. From here part of the fuel goes through the valve 21 to the pilot light, and the remainder passes through the pipe 22, into a coil on top of the boiler, which serves to raise its temperature so that it is more quickly vaporized on reaching the burner. Leaving the coil it passes through the valve 23 to an automatic regulator. This serves to shut off the gasoline supply to the main burnner when the boiler pressure reaches the required amount. It is operated by the action of the steam pressure upon a diaphragm.

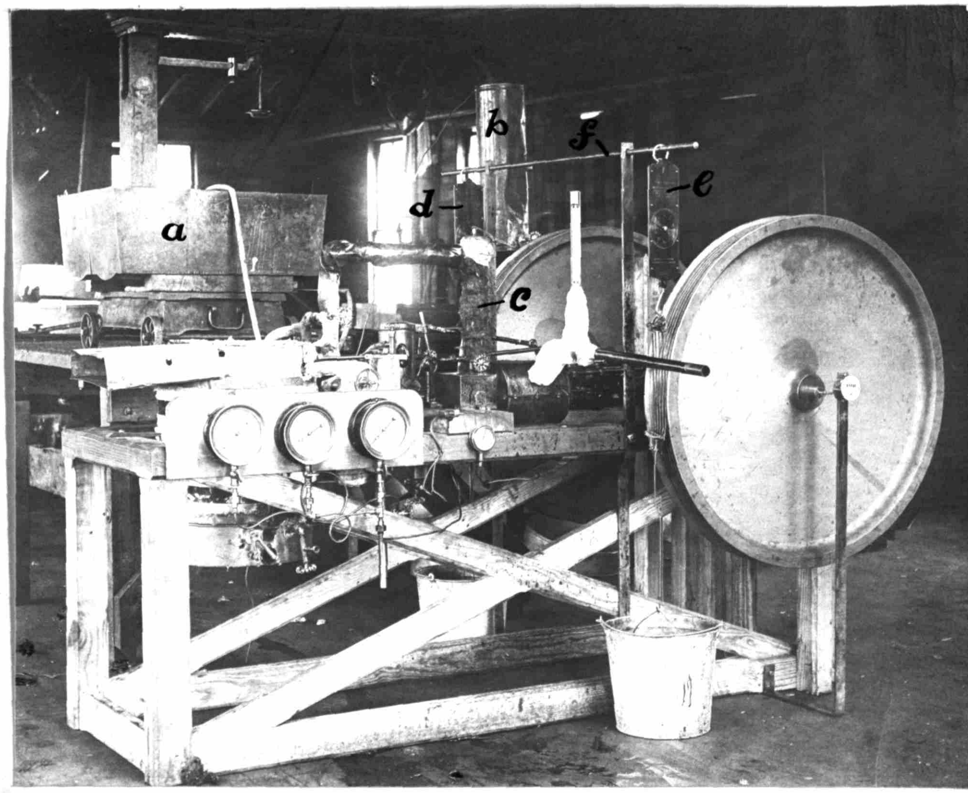
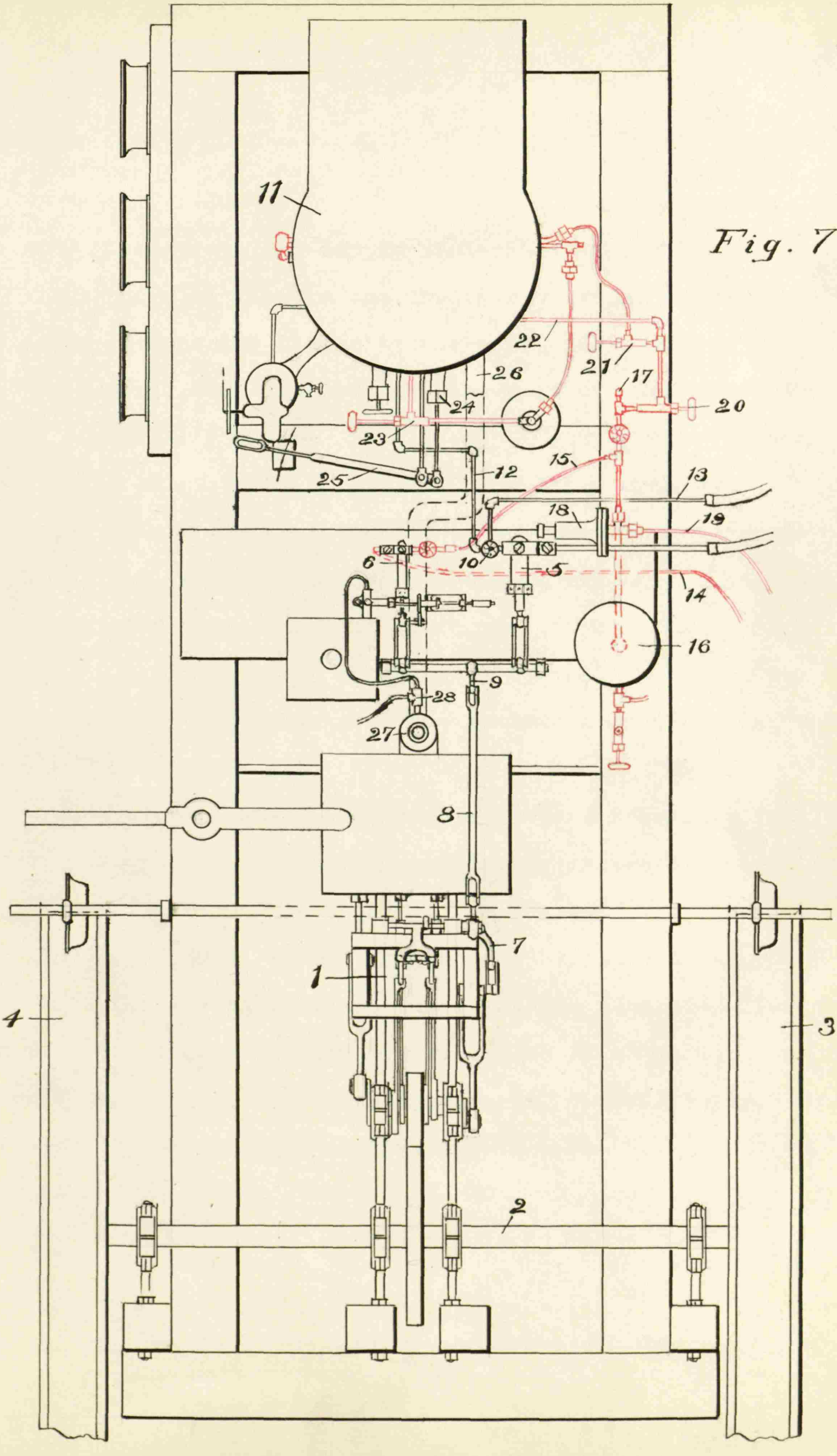


Fig. 6

Fig. 7



The throttle valve, 24, is controlled by the lever, 25. The steam, passing through the throttle valve and superheating coils, leaves the boiler by the pipe, 26. Before entering the engine, the steam passes through the thermometer jacket, 27 (also C. Fig. 6). This consists simply of a copper tube closed at the bottom, encased by a large iron pipe. The steam passes downward, completely surrounding the copper tube, and out into the steam chest of the engine. The thermometer is immersed in oil in the copper tube. The pipe entering the jacket at 28 serves as a connection to a steam gauge, to give the pressure in the jacket, and also as an inlet for the cylinder oil.

The cylinders are oiled by a mechanically operated device consisting of a small pump intermittently driven by a cam operated from a ratchet wheel.

The arrangement of the friction brakes is well shown in Fig. 6. The spring balances, d and e, are supported from the rod f. The counterweights are suspended in water to check the vibrations. The brake band consists of 5 small ropes, the strain being distributed evenly between them.

CHAPTER III.

Details of Tests.

The feed water was weighed in the tank from which it was pumped to the boiler. The tank was set on a Fairbank platform scale. The connections to the pump were made with flexible rubber tubing. The scales were in good condition, and were sensitive and accurate to 1/4 lb. At the beginning and end of a test the water level in the boiler was brought to a fixed point, and the scales balanced. The only possible error with this method was in determining the water level from the indicator. The higher the boiler pressure the less sensitive the indicator became. At pressures less than 200 lbs. the water level could certainly be found within 1/4". With the highest pressures, the error could not possibly be greater than 1/2". The area of the boiler being about 84 sq. in., an error of 1/2" in water level would give an error of 42 cu. in. or 1.58 lbs. In the average test this would give a maximum possible error of 1.8% in the total amount of water, and an error of about .7% in the water per H.P. hour. The gasoline was weighed in the supply tank at the beginning and end of the test. The weighing was done on a pair of small Fairbanks scales, which were tested and found to be accurate within 1/2 ounce. It was necessary to take the supply from the bottom of the tank, and since rubber tubing could not be used on account of the gasoline, an eight foot length of flexible drawn copper tubing was arranged so that no pull would be exercised on the connections. This was found to have no effect on the balance of the scales. The by-pass pipe was supported entirely free from the tank, and discharged into the top through a hole.

An error of 1/2 oz. in weighing the gasoline used would produce in the average test an error of about .45% in the total amount used and .18% in the gasoline per H.P. hour.

It is believed that a very accurate determination of the power developed could be made with the apparatus used. The scales for measuring the pull were two large spring balances, reading to ounces, and having a range of 60 lbs. These scales were carefully tested, and the maximum error was found to be 3 oz. at 50 lbs. pull. By having the counterweights immersed in water, the fluctuations of the balance needles never exceeded 1/2 lb. The pull changed quite rapidly with the speed of the engine, but as the r.p.m. never varied by more than 4 or 5 per minute, the mean of three-minute readings was thought to give a result well within the accuracy of the rest of the test. At first considerable trouble was caused by the heating of the wheels, which resulted in a rapid increase in the pull. By the continuous application of kerosene to the ropes, this difficulty was entirely overcome, the pull remaining practically constant, even if the wheels became very hot.

The counterweights were weighed immersed in the water, with the same balance used in connection with them. Due allowance was made for the weight of the rope which did not act on the brake wheel. An error of 1/2 lb. in measuring the effective pull would cause an error of .9% in the calculated horse power, with a 2.5 H.P. test.

It is to be observed that the power measured is the net power developed, or the power which the engine is actually capable of delivering to the rim of the wheel. The friction losses are practically the same as in the automobile, the brake wheel shaft running on ball bearings as does the ordinary rear axle. The brake wheels weigh about 350 lbs. apiece, thus giving about the same load on the outside bearings as in a carriage.

The brake wheels were of sufficient weight to secure smooth running of the engine, but the fly wheel effect of a carriage is, of course, much greater.

The revolutions of the brake wheels were taken with an ordinary counter. The units place could be read at the highest speed.

The gauges used were tested before beginning the experiments. No attempt was made to determine the boiler pressure closer than five pounds, as this has no bearing on the results. Readings were taken, however, at three-minute intervals, in order to have a record of any undue fluctuation which might have an influence on the other conditions of the test.

The steam chest pressure, or what was actually found, the pressure in the thermometer jacket, was determined as closely as possible. Up to pressures of 60 lbs. a gauge reading to tenths of a pound was used. Above 60 lbs. a gauge which could be read to 1/2 lb. was substituted. These gauges were carefully compared and tested. The 60 lb. gauge was accurate within 1/4 lb. The accuracy of the other gauge was within the limits of 1/2 lb. readings.

The back pressure on the engine was found to be less than 1/10 lb. It was therefore assumed to be 14.7 lbs. absolute.

The temperature of the feed water was read at 12 min. intervals, during the test. A centigrade thermometer was used. This could be read to 1/10 of a degree.

The temperature of the gases after leaving the boiler was found by placing a thermometer in the bonnet. It was observed that the temperature varied greatly in different parts of the bonnet. For purposes of comparison the temperature was always taken centrally over the boiler, above the gasoline coil. This coil served to heat the cold gasoline before it was supplied to the burner, and it was due to this that the bonnet temperature was always below the boiler temperature.

The temperature of the steam supplied to the engine was observed by means of the thermometer jacket already described. The thermometer was immersed its whole length in an oil bath, thus removing the necessity for steam exposure corrections. Readings were taken to single degrees, the thermometer being easily accurate to this extent. The tube holding the oil was of thin copper, and, being completely surrounded by moving steam, must have followed the fluctuations in temperature very closely.

The exhaust temperature was found by a Crosby thermometer, having the bulb surrounded by moving steam. The exhaust pipe was wrapped with a thick layer of asbestos to prevent loss of heat before taking the temperature.

The various points of cut-off in the series of tests to observe the gain in linking up the engine were found in the following manner. In each test the space between the end of the link blocks and the end of the link, on the side of engine away from the pump rocker, was measured carefully, with the crank on the crank end dead point. After the completion of all the tests, the steam chest cover was removed, and the actual points of cut-off of each cylinder corresponding to these positions were noted.

CUT-OFF IN PERCENT OF STROKE.

Position of Link Blocks	Cylinder No.1 H E	C E	Cylinder No.2 H E	C E	Average C.O.
Full Gear	73	54	76	51	63.5
5/16	65	48	68.5	44	56.3
1/2	51.5	37	55	33	44.1
3/4	34	23	38	19.5	28.6
7/8	25.5	14	29	12.5	20.2
15/16	22	12.5	25.5	9	18.2

The cut-offs used in plotting the results are the average of the four strokes, as taken from the above table.

The same quality of gasoline was used in all the tests. The heat of combustion of one sample was determined by the Junkers' Gas Calorimeter. Four runs were made with the following results.

18960 B.T.U. per lb.
18790 " " "
18700 " " "
18760 " " "

Average 18800 B.T.U. per lb.

This result is considered correct within one percent.

CHAPTER IV.

Account of Tests.

The first five tests run were of one-half hour duration. Three of these tests were carried out under similar conditions in order to observe how closely the results would check up. A considerable variation was found to exist, and on looking over the data, it was observed that there was a large difference in the exhaust temperature of the separate tests. In some it was noticed that this temperature rose steadily throughout the run. It was therefore decided to warm up the engine for a longer time before beginning readings, and to increase the length of the run.

Tests Nos. 6, 7 and 8 were two-hour tests, but the water and gasoline were weighed at the end of each hour, thus giving practically two tests. Great care was taken to allow the engine to warm up until the temperature of the exhaust became consistent, one hour being necessary when starting with a cold engine. On comparing the results of these tests, it was found that the two halves of each run checked up within one or two per cent, and no fluctuations in exhaust temperature were found. It was therefore decided to make the succeeding tests of one hour duration.

In these preliminary runs several things of importance in conducting the remainder of the test were noted.

The back pressure was found to be practically atmospheric pressure, and the amount of superheat at the exhaust was therefore calculated by assuming the temperature of the saturated steam as 212°F.

It was seen to have little effect on the burner draught, whether or not the steam was exhausted into the bonnet. Hence, it was thought best to deliver the steam directly out of doors, instead of into the bonnet, as in the automobile, the back pressure not being affected.

In the first tests, the water in the boiler was regulated in the usual manner, by closing and opening the by-pass valve when necessary. As this caused a slight change in the speed of the engine, another method was tried in the two-hour tests. Instead of closing the by-pass valve tightly when the water in the boiler was low, and opening it wide when it became too high, the valve was adjusted so as to just maintain a constant level by allowing a little water to flow back all the time. In this way changes in speed were avoided, but the engine was kept pumping against boiler pressure during the entire test. It was thought that as the stroke of the pump was quite closely adjusted to supply about the right amount of water, the additional work would be negligible. In comparing the results of the tests, however, it was at once seen that this was not the case, and therefore in all other tests the usual method was followed. Tests Nos. 6, 7 and 8 were discarded on account of this difference.

It was anticipated that the raising and lowering of the water level would, by changing the amount of moisture in the steam at the throttle, have an influence on the degree of superheat obtained. No fluctuation due to this cause could be observed.

The change in superheat, observed in all the tests, was due to the changes in the gasoline supply to the main burner. When the by-pass was opened and no cold water was pumped into the boiler, the fire was necessarily reduced, and the superheat would drop immediately. On closing the by-pass, the temperature of the steam would again rise.

It was found that care had to be taken not to screw up stuffing boxes unnecessarily tight. The lubrication of the cylinders was also seen to have a direct influence on the results. With one exception, the oil worked regularly and fed a uniform supply of oil in all the tests. One test, during which the oil did not feed properly, was discarded.

No difficulty was found in bringing the water level to the same point at the beginning and end of the test. Although the position of the indicator was constantly changing, it was possible to estimate very closely what the conditions would be four or five minutes ahead and regulate the by-pass accordingly. It was usually possible to have the level rising at the beginning and end of the hour, thus throwing out the error due to the lag of the indicator. The time on one test was lengthened to one hour and a half to allow the water to reach the required point.

The bonnet or flue gas temperature was not taken in tests

9, 10 and 11, owing to a broken thermometer.

Records of each test, in which there was no known error follow:

KEY TO RECORDS OF TEST.

COLUMN I.

Time.

COLUMN II.

Counter Readings.

COLUMN III.

Boiler Pressures.

COLUMN IV.

Steam Chest Pressures.

COLUMN V.

Bonnet or Flue Gas Temperature.

COLUMN VI.

Temperature of Superheated Steam at the Engine.

COLUMN VII.

Temperature of Exhaust Steam.

COLUMN VIII.

Feed Water Temperature.

COLUMN IX.

Readings of Brake Scale No.1.

COLUMN X.

Readings of Brake Scale No.2.

TEST NO. 9.

Gasoline Press = 100.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 9.80.
Counter weight brake No. 2 =

1	2	3	4	5	6	7	8	9	10
11.30	97931	400	33.2		594	290			35.6
.33	98541	400	33.2		578	290			35.2
.36		400	34.3		582	289	10.8		36.5
.39	99714	400	34.2		605	290			36.2
.42	00317	400	33.3		608	292			34.9
.45	00932	400	33.2		502	291			35.6
.48	01531	400	33.8		568	291	10.9		35.5
.51	02118	400	34.0		587	291			35.9
.54	02726	395	34.2		609	291			36.2
.57	03352	400	34.0		616	295			36.0
12.00	03971	400	34.0		615	296	10.9		36.0
. 3	04601	400	33.3		590	298			36.0
. 6	05218	400	33.2		571	296			35.5
. 9	06427	400	34.2		594	295			36.5
.12		400	34.0		608	295	11.0		36.7
.15		400	34.0		592	296			36.5
.18		400	33.8		573	294			36.9
.21	08234	400	34.1		578	292			36.8
.24	08829	400	34.1		607	292	11.1		36.7
.27	09432	400	34.2		613	294			36.8
.30	10042	400	33.8		610	296			36.8
Total	12111		710.1		1248.0	6154			753.8
Aver.	201.85	400	33.81		594.28	293.04	10.9		35.895

Water at start = 158.50
Water at end = 105.25
Water used 53.25

Gasoline at start = 22.25
Gasoline at end = 17.50
Gasoline used 4.75

TEST No. 10.

Gasoline Press = 100
Cut off in percent of stroke = 64
Counter weight 9.87 lbs.

1	2	3	4	5	6	7	8	9	10
1.30	10042	400	33.8	236	610	296		36.8	
.33	10645	400	33.6	236	574	295		36.5	
.36	11230	400	35.0	236	594	294	12.2	37.5	
.39	11811	400	35.2		610	295		38.2	
.42	12395	400	35.2		612	295		38.2	
.45	12986	400	34.2		600	296		37.3	
.48	13580	400	34.2		574	296	12.2	37.0	
.51	14162	400	34.8		574	292		36.9	
.54	14770	400	35.6		594	293		37.6	
.57	15384	400	35.0		612	295		37.3	
.60	15997	400	35.0		614	296	12.3	37.3	
. 3	16612	400	34.8		609	297		37.3	
6	17234	400	34.6		582	297		37.3	
9	17833	400	34.1		567	294		36.8	
.12	18425	400	34.8		587	292	12.4	36.8	
.15		400	34.8		608	292		37.0	
.18		400	34.8		612	295		37.4	
.21	20250	400	34.3		601	296		37.1	
.24	20853	400	34.8		592	295	12.4	37.0	
.27	21462	400	34.2		595	295		37.1	
2.30	22063	400	34.7		583	295		37.0	
Total	12021		727.5		12504	6191		781.4	
Aver.	200.35	400	34.64		59542	294809	12.3	37.21	

Water at start	105.25		Gasoline at start	17.50
Water at end	48.75		Gasoline at end	12.75
Water used	56.50		Gasoline used	4.75

TEST NO. 11.

Gasoline Press. 100
Cut off in percent of stroke 64%
Counter weight = 12 1-16 lbs.

1	2	3	4	5	6	7	8	9
3.00	30080	400	37.8		593	278		41.6
.03	30687	400	37.4		595	280		41.7
6	31297	400	37.1		603	284	10.0	41.8
9	31910	400	37.3		594	287		41.5
12	32516	400	37.5		607	288		41.6
15	33141	400	37.5		608	290		42.7
18	33757	400	37.0		556	290	10.0	42.3
21	34359	400	37.1		555	290		42.0
24	34967	400	37.4		603	290		42.2
27	35579	400	37.4		613	290		42.1
30	36198	400	37.5		616	293	10.1	42.1
33	36811	400	37.4		615	296		42.2
36	37436	400	37.0		596	297		42.2
39	38050	400	36.9		575	296		42.0
42	38647	400	37.1		588	292	10.1	42.1
45	39250	400	37.3		608	295		42.2
48	39865	400	37.0		610	295		42.2
51	40472	400	37.0		588	295		42.0
54	41074	400	37.3		606	296	10.1	42.3
57	41687	400	37.0		600	296		42.3
4.00	42289	400	37.1		585	296		42.3
Total	12209		782.1		12514	6114		883.4
Aver.	203.48	400	37.24		595.90	291.14	10.06	42.066

Water at start	183.50	Gasoline at start	21.75
Water at end	123.25	Gasoline at end	16.50
Water used	60.25	Gasoline used	5.25

TEST No. 12.

Gasoline Press = 100
Cut off in percent of stroke = 64.
Counter weight = No. 1 = 12.00, No. 2 = 12.875.

1	2	3	4	5	6	7	8	9	10
4.00	71904	390	63	395	581	273		44.5	43.8
.03	72493	390	62	395	580	273		44.4	44.0
.6	73089	390	62	395	580	273	11.6	44.3	44.0
.9	73687	390	62	398	580	274		44.2	44.5
.12	74279	400	62	400	580	274		45.0	45.2
.15	74904	425	64	398	576	275		44.5	45.1
.18	75312	400	63	398	581	275	11.6	44.1	44.8
.21	76107	395	63	403	590	276		44.2	44.9
.24	76700	400	63	403	585	276		44.0	45.2
.27	77299	400	63	403	582	276		44.0	45.4
4.30	77891	395	63	398	585	277	11.7	43.8	45.7
.33		400	63	403	582	277		43.0	45.8
.36		400	64	398	581	278		44.0	46.5
.39	79649	400	64	400	584	275		43.4	46.6
.42	80206	390	64	400	583	275	11.8	43.2	47.0
.45	80780	395	64	395	583	276		43.5	45.4
.48	81362	398	64	398	583	275		43.4	45.7
.51	81941	395	64	398	583	275		43.4	45.9
.54	82324	395	64	395	584	275	11.8	43.4	46.0
.57	82905	400	64	395	583	275		43.4	46.5
5.00	83670	400	64	400	574	275		43.4	46.7
Total	11766	6348	1329	8368	12230	5778		921.1	954.5
Averg.	196.1	397	63.3	398	582.3	275	11.7	43.86	45.45

Water at start 201.75
Water at end 103.25
Water used 98.50

Gasoline at start 25 lbs. 1oz
Gasoline at end 15 " 4
Gasoline used 9 " 13"

TEST NO. 13.

Gasoline Press. 100.
Cut off in percent of stroke 64.
Counter weight 5 lbs. 6 oz.

1	2	3	4	5	6	7	8	9
9.35	96981	405	29.3	378	578	282		25.4
.38	97592	400	29.2	378	610	284		25.3
.41		410	29.3	358	585	287	6.2	25.2
.44		410	29.4	353	568	288		24.8
.47	99453	440	29.6	360	568	286		25.0
.50	00260	430	29.9	368	595	287		25.2
.53		405	29.2	353	583	287	6.2	25.0
.56	01386	410	29.5	370	591	286		24.8
.59	01890	420	30.7	363	602	288		26.0
10.02	02490	415	30.6	358	583	287		25.7
5	03079	410	30.0	363	583	288	6.25	25.5
8	03669	415	30.6	369	598	288		25.6
11	04267	410	30.2	372	608	290		25.7
14	04799	415	29.9	352	590	291		25.7
17		410	29.9	352	572	291	6.3	25.3
20	06065	415	29.9	361	588	289		25.2
23	06635	420	30.8	364	594	288		25.5
26	07218	415	30.6	358	585	289		25.8
29	07800	410	30.1	354	582	289	6.3	25.6
32	08382	410	30.2	362	583	287		25.6
10.35	08972	425	29.8	354	592	287		25.4
Total	11991	8700	628.7	7600	12338	6039		535.5
Aver.	19985	414.28	29.92	361.90	587.52	287.57	6.25	25.50

Water at start	172.50	Gasoline at start	16.50
Water at end	125.50	Gasoline at end	12.125
Water used	47.00	Gasoline used	4.375

TEST NO. 14.

Gasoline Press. 95.
Cut off in percent of stroke 44%.
Counter weight No. 1 7.0
Counter weight No.2 7.4

1	2	3	4	5	6	7	8	9	10
11.00	93152	430	73	380	598	254	9.9	30.6	31.3
.03	93829	430	72	400	582	254		30.5	31.3
6	94490	430	72	403	585	254		30.5	31.4
9	95156	420	72	400	580	253	10.0	30.0	31.1
12	95812	420	73	415	600	253		30.6	31.6
15	96489	430	72	395	582	253		30.3	31.4
18		415	72	400	582	252	10.2	30.2	31.7
21	97803	430	73	408	604	253		30.2	31.7
24	98480	435	73	410	606	254		30.2	31.8
27	99151	430	72	395	581	254	10.4	30.2	31.7
30	99799	430	73	406	605	256		30.0	31.8
33		430	73	406	607	257		29.9	31.9
36	01126	430	72	401	603	256	10.6	29.9	32.0
39		430	72	395	573	255		29.8	31.9
42	02446	415	72	402	583	253		29.4	31.8
45	03094	430	73	404	607	254	11.0	29.8	32.2
48	03759	430	73	407	610	255		29.7	32.1
51	04422	430	73	407	607	257		29.8	32.5
54		425	72	404	592	256	11.2	29.7	32.4
57	05750	420	72	400	582	256		29.3	31.9
60	06393	425	72	403	594	256	11.3	29.4	32.0
Total	13241	8965	1521	8441	12463	5349	84.6	630.0	6674
Aver.	220.68	427	72.4	402	593.4	254.7	10.57	30.0	31.78

Water at start 215.25
Water at end 146.25
Water used 69.00

Gasoline at start = 15 - 15.
Gasoline at end = 8 - 14 1/2.
Gasoline used 7 - 14 1/2.

TEST No. 15.

Gasoline Press = 110
Cut off in percent stroke = 44.
Counter weight brake No. 1 = 5 1/8.
Counter weight brake No. 2 = 4 5/8.

1	2	3	4	5	6	7	8	9	10
12.00	36591	425	63		375	590	250	24.5	25.2
.03	37208	420	63		375	581	252	24.5	24.8
. 6	37818	420	63	17.6	382	607	253	24.3	25.0
. 9	38433	430	64		380	607	256	24.3	25.0
.12	39069	425	63		375	584	257	24.4	25.1
.15	39683	420	63		379	585	257	24.1	25.8
.18	40297	420	63	17.6	388	608	258	24.1	24.8
.21	40925	440	64		382	611	261	25.3	24.3
.24	41574	425	63		375	584	261	24.2	24.9
.27	42191	420	63		384	592	260	23.9	24.7
.30	42812	425	63	17.6	385	612	260	23.9	24.8
.33	43435	430	64		381	614	262	24.3	25.2
.36	44092	430	63		373	588	263	24.0	24.8
.39	44733	425	62		375	574	261	23.9	24.8
.42		420	63	17.6	380	600	261	23.8	24.8
.45		425	63		384	615	262	23.9	24.8
.48	46587	425	63		386	619	264	23.8	24.9
.51	47236	445	64		384	606	265	24.1	25.3
.54	47887	415	63	17.8	378	581	264	23.9	24.9
.57	48504	420	63		384	602	263	23.9	25.0
.60	49146	425	63		384	609	264	24.1	25.3
Total	12555	8930	1326		7989	12569	5454	5072	5242
Aver.	20925	42523	6314	17.6	38042	59852	25971	2415	2496

Water at start 205.5
Water at end 144.75
Water used 60.75

Gasoline at start 14-15
Gasoline at end 9-12 1-2
Gasoline [illegible]

TEST NO. 16.

Gasoline Press. 110.
Cut off in percent of stroke 64%
Counter weight, No.1 5 1-8
Counter weight, No.2 4 5-8

1	2	3	4	5	6	7	8	9	10
3.20	58030	425	44		395	616	295	24.5	25.7
23	58623	425	44		393	604	291	24.1	25.4
26	59216	420	44	17.9	395	611	293	24.2	25.5
29	59812	420	44		396	612	295	24.2	25.6
32	60425	425	43		383	590	296	24.2	25.6
35		425	43		381	575	295	24.2	25.8
38		425	44	18.0	392	604	294	23.9	25.7
41		425	44		397	615	296	24.0	25.8
44	62819	420	44		397	614	297	24.0	25.9
47	63415	430	44		394	612	298	23.7	26.3
50	64025	425	43	18.0	380	583	297	23.9	26.1
53	64621	415	43		380	574	295	23.9	26.2
56		420	44		392	601	295	23.8	26.3
59		420	44		395	615	296	23.8	26.4
2	66387	420	44	18.0	396	616	297	23.8	26.5
5	66981	420	44		396	615	299	23.8	26.6
8		425	44		395	612	300	23.8	26.7
11		425	44		382	592	300	23.8	26.7
14		415	44		380	575	297	23.8	26.7
17	69344	420	44		391	582	296	23.6	26.9
4.20	69931	420	44		392	609	295	23.7	26.9
Total	11901	8865	920		8202	12637	6017	5029	5503
Aver.	198.35	422.1	43.80	18.0	39057	60176	28652	23.94	26.20

Water at start	210.75	Gasoline at start	15 - 2
Water at end	139.0	Gasoline at end	8 - 12
Water used	71.75	Gasoline used	6 - 6

TEST NO. 17.

Gasoline Press. 110
Cut off in percent of stroke = 29.
Counter weight brake No. 1 = 5 1/8
Counterweight brake No. 2 = 4 5/8.

1	2	3	4	5	6	7	8	9	10
4.45	73898	425	94		366	576	245	24.2	25.6
.48	74421	415	94		372	575	244	24.2	25.7
.51	75047	420	95	19.1	382	602	242	24.2	25.6
.54		425	95		385	613	242	24.5	26.0
.57		425	95		371	583	242	24.3	26.0
.60	76970	420	95		381	592	242	24.3	25.8
3	77610	420	95	192	385	610	242	24.4	25.9
6		425	95		370	598	242	24.5	26.1
9	78910	425	94		365	578	241	24.5	26.1
12		425	95		375	599	241	24.3	26.1
15		425	95	19.2	378	612	241	24.3	26.2
18	80816	430	95		378	616	242	24.6	26.5
21	81467	425	94		362	582	242	24.4	26.4
24	82089	420	74		375	595	242	24.5	26.3
27		425	95	19.2	378	612	242	24.5	26.5
30		430	95		369	606	242	24.8	26.8
33		425	94		362	580	242	24.3	26.7
36		425	93		358	575	241	24.2	26.5
39	85235	420	95	19.2	375	605	241	24.5	26.9
42	85861	425	95		372	612	241	24.7	27.1
45	86481	425	95		375	607	241	24.4	27.2
Total	12583		1987		7834	12528	50805	126	552.0
Aver.	209.72	425	94.61	19.2	37285	59658	24190	24.41	26.29

Water at start 175.0
Water at end 117.0
Water used 58.0

Gasoline at start 12 - 11 1-2
Gasoline at end 7 - 13 1-2
Gasoline used 4 - 14

TEST NO. 18.

Gasoline Press. 80 - 90
Cut off in percent of stroke = 29.
Counter weight brake No. 1 = 14 1/2.
Counter weight brake No. 2 = 13 1/4.

1	2	3	4	5	6	7	8	9	10
4.00	97930	420	133		409	602	247	46.9	47.7
3	98611	415	132		407	595	247	46.5	47.3
6	99262	410	132	16.6	416	606	247	46.5	47.3
9	99912	410	133		416	607	247	46.4	47.8
12		415	133		417	606	247	46.7	47.9
15	01236	415	133		418	605	247	47.2	48.8
18	01919	415	132	16.7	408	595	246	46.6	48.0
21	02572	410	132		413	605	244	46.7	48.3
24	03236	415	133		417	606	245	46.6	48.5
27		435	134		406	598	246	47.4	49.4
30	04572	420	133	16.7	413	601	244	47.0	48.9
33		415	133		414	605	243	46.9	49.1
36	05880	440	136		411	602	243	47.9	50.6
39	06542	415	133		406	600	244	47.0	49.8
42	07184	420	134	16.8	400	605	244	47.4	49.8
45	07829	415	134		408	605	243	47.1	50.1
48		415	134		418	605	243	47.3	50.7
51		435	134		405	595	243	48.2	51.5
54	09736	420	135	16.8	419	602	244	47.3	51.0
57	10359	425	136		425	606	245	47.6	51.3
5.00	10996	425	138		425	606	246	47.8	51.8
Total	13066	8805	2807		8671	12657	105	9890	10356
Aver.	217766	419.0	133.7	16.7	422.4	602.3	245.0	47095	49.31

Water at start	201.75	Gasoline at start	14 - 2
Water at end	110.00	Gasoline at end	5 - 13 1-2
Water used	91.75	Gasoline used	8 - 4 1-2

TEST NO. 19

Gasoline Press. 110
Cut off in percent of stroke = 56.
Counter weight brake No. 1 = 6 16/16.
Counter weight brake No. 2 = 4 1/2.

1	2	3	4	5	6	7	8	9	10
4.10	20002	425	52		358	595	271	26.3	25.7
13	20643	425	52		381	582	271	25.9	25.6
16	21266	425	52	12.6	394	603	272	26.2	25.8
19	21996	425	52		398	613	273	26.2	25.8
22		430	52		399	612	274	26.4	26.2
25		430	52		381	582	276	26.2	26.9
28	23801	420	52	12.7	388	584	275	26.0	25.8
31		430	52		395	610	276	26.2	25.9
34	25065	430	52		392	613	278	26.2	25.9
37		430	52		381	588	278	26.3	26.2
40		425	52	12.8	383	590	277	26.1	26.0
43		430	53		395	610	278	26.2	26.3
46		425	52		390	611	280	26.3	26.4
49		425	52		375	575	278	26.2	26.3
52		425	52	12.9	390	582	274	26.4	26.4
55	29463	425	53		386	598	275	26.4	26.5
58		430	53		394	612	277	26.4	26.7
61		430	53		384	600	278	26.5	26.9
4		420	52	12.9	383	587	277	26.2	26.5
7	31931	425	53		391	605	277	26.3	26.8
5.10	32548	425	52		381	606	278	26.5	27.0
Total	12596	8975	52.23		8119	12558	5793	5524	551.6
Aver.	209.1	427		12.8	3866	597.6	2759	2626	25.27

Water at start 216.5
Water at end 148.75
Water used 67.75

Gasoline at start 15 - 10 1-2
Gasoline at end 9 - 14
Gasoline used 5 - 12 1-2

TEST No. 20.

Gasoline Press = 110
Cut off in percent stroke = 20
Counter weight Brake No. 1 = 6 15-16.
Counter weight Brake No. 2 = 4 1-2.

1	2	3	4	5	6	7	8	9	10
5.30	34841	435	117		392	600	242	28.0	28.3
.33	35482	440	113		384	601	241	27.4	27.9
.36	36107	425	112	14.2	375	582	241	27.0	27.4
.39	36698	425	113		387	594	242	27.3	27.7
.42		430	115		383	605	242	27.6	27.9
.45		430	118		373	580	241	27.4	27.8
.48	38519	430	118	14.2	386	594	241	27.2	27.7
.51	39124	430	115		387	611	241	27.6	28.0
.54	39753	435	115		376	596	241	27.7	28.1
.57	40374	425	112		374	575	240	27.4	27.7
.60	40962	430	114	14.2	385	594	240	27.4	27.8
. 3	41570	430	115		388	611	240	27.7	28.0
. 6		440	115		379	602	241	27.7	28.3
. 9	42819	425	115		379	581	241	27.5	28.3
.12	43412	430	114	14.2	383	600	241	27.4	28.0
.15	44019	435	117		387	611	241	27.7	28.4
.18		430	117		382	608	242	27.8	28.5
.21		430	113		372	577	241	27.6	28.3
.24	45843	430	113	14.2	384	593	240	27.4	28.0
.27	46439	430	115		383	611	240	27.6	28.4
6.30	47052	430	117		384	605	241	27.7	28.7
Total	12211	9045	2423		8023	12531	5030	578.1	5892
Aver.	20352	4307	1153	14.2	3819	5966	2410	2752	2909

Water at start 187.25
Water at end 127.50
Water used 59.75

Gasoline at start 15 - 6oz.
Gasoline at end 10 - 5 1-2 oz
Gasoline used 5 - 1-2

TEST NO. 21.

Gasoline Press = 110.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 5.75.
Counter weight brake No. 2 = 3 15/16.

1	2	3	4	5	6	7	8	9	10
10.00	53207	100	43		301	508	245	25.7	24.6
3	53860	100	44		302	507	246	25.5	24.5
6	54496	100	44.5	8.6	302	506	247	25.8	24.3
9	55121	100	45		302	504	247	25.7	24.2
12	55747	100	44		287	481	246	25.4	24.2
15	56346	100	43		282	481	244	25.6	24.3
18	56957	100	43	8.6	299	505	244	25.4	24.3
21	57577	100	44		303	511	246	25.6	24.4
24	58299	100	44		303	511	246	25.3	24.5
27	58819	100	44		302	508	246	25.4	24.4
30		100	44	8.6	300	506	246	25.3	25.0
33		100	44		287	481	245	25.3	24.4
36	80679	100	44		284	479	243	25.2	24.4
39	81280	100	44		294	496	243	25.4	24.6
42		100	44	8.6	301	510	245	25.4	24.6
45		100	44		303	513	247	25.4	24.7
48		100	44		302	512	247	25.4	24.7
51	63786	100	44		291	492	247	25.4	24.7
54	64395	100	44	8.7	297	501	247	25.4	24.7
57	65017	100	44		302	511	246	25.4	24.7
11.00	65650	100	44		301	512	247	25.9	25.3
Total	12443		922.5		6245	10535	5160	534.9	515.5
Aver.	207.38	100	43.90	8.6	298.4	501.7	245.7	25.47	24.54

Water at start = 193.5
Water at end 114.5
Water used 79.0

Gasoline at start 15-7 1/2
Gasoline at end 9-4 1/2
Gasoline used 6-3

TEST No. 22.

Gasoline Press = 110.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 5.75
Counter weight brake No.2 = 3 15/16.

1	2	3	4	5	6	7	8	9	10
11.25	69676	210	44		354	548	257	25.4	25.1
.28	70291	235	45		351	547	257	26.1	25.8
31	70883	205	44	8.6	351	548	261	25.1	24.8
34	71460	200	44		352	558	262	25.2	24.8
37	72058	200	44		354	562	264	25.4	25.1
40	72678	220	45		349	555	265	25.9	25.7
43		220	45	8.6	343	537	263	25.8	25.6
46		205	44.5		351	554	263	25.3	25.0
49		200	44.5		353	564	265	25.3	25.1
52		200	44.5		352	563	266	25.3	25.1
55	75717	200	44.5	8.7	352	561	266	25.3	25.1
58	76337	215	45		343	544	266	25.8	25.4
61	76956	195	44		343	534	264	25.4	25.1
4	77549	200	44.5		352	554	264	25.4	25.1
7	78147	200	44.5	8.8	352	562	266	25.8	25.4
10		210	44.5		356	566	266	25.7	25.5
13	79406	230	45.5		353	558	267	25.9	25.8
16	80017	200	44.5		347	531	266	25.7	25.4
19		220	45.0	8.8	360	561	266	25.8	25.6
22	81278	220	45.0		361	568	267	25.8	25.6
12.25	81912	215	45.0		358	567	268	25.8	25.6
Total	12236	4400	936.5		7387	11642	5549	5376	531.7
Aver.	203.93	209.5	44.6	8.7	351.8	554.4	264.2	25.60	25.32

Water at start = 212.75
Water at end = 136.50
Water used 76.25

Gasoline at start = 14 - 40
Gasoline at end = 8 - 0
Gasoline used 6 - 4

TEST No. 23.

Gasoline Press = 110.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 5.75.
Counter weight brake No. 2 = 3 15/16.

1	2	3	4	5	6	7	8	9	10
1.00	86798	570	46		398	616	286	26.2	25.9
3	87419	560	46		408	625	290	26.2	25.9
6		570	46	9.0	408	635	297	26.2	26.0
9		570	46		398	620	298	26.0	25.8
12	89516	570	45		392	595	298	25.8	25.6
15		560	45		402	610	296	25.8	25.5
18		565	45	9.0	410	636	298	26.0	25.6
21	91159	560	45.5		412	642	301	25.9	25.6
24	91783	560	45.5		412	643	304	25.9	25.6
27	92405	560	46.		412	643	306	25.9	25.6
30	93004	565	45	9.1	410	641	307	25.4	25.2
33	93588	570	45		408	637	307	25.7	25.6
36	94191	570	44		391	611	307	25.4	25.3
39	94781	570	44		393	594	302	25.4	25.3
42	95371	560	45	9.2	404	620	300	25.7	25.6
45	95991	570	45.5		410	637	302	25.8	25.7
48	96609	565	45.5		408	638	303	25.8	25.7
51	97231	570	45.5		408	638	305	25.8	25.7
54	97864	570	45.5	9.2	398	619	306	26.0	25.8
57	98473	560	45.5		406	625	305	25.8	25.6
2.00	99095	560	45.5		405	631	306	25.9	25.7
Total	12297	11870	948.0		8511	13356	6324	5426	537.5
Aver.	204.95	565	45.14	9.15	405.3	624.7	301.1	25.83	25.60

Water at start = 212.25
Water at end = 138.25
Water used 74.00

Gasoline at start = 15 - 7 1/2
Gasoline at end = 8 -14 1/2
Gasoline used 6 - 9

TEST No. 24.

Gasoline Press = 105.
Cut off percent stroke = 64.
Counter weight brake No. 1 =7.0
Counter weight brake No. 2 = 4 15/16.

1	2	3	4	5	6	7	8	9	10
2.50	07092	390	44.2		380	582	284	25.3	27.6
.53	07540	390	44.0		392	589	284	25.3	27.5
.56		390	44.0	17.6	396	594	284	25.3	27.6
.59		410	44.0		383	589	284	25.7	28.0
.62	08911	395	44.0		384	577	283	25.3	27.6
. 5		400	44.0		395	594	282	25.4	27.7
8		400	44.0	17.7	396	597	283	25.4	27.8
.11	10284	410	44.0		382	592	284	25.7	28.0
.14		390	44.0		384	577	282	25.4	27.8
.17		405	44.1		395	596	282	25.4	27.9
.20	41679	400	44.0	17.7	395	601	282	25.4	27.9
.23		400	44.0		395	602	284	25.4	27.9
.26		405	44.2		398	602	284	25.6	28.0
.29		420	44.2		382	598	284	25.8	28.2
.32	13529	405	44.2	17.7	382	582	284	25.4	27.9
.35		400	44.2		393	592	282	25.4	27.9
.38		400	44.2		394	598	282	25.4	28.0
.41		405	44.2		398	600	284	25.5	28.1
.44	15378	415	44.3	17.7	380	588	285	25.9	28.4
.47	15851	400	44.2		383	576	283	25.6	28.3
3.50	16298	410	44.4		395	589	282	25.6	28.3
Total	9206	8440	4	17.7	182	12415	5948	5351	5864
Aver.	153.43	402	44.11	17.7	385.8	591.2	282.9	25.48	27.90

Water at start = 195.5
Water at end = 139.0
Water used 56.5

Gasoline at start = 14 - 7oz.
Gasoline at end = 9 - 11 oz.
Gasoline used 4 - 12 oz.

TEST NO. 25.

Gasoline Press = 110.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 5 3/16.
Counter weight brake No. 2 = 3 14/16.

1	2	3	4	5	6	7	8	9	10
4.20	21360	400	44.2		407	597	295	25.3	23.0
.23	22061	395	44.0		406	602	296	25.2	23.1
.26		395	44.2	18.0	407	608	297	25.2	23.1
.29	23452	405	43.3		386	590	299	23.6	23.4
.32	24156	390	43.8		392	593	298	23.6	23.4
.35	24847	395	44.0		406	605	299	23.8	23.6
.38	25774	425	44.6	18.0	384	607	301	24.2	23.9
.41	26319	395	44.0		467	592	301	23.9	23.6
.44	27036	400	44.2		402	607	302	24.1	23.5
.47	27774	420	44.5		390	600	303	24.4	24.0
.50		390	44.1	18.1	393	595	302	24.0	23.8
.53	29230	400	44.2		396	606	302	24.2	23.7
.56	29970	420	44.2		385	592	303	24.4	24.1
.59		400	44.3		394	598	301	24.2	23.9
2		405	44.5	18.1	398	611	301	24.3	24.0
5	32153	405	44.8		402	616	304	24.3	24.0
8	32880	410	44.8		401	614	305	24.4	24.1
.11		425	44.8		394	602	307	24.7	24.4
.14	34357	400	44.5	18.2	392	593	304	24.2	24.1
.17	35066	405	44.8		398	611	303	24.3	24.2
5.20	35793	405	44.9		398	612	304	24.4	24.3
Total		8445	9307		4338	11251	6327	510.7	4992
Aver.	240.55	402.1	44.31	18.1	397.0	602.4	301.3	24.24	23.76

Water at start = 173.25
Water at end = 90.0
Water used 83.25

Gasoline at start = 14 - 8oz.
7 - 6 1/2oz.
Gasoline used 7 - 1 1/2oz.

TEST No. 26.

Gasoline Press = 110.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 4 11/16.
Counter weight brake No. 2 = 3 6/16.

1	2	3	4	5	6	7	8	9	10
9.40	42153	425	43.7		379	600	276	23.1	24.3
.43	42693	425	43.7		378	604	277	23.2	24.4
.46	43234	425	43.6	10.8	379	607	281	23.2	24.3
.49		425	43.6		380	607	283	23.3	24.4
.52		425	42.9		372	586	285	23.0	24.4
.55		425	42.9		371	574	283	22.8	24.1
.58		425	43.0	10.8	377	602	284	23.0	24.2
.61		425	43.1		377	608	286	23.0	24.2
. 4	46511	425	43.0		379	610	287	23.1	24.2
. 7		425	43.0		379	610	289	23.0	24.2
.10		425	42.3	10.9	375	597	291	22.9	24.3
.13	48171	425	42.1		369	577	289	22.8	24.1
.16		425	42.6		378	590	287	22.8	24.0
.19	49258	425	42.9		379	606	288	22.8	24.2
.22		425	43.0	11.0	380	611	290	22.8	24.1
.25	50366	425	42.9		379	611	291	22.7	24.1
.28	50919	425	42.2		375	603	292	22.8	24.2
.31		425	42.4		375	592	292	22.7	24.0
.34		425	42.6	11.0	379	604	292	22.7	24.1
.37		425	42.0		370	594	292	22.8	24.2
10.40	53130	425	42.3		375	590	291	22.7	24.0
Total	10977	8925	8998		7905	12583	6026	4812	5080
Aver.	182.95	425	42.85	10.9	376.43	599.19	286.95	22.914	24.19

Water at start = 181.50
Water at end = 118.50
Water used 63.00

Gasoline at start = 11 - 10oz.
6 - 4oz.
Gasoline used 5 - 6

TEST No. 27.

Gasoline Press = 110.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 3 12/16.
Counter weight brake No. 2 = 3 6/16.

1	2	3	4	5	6	7	8	9	10
11.00	56011	420	43.2		382	600	284	19.4	25.8
.03	56690	430	44.0		388	610	289	21.4	25.8
. 6	57383	425	43.9	11.8	375	586	291	21.0	25.5
. 9	58048	415	44.0		383	590	292	20.9	25.4
.12	58715	420	44.0		389	611	294	21.2	25.6
.15		420	44.2		392	616	297	21.2	25.6
.18		425	44.0	11.8	379	601	298	21.3	25.8
.21		420	43.9		384	591	297	21.0	25.5
.24		420	44.0		389	612	298	21.2	25.7
.27		425	44.3		393	616	300	21.2	25.7
.30		425	44.0	12.0	379	600	301	21.2	25.8
.33		420	44.0		383	594	299	21.0	25.4
.36		420	44.0		388	610	300	21.2	25.8
.39		425	44.4		388	615	301	21.2	25.7
.42		430	44.0	12.1	380	602	302	21.2	25.9
.45		415	44.0		377	582	299	21.0	25.6
.48	66996	415	44.0		385	609	298	21.0	25.7
.51	67568	425	44.5		388	615	300	21.2	25.9
.54	68231	425	44.0	12.2	379	601	301	21.2	26.0
.57	68935	415	44.0		384	600	298	20.9	25.8
.00	69607	420	44.0		387	609	299	21.0	25.9
Total	13596	8855	924.4	59.9	8072	12670	6238	4419	5389
Aver.	226.6	421.66	44.02	11.98	384.19	603.33	297.05	21.04	25.66

Water at start = 161.00
Water at end = 81.25
Water used 79.75

Gasoline at start = 15 - 3 1/2
8 - 5 1/2
Gasoline used 6 14

TEST NO. 28.

Gasoline Press = 100.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 3 4/16.
Counter weight brake No. 2 = 3 0/16.

1	2	3	4	5	6	7	8	9	10
12.40	75114	405	43.5		400	602	292	20.0	23.4
.43		425	43.6		388	593	297	20.3	23.6
.46	76745	390	42.9	11.2	394	598	297	19.9	23.7
.49	77524	405	43.6		403	608	300	20.2	23.8
.52	78328	410	44.0		408	608	302	20.3	23.7
.55	79164	425	44.0		395	585	303	20.3	23.8
.58	79954	375	42.8	11.3	397	590	301	19.7	23.7
.61	80715	400	43.9		402	609	302	20.0	24.0
. 4		405	44.0		405	611	304	20.2	23.9
. 7		415	44.1		400	607	305	20.2	23.9
.10		425	44.0	11.6	397	583	305	20.4	24.2
.13		400	43.8		398	596	303	20.0	24.1
.16		395	43.8		399	608	303	20.0	24.2
.19		395	43.4		398	608	304	19.8	23.9
.22		430	44.0	11.8	394	601	305	20.5	24.0
.25		360	42.8		386	590	303	19.7	23.9
.28	87824	430	44.0		394	593	303	20.6	24.3
.31	88615	405	44.0		402	598	302	20.1	24.6
.34	89413	410	44.2	12.0	406	611	304	20.3	24.7
.37	90190	410	44.2		402	604	306	20.2	25.1
1.40	90954	395	44.1		400	601	305	19.9	25.1
Total	1584	8510	918.7	57.9	8358	12604	6346	4226	5057
Aver.	264.0	405.23	43.74	11.58	398	600	30.21	20.12	24.08

Water at start = 202.0
Water at end = 113.25
Water used 88.75

Gasoline at start = 14 - 4 1/2
Gasoline at end = 6 - 3
Gasoline used 8 - 1 1/2

TEST NO. 29.

Gasoline Press = 120.
Cut off percent stroke = 20
Counter weight brake No. 1 = 10 14/16.
Counter weight brake No. 2 = 6 0/16.

1	2	3	4	5	6	7	8	9	10
2.40	98404	380	167		425	598	240	44.4	46.3
.43		360	166		423	583	242	44.3	46.9
.46	99761	360	166	11.6	418	590	243	44.7	47.8
.49	00427	360	166		416	589	242	44.7	49.1
.52	01075	375	169		415	589	242	44.4	50.4
.55		360	168		408	576	242	45.2	48.4
.58		360	170	11.8	411	586	242	45.2	49.1
. 1		360	170		409	584	240	45.7	48.0
. 4		350	170		401	581	242	46.2	50.4
. 7		340	163		401	585	242	45.0	49.0
.10	05006	350	166	11.8	404	587	242	45.0	45.9
.13	05656	355	167		403	585	243	45.2	46.3
.16		360	168		402	583	241	45.1	47.8
.19		360	165		410	583	242	45.9	46.0
.22		425	178	12	406	578	243	47.9	48.3
.25		385	173		420	586	242	47.6	50.4
.28		370	174		419	590	242	43.8	52.3
.31		370	173		414	598	242	44.2	53.0
.34		370	175	12.1	410	600	243	44.4	51.7
.37		375	176		408	600	243	44.2	54.5
3.40	11502	375	177		412	600	242	44.4	53.0
Total	13098	7700	3567	59.3	8635	1251	5082	9475	1034.0
Aver.	218.30	3.69	169.85	11.87	411.19	595.71	242.0	45.12	49.26

Water at start = 199.5
Water at end = 96.0
Water used 103.5

Gasoline at start = 14 - 4
Gasoline at end = 2 - 8
Gasoline used 11 - 12

TEST NO. 30.

Gasoline Press = 100.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 4 1/4.
Counter weight brake No. 2 = 3.

1	2	3	4	5	6	7	8	9	10
3.40	22247	390	45.0		390	525	252	23.8	24.0
.43		400	45.0		389	530	252	25.3	24.2
.46		415	46.0	13.0	388	531	257	25.8	24.0
.49	24146	430	46.0		380	512	256	25.8	24.0
.52	24784	390	45.5		380	512	255	24.7	24.5
.55	25388	395	45.5		384	530	254	24.8	24.4
.58		400	45.5	13.0	386	531	256	24.7	24.2
. 1		375	45.0		380	531	257	24.7	24.3
. 4		410	45.8		391	536	257	24.5	24.0
. 7		420	46.0		395	537	258	24.8	23.8
.10		375	45.0	13.1	385	529	257	24.8	23.8
.13		415	45.1		375	523	257	25.4	23.2
.16		415	45.2		389	517	256	25.5	23.1
.19		420	46.0		394	534	256	26.0	23.1
.22		410	45.3	13.2	394	537	257	25.7	22.9
.25		405	45.2		396	536	258	25.7	22.7
.28	32352	410	45.2		396	536	260	25.8	22.8
.31		410	45.1		379	521	259	26.4	22.4
.34	33668	405	45.0	13.3	389	529	258	25.8	22.4
.37	34309	405	45.0		392	534	258	26.0	22.4
4.40	34964	405	45.1		390	530	258	26.3	22.3
Total	12717	8480	952.5	65.6	8142	11101	5388	5323	492.5
Aver.	2119.5	403.8	45.35	13.12	387.71	528.6	256.57	25.34	23.45

Water at start = 173.25
Water at end 91.50
Water used 81.75

Gasoline at start = 14 - 10
Gasoline at end = 7 - 12 1/2.
6 - 13 1/2

TEST NO. 31.

Gasoline Press = 100.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 4 1/16.
Counter weight brake No. 2 = 3 10/16.

1	2	3	4	5	6	7	8	9	10
5.15	39000	90	45.0		306	441	227	24.9	24.1
.18	39592	90	45.0		306	442	228	25.0	24.2
.21	40189	85	45.0	13.8	306	440	228	25.1	23.9
.24		85	45.0		300	438	228	25.1	23.9
.27	41444	100	47.0		296	432	227	26.3	24.4
.30	42100	85	46.1		295	432	227	25.3	24.2
.33	42701	85	45.2	13.9	297	439	227	25.3	23.8
.36	43301	80	45.2		300	440	227	25.3	23.9
.39		80	45.0		305	438	227	25.4	23.8
.42	44514	80	45.1		306	439	227	25.4	23.9
.45		80	45.1	14.	306	438	227	25.4	23.6
.48		80	45.1		306	436	227	25.6	23.7
.51	46334	80	45.1		306	435	227	25.7	24.0
.54		90	45.2		296	430	227	25.6	24.0
.57		80	45.2	14.2	300	432	227	25.7	24.6
.60		80	45.2		304	438	226	25.7	24.1
. 3		80	45.2		306	436	227	25.7	23.8
. 6		85	45.2		306	435	227	25.7	24.3
. 9		80	45.2	14.2	308	445	228	25.8	23.9
.12	49508	80	45.2		308	445	228	25.8	24.5
6.15	50494	80	45.8		306	437	228	25.8	24.8
.18		90	45.9	14.0	305	435	228	27.8	24.8
.21		80	47.0		305	435	228	26.2	24.7
.24		80	46.8		307	442	228	26.2	25.2

TEST NO. 31 (continued).

Gasoline Press = 100.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 4 1/16.
Counter weight brake No. 2 = 3 10/16.

1	2	3	4	5	6	7	8	9	10
.27		80	46.8		307	443	227	26.3	24.4
.30	53454	80	46.8	14.0	305	441	227	26.3	25.4
.33	44027	80	48.1		304	440	227	26.3	26.2
.36	54604	80	47.0		306	438	227	26.2	23.9
.39	55204	80	46.0		306	437	227	25.8	24.4
.42	55808	80	46.0	14.0	306	435	227	26.0	24.9
.45	56401	80	46.0		305	434	227	26.0	25.1
Total	17401	1647.0	1417.5	112.1	9425	1356.8	7045.9	598.7	754.4
Aver.	193.34	82.35	45.91	14.01	304.39	438.2	227.28	25.87	24.46

Water at start = 161.25
Water at end = 31.50
Water used = 129.50

Gasoline at start = 13 6 1/2.
Gasoline at end = 3 13
Gasoline used = 9 9 1/2.

TEST NO. 32.

Gasoline Press = 105.
Cutt off percent stroke = 64.
Counter weight brake No. 1 = 7.0.
Counter weight brake No. 2 = 7 1/8.

1	2	3	4	5	6	7	8	9	10
3.15	85764	200	44.1		359	491	244	28.2	24.9
.18	86440	200	43.8		358	493	244	27.4	25.3
.21	87081	200	42.9	16.2	338	475	244	27.3	25.6
.24	87717	200	43.0		345	478	243	27.3	25.2
.27		200	43.1		352	496	244	27.2	25.6
.30		200	43.8		351	497	245	27.4	25.5
.33	8	200	43.1	16.2	342	483	245	27.2	25.7
.36	90254	200	43.2		333	473	243	27.2	25.9
.39	90870	200	44.2		343	479	242	27.8	24.5
.42	91519	200	43.1		351	494	243	27.8	24.4
.45	92145	200	43.2	16.3	352	497	245	27.7	24.7
.48	92787	200	43.0		347	493	246	27.8	24.7
.51		200	43.0		332	470	244	27.8	25.0
.54		200	43.7		346	477	243	27.9	25.2
.57		200	43.9	16.6	352	496	244	27.9	25.4
.60		200	44.0		353	498	245	27.8	25.8
.03		200	44.1		350	497	246	27.9	20.0
. 6		200	44.0		337	475	245	27.7	26.0
. 9		200	44.8	16.8	348	490	243	27.9	27.0
.12	97781	200	45.2		351	495	244	27.9	27.6
4.15	98367	200	45.3		345	490	244	27.8	28.0
Total	12603		918.4	82.1	7285	10237	5126	580.9	538.3
Aver.	210.05	200	43.73	16.4	346.90	487.47	244.09	27.66	25.63

Water to start = 165.50
Water at end = 86.25
Water used = 79.25

Gasoline at start = 14 - 4 1/2.
Gasoline at end = 7 - 15.
Gasoline used = 6 - 5 1/2

TEST NO. 33.

Gasoline Press = 105.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 7.0
Counter weight brake No. 2 = 7 1/8.

1	2	3	4	5	6	7	8	9	10
4.35	01566	300	43.8		373	512	248	27.6	25.6
.38	02188	300	44.3		372	516	249	27.8	26.4
.41	02805	300	44.1	16.0	352	495	249	27.7	26.6
.44		300	44.6		351	491	247	27.9	27.1
.47		300	45.2		372	518	247	28.3	25.8
.50		300	44.6		378	525	251	28.4	25.7
.53		300	44.8	16.0	378	525	254	28.5	25.9
.56		300	44.4		374	525	255	27.3	26.5
.59		300	44.7		377	522	256	27.6	27.0
5.02		300	44.6		355	498	254	27.7	27.7
.05	07714	300	44.8	16.1	370	508	251	27.9	26.7
. 8	08325	300	45.1		377	521	253	28.0	27.3
.11	88932	300	45.2		378	523	254	28.3	27.2
.14		300	45.4		377	523	254	28.4	27.2
.17		300	45.2	16.2	358	505	254	28.4	27.9
.20		300	44.1		353	493	251	28.4	25.3
.23		300	43.8		372	513	251	27.9	25.9
.26		300	44.0		378	523	254	27.4	26.3
.29	12594	300	44.2	16.2	378	524	255	27.7	26.3
.32	13210	300	44.3		373	516	225	27.8	26.5
5.35	13818	300	44.8		371	505	255	27.8	26.8
Total	12252		9360	80.5	7517	10781	5307	5868	5577
Aver.	204.20	300	44.57	16.1	35795	513.38	25.27	27.94	26.55

Water to start = 21.75
Water to end = 43.75
Water used = 78.00

Gasoline to start = 13 - 13.
Gasoline to end = 7 - 8
Gasoline used = 6 - 5

TEST NO. 34.

Gasoline Press = 105.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 7 1/16.
Counter weight brake No. 2 = 7 10/16.

1	2	3	4	5	6	7	8	9	10
2.15	26029	460	44.0		402	724	347	27.4	27.0
.18		460	43.2		389	690	350	27.2	26.9
.21	27367	460	43.1	20.7	389	654	350	27.0	26.8
.24		460	43.9		404	690	350	27.1	27.0
.27	28673	465	44.1		411	720	353	27.2	27.3
.30	29335	460	44.2		413	730	357	27.2	27.7
.33		465	42.8	20.8	412	733	361	26.3	27.0
.36	30567	465	42.2		401	728	362	26.3	27.3
.39	31157	460	42.9		389	683	362	26.4	27.9
.42	31742	460	43.2		394	690	360	26.6	27.3
.45		460	43.2	20.8	399	713	360	26.8	26.7
.48	32937	460	42.9		404	727	363	25.7	27.4
.51	33545	460	43.0		404	732	367	26.2	27.9
.54	34159	460	42.4		397	715	367	26.3	27.8
.57	34762	460	42.9	20.9	389	676	365	26.3	28.6
3.00		460	42.9		392	672	363	26.4	26.9
. 3		460	43.9		402	719	362	26.8	28.0
. 6		460	42.2		406	735	364	27.1	25.6
. 9	37152	460	42.3	20.9	407	742	366	27.2	25.7
.12	37774	460	42.2		398	710	369	27.3	25.8
.15	38366	460	42.6		402	718	368	27.2	26.0
Total	12337		904.1	104.1	8464	14901	7566	5620	568.7
Aver.	205.61	460	43.05	20.82	403.05	709.6	360.29	26.76	27.08

Water at start = 225.50
Water at end = 160.25
Water used = 65.25

Gasoline at start = 14 - 14 1
Gasoline at end = 9 - 2 /2.
Gasoline used = 5 = 12 1/2

TEST NO. 35.

Gasoline Press = 105.
Cut off percent stroke = 64.
Counter weight brake No. 1 = 7 1/16.
Counter weight brake No. 2 = 7 10/16.

1	2	3	4	5	6	7	8	9	10
3.50	42774	200	44.1		333	673	326	28.1	27.2
.53	43418	200	44.2		333	679	328	28.3	27.4
.56	44059	200	43.4	20.5	317	654	332	28.0	27.2
.59	44681	200	43.2		307	630	331	27.9	27.2
.62	45294	200	44.0		324	650	330	28.0	27.4
.65		200	44.1		326	676	332	28.2	27.6
. 8		200	44.0	20.4	328	685	336	26.7	28.2
.11		200	33.9		327	688	340	27.0	28.3
.14		200	44.0		327	689	342	27.2	28.6
.17		200	43.5		310	643	342	27.5	27.8
.20		200	43.3	20.6	306	625	339	27.4	27.6
.23		200	43.6		318	633	335	26.8	27.8
.26		200	43.7		329	668	335	27.1	28.2
.29		200	44.1		333	686	337	27.4	28.3
.32		200	44.3	20.7	333	688	340	27.6	28.8
.35		200	44.8		333	691	342	27.8	28.9
.38		200	44.3		333	691	345	28.0	28.2
.41	53425	200	44.5		319	673	345	27.9	28.5
.44	54043	200	44.4	20.8	310	638	342	27.9	28.5
.47	54650	200	44.8		321	658	341	28.1	29.0
4.50	55260	200	45.2		327	669	341	28.1	29.2
Total	12486		915.4	103.0	6794	13987	7081	5810	589.9
Aver.	208.10	200	43.6	20.63	23.52	6661	337.19	27.67	28.09

Water at start = 220.0
Water at end = 149.50
Water used 70.5

Gasoline at start = 14 - 2.
Gasoline at end = 8 - 5 1/2.
Gasoline used = 5 - 12 1/2.

DATA.

BOILER:

Diameter = 14 inches.

Tubes 298, 13 x $\frac{1}{2}$, 20 gauge copper tubes.

Heating surface 37.04 sq. ft.

ENGINE:

Cylinders $2\frac{1}{2}$ diameter.

Stroke $3\frac{1}{2}$ inches.

Rev. of engine : rev. of brake wheels = 5:2.

Oil supplied to engine cylinders,

= .000884 quarts in 1000 revolutions.

= 1 quart in 1,130,000 revolutions, which is equivalent to 625 miles.(app)

BRAKE WHEELS:

Average Diameter 3.465 feet.

Circumference 9.437 feet.

Effective diameter to middle of ropes 3.475 feet.

Effective circumference 9.480 feet.

Brake constant $\frac{9.48}{33000}$ = .0002872.

Log. of brake constant = 6.45818-10.

Heat of combustion of gasoline used = 18800 B.T.U. per lb.

Weight of 1 gal. gasoline = 5 lbs. 13 oz. = 5.8125 lbs. by actual measurement.

COMPUTATION OF SAMPLE TEST.

Test No.29

Counter Reading at end	=	111502
" " at beginning	=	98404
	Total Revolutions =	13098

$\frac{13098}{60}$ = 218.30 r.p.m.

Sum of average Scale Readings	=	94.38
Weight of counter weights	=	16.875
	Effective Pull =	77.505

Horse Power.

218.30 X 77.505 X constant = 4.859 H.P.

Log Constant = 6.45818-10

Log 218.30 = 2.33705

Log 77.505 = 1.88933

0.68656 = log. 4.859.

Water Per H. P. Hr.

Log 103.5 = 2.01494

Log 4.859 = 0.68656
1.32838 $\frac{103.5}{4.859}$ = 21.30

Gasoline Per H. P. Hr.

Log 11.75 = 1.07004

Log 4.859 = 0.68656
0.38348 $\frac{11.75}{4.859}$ = 2.418

British Thermal Units per H. P. per min.

169.85 14.7- 184.55 lbs. absolute press.

Temperature of Steam- 595.71

Temperature Sat.Steam- 375.03

220.68

For specific heat of superheat steam we have by Weyrauch's formula:

Cp - 0.430 0.000210 (596-32) = .55

Whence, 220.68 X .55 - 121.37.

Total Heat of Sat. Steam =	1196.31
Sperheat =	121.37
Total heat of steam =	1317.68
Assuming feed water at 212° the heat of liquid =	180.8
	1136.88 B.T.U.

$$\frac{1136.88 \text{ X } 21.30}{60} = 403.59 \text{ B.T.U. per H.P. per min.}$$

Water Actually Evaporated per lb. Gasoline.

Log. 103.5 = 2.01494

Log. 11.75= 1.07004

0.94490

$$\frac{103.5}{11.75} = 8.808 \text{ lbs.}$$

Equivalent Evap. from and at 212° per lb. gas.

Feed Water Temp. = 13.1° C, = 53.56° F.

Total Heat of Steam = 1317.68

Heat of Liquid = 21.67

1296.01

Equivalent Evaporation $\frac{1296.01 \times 103.5}{965.8} = 138.9$ lbs.

Equivalent Evaporation per lbs. gas = $\frac{138.9}{11.75} = 11.83$ lbs.

Efficiency of Boiler $\frac{1296.01 \times 103.5 \times 100}{18800 \times 11.75} = 60.7\%$

No. of Test	9	10	11	12	13
R.P.M.(Brake Wheels)	201.85	200.35	203.48	196.10	199.85
Boiler Pressure	400.0	400.0	400.0	397.0	414.3
Steam ch.Press.	33.81	34.64	37.24	63.30	29.92
Feed Water Temp. C°	10.9	12.3	10.66	11.7	6.25
Bonnet Temp.				398	361.9
Temp.Steam at Eng.	594.3	595.4	595.9	582.3	587.5
Temp.of Exh.	293.0	294.8	291.1	275.0	287.6
Deg. Sup. at Eng.	315.3	315.4	312.7	272.3	313.8
Deg.of Sup.at Exh.	81.0	82.8	79.1	63.0	75.6
R.P.M. of Engine	504.6	500.9	508.7	490.3	499.6
Cut-off in % stroke	64	64	64	64	64
Horse Power	1.510	1.575	1.755	3.629	1.150
Water per H.P. hr.	35.5	35.8	34.3	27.14	40.62
Gas per H.P. hr.	3.162	3.016	2.990	2.705	3.782
B.T.U. per H.P. min	686	692	663	518	783
Actual Evap.	11.21	11.89	11.49	10.03	10.75
Equiv.Evap.	15.36	16.35	15.74	13.30	14.22
Efficiency of Boiler	78.7	83.9	80.7	69.7	75.7

No. of Test	14	15	16	17	18
R.P.M.(Brake Wheels)	220.68	209.25	198.35	209.72	217.77
Boiler Pressure	427	425	422	425	419
Steam Ch.Pressure	72.40	63.14	43.80	94.61	133.7
Feed Water Temp.	10.6	17.6	18.0	19.2	16.7
Bonnet Temp.	402	380	391	373	423
Temp. St. at Eng.	593.4	598.5	601.8	596.6	602.3
Temp. Exhaust.	254.7	259.7	286.5	241.9	245.0
Deg. Sup. Heat.	275.7	288.6	310.9	262.5	244.9
Sup.Heat at Exh.	42.7	47.7	74.5	29.9	33.0
R.P.M. of Engine	551.7	523.1	495.8	524.3	544.4
Cut off in % stroke	44	44	64	29	29
Horse Power	3.002	2.366	2.301	2.466	4.270
Water per H.P. hr.	22.98	25.68	31.19	23.51	21.49
Gasoline per H.P. hr.	2.63	2.18	2.77	1.978	1.940
B.T.U.per H.P.min.	439	494	603	450	411
Actual Evaporation	8.73	11.78	11.25	11.91	11.09
Equiv. Evaporation	11.89	15.91	15.29	15.97	14.88
Efficiency of Boiler	60.8	81.6	78.3	81.9	76.3

No. of Test.	19	20	21	22	23
R.P.M.(Brake Wheels)	209.10	203.32	207.38	203.93	204.95
Boiler Pressure	427	431	100	209	565
Steam Ch. Press.	52.23	115.30	43.90	44.60	45.14
Feed Water Temp.	12.8	14.2	8.6	8.7	9.15
Bonnet Temp.	386	382	298	351	405
Temp.St. at Eng.	597.6	596.6	501.7	554.4	624.7
Temp.of Exhaust	275.9	241.0	245.7	264.2	301.1
Deg.Superheat	298.0	249.5	210.8	262.7	332.5
Superheat at Exh.	63.9	29.0	33.7	52.0	89.1
R.P.M.of Engine.	522.7	508.8	518.5	509.8	512.3
Cutoff in % stroke	56	20	64	64	64
Horse Power	2.407	2.640	2.401	2.415	2.457
Water per H.P.hr.	28.20	22.63	32.90	31.57	30.12
Gasoline per H.P.hr.	2.398	1.905	2.573	2.588	2.672
B.T.U. per H.P.min.	543	432	606	597	589
Actual Evap.	11.71	11.88	12.77	12.21	11.28
Equiv.Evap.	16.09	15.98	16.62	16.48	15.62
Efficiency Boiler	82.5	82.0	85.3	84.3	80.2

No. of Test.	24	25	26	27	28
R.P.M. (Brake Wheels)	153.40	240.55	182.95	226.60	264.0
Boiler Pressure	402	402	425	422	405.
St.Chest Press.	44.11	44.31	42.85	44.02	43.74
Feed Water Temp.	17.7	18.1	10.9	12.0	11.6
Bonnet Temp.	385	397	376	384	399
Temp.St.at Engine	591.2	602.4	599.2	603.3	600.0
Temp.of Exhaust	282.9	301.3	286.9	297.1	302.1
Degrees Superheat	300.0	311.0	309.4	312.2	309.2
Super.at Exhaust	70.9	89.3	74.9	85.1	90.1
R.P.M. of Engine	383.5	601.3	457.3	566.5	660.0
Cut-off in % Stroke	64	64	64	64	64
Horse Power	1.785	2.690	2.051	2.576	2.877
Water per H.P.hr.	31.66	30.95	31.20	30.97	30.84
Gasoline per H.P. hr.	2.660	2.640	2.673	2.67	2.815
B.T.U. per H.P. Min.	610	598	586	598.9	579
Actual Evap.	11.90	11.74	11.91	11.60	10.98
Eqiv. Evap.	16.24	15.91	16.40	15.86	14.99
Efficiency Boiler	83.3	81.6	83.7	81.4	76.9

No. of Test	29	30	31	32	33
R.P.M.(Brake Wheels)	218.30	211.9	193.3	210.05	204.20
Boiler Pressure	369	401	82	200	300
St.Chest Press.	169.85	45.35	45.91	43.73	44.57
Feed Water Temp.	11.87	13.12	14.01	16.4	16.1
Bonnet Temp.	411	387.7	304.4	346.9	357.9
Temp.St. at Eng.	595.7	528.6	438.2	487.5	513.4
Temp. of Exhaust.	242.0	256.6	227.3	244.1	252.7
Degrees of Sup. Heat	220.7	236.0	142.0	196.7	221.7
Super. at Exhaust	30.0	44.6	15.3	32.1	4.07
R.P.M. of Engine	545.7	529.7	483.2	526.1	510.5
Cut-off in % stroke	20	64	64	64	64
Horse Power	4.859	2.529	2.368	2.363	2.367
Water per H.P. hr.	21.30	32.33	36.53	33.54	32.95
Gasoline per H.P. hr.	2.418	2.682	2.698	2.678	2.665
B.T.U. per H.P. hr.	404	604	651	614	609.5
Actual Evap.	8.81	11.96	13.53	12.51	12.36
Equiv. Evap.	11.83	15.80	17.14	16.18	16.19
Efficiency Boiler	60.7	81.0	88.1	83.0	82.8

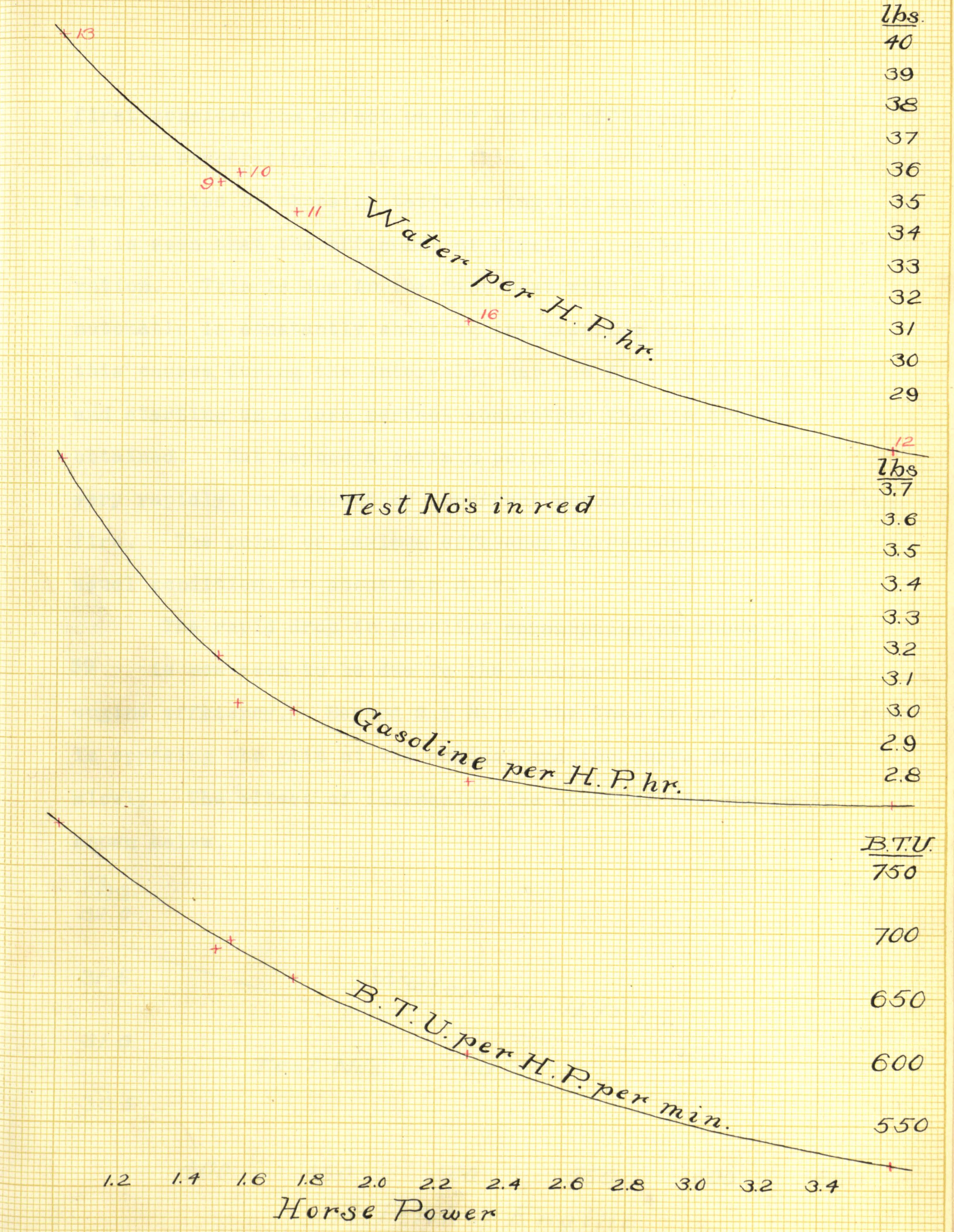
No.of Test	34	35
R.P.M.(Brake Wheels)	205.61	208.10
Boiler Pressure	460	200
St. Ch. Press.	43.05	43.6
Feed Water Temp.	20.8	20.6
Bonnet Temp.	403	324
Temp. St at Eng.	709.6	666.0
Temp. of Exhaust	360.3	337.2
Deg.of Sup.at Eng.	419.6	375.4
Deg.of Sup.at Exh.	158.3	125.2
R.P.M. of Engine	514.0	520.0
Cut-off in % Stroke	64	64
Horse Power	2.312	2.455
Water per H.P. hr.	28.22	28.54
Gas per H.P. hr.	2.502	2.356
B.T.U. per H.P. min.	574	569
Actual Evap.	11.29	12.19
Equiv.Evap.	15.93	16.91
Efficiency Boiler	81.8	86.7

CHAPTER V.

Results of Tests.

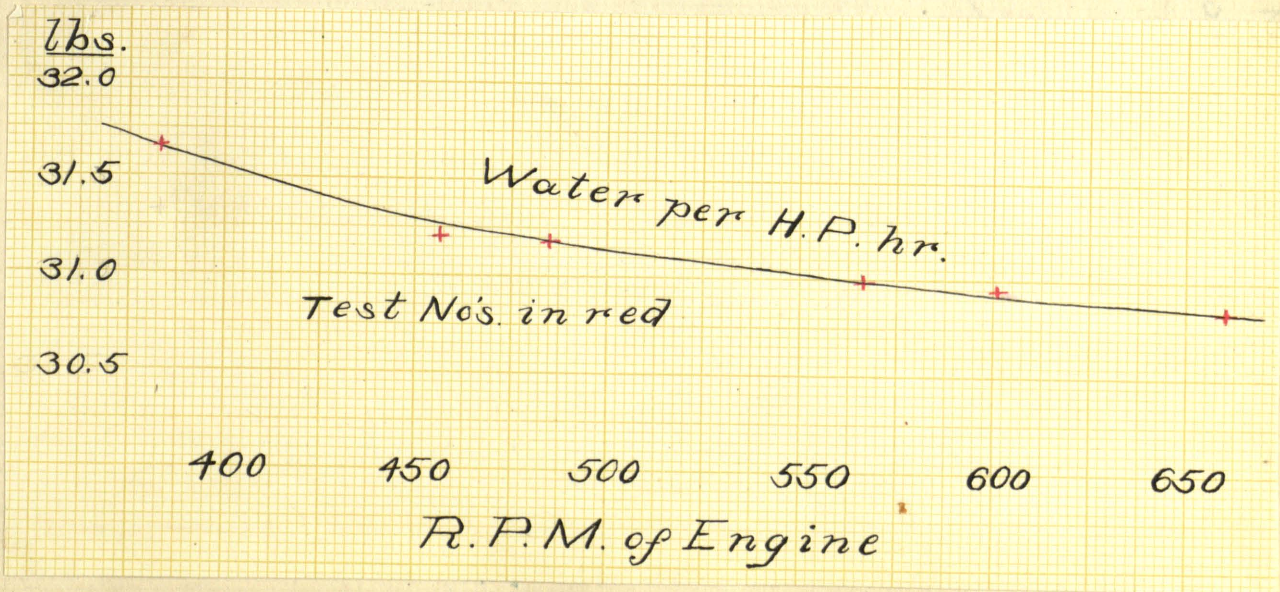
Four separate series of tests were made. Tests No. 9, 10, 11, 12, 13 and 16 were run under different loads, in order to study the relation between power and efficiency. To observe the effect of varying the cut-off, tests No. 15, 17, 19 and 20 were run linked up differently, but with other conditions the same. In tests 24 to 29, the revolutions of the engine were varied from 380 to 660 per minute, in order to determine the gain in efficiency with increase of speed. Tests No. 21 to 23, and 30 to 35 compose a series made to study the effect of superheating the steam. These groups will be considered individually.

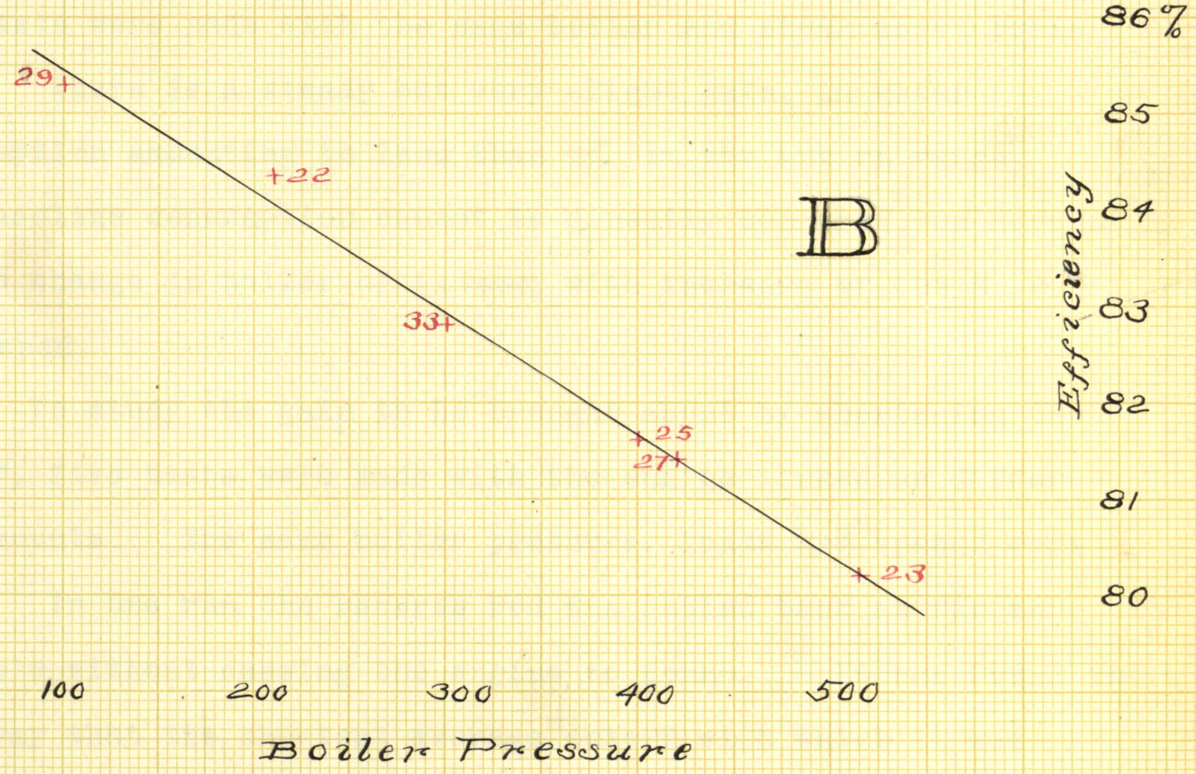
In the first series, the boiler pressure was kept constant to secure the same temperature of the flue gases in each test. The link motion was set in full gear, as the engine is usually run in this way. The revolutions of the engine were kept as near to 500 as possible. This speed was thought to represent ordinary conditions, as it corresponded to about 17 miles per hour. The power developed ranged from 1.0 to 3.6 H. P. The results which are plotted on page 59 A, show a gain in efficency with the increase in H. P. This is due, first to proportionally less friction with greater loads, and second to the higher steam chest pressure. The gain in water economy and B. T. U. in going from 1.0 to 3.6 H. P. is seen to be about 30%. To understand the curve of gasoline consumption, we must


lbs.
40
39
38
37
36
35
34
33
32
31
30
29
13
9
10
11
16
12
Water per H.P. hr.
lbs
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
Test No's in red
Gasoline per H.P. hr.
B.T.U.
750
700
650
600
550
B.T.U. per H.P. per min.
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
Horse Power

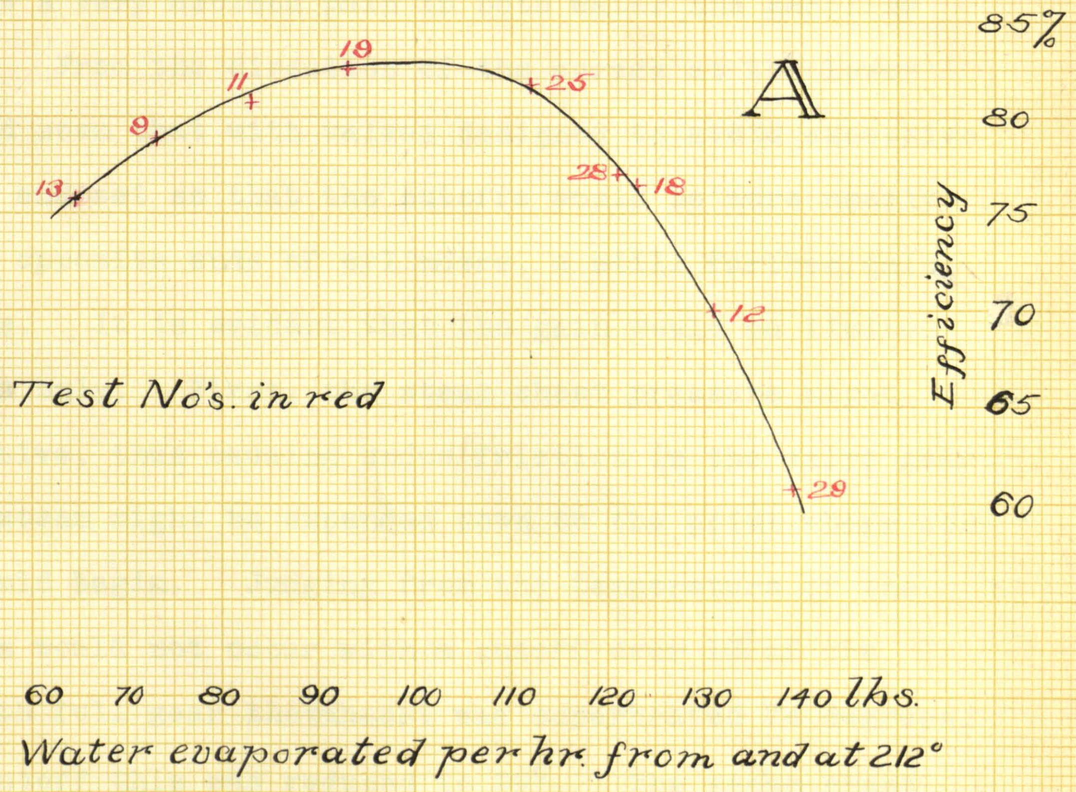
first consider the effect on the boiler efficiency of increasing the evaporation. To show this, the curve A, page 61 has been plotted by choosing tests having the same boiler pressure. It is seen that the efficiency at first increases with the evaporation. This is due to the fact that with a light load the automatic is constantly shutting the gasoline off and on, and this causes, during the intervals that the fire is dying out and starting up a less perfect combustion than is ordinarily obtained. But beyond a certain point, the efficiency drops very rapidly, on account of imperfect combustion when forcing the fire. The point of maximum efficiency corresponds, under the usual condition, to about 2.5 H. P.

The rapid drop in gasoline consumption, as shown on page 59 is now seen to be due to the combined gain in boiler and engine efficiency. Beyond 2.5 H. P. the loss in boiler efficiency is opposing the gain at the engine, and the curve drops very slowly. The effect of increasing the speed of the engine is shown below.





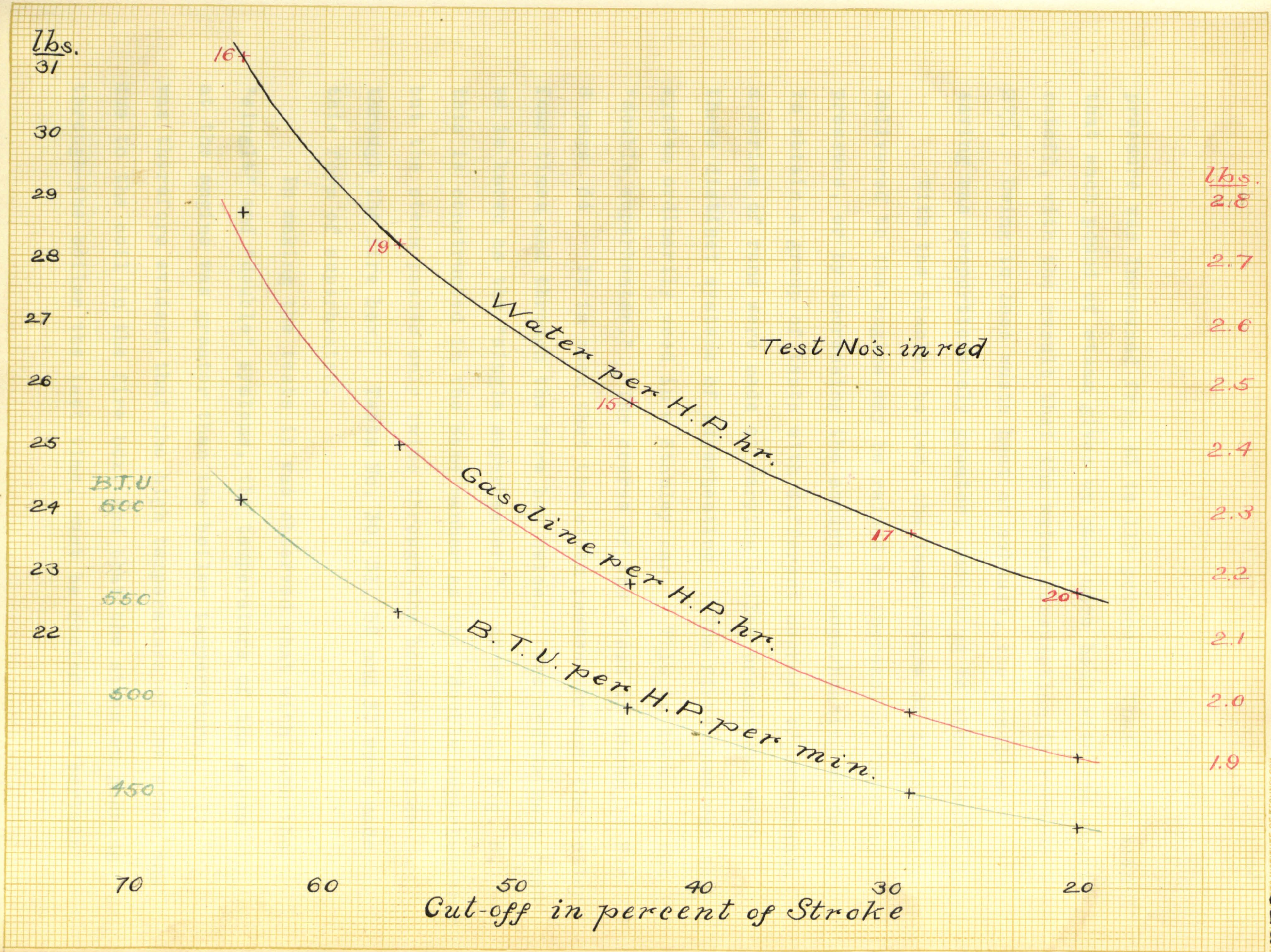
86%
85
84
83
82
81
80
Efficiency
B
29
22
33
25
27
23
100
200
300
400
500
Boiler Pressure



85%
80
75
70
65
60
Efficiency
A
13
9
11
19
25
28
18
12
29
Test No's. in red
60
70
80
90
100
110
120
130
140 lbs.
Water evaporated per hr. from and at 212°

Six tests were made with the same boiler and steam chest pressure. There is a steady but very slight gain, in water consumption amounting to less than 3% in the entire range. The gasoline consumption cannot be directly compared, on account of the change in boiler efficiency, with increase of the H. P. developed.

To study the gain to be brought about by shortening the cutoff, five tests were made with the engine linked up different amounts. The same boiler pressure, loads and speeds were used. In one run the reverse rod was pulled back as far as possible without causing the engine to pound. It was found in this way that the shortest average cutoff with which it was possible to run was 20%. The curves plotted from the results (P 62 A) show a very decided gain in both water and gasoline consumption. From the direction of the curves at the lower end, it would seem that with valves designed to avoid excessive compression, and set so that the cutoffs would be more nearly equal at the opposite ends of cylinders, a still further gain might be made. It is evident that the gain would be limited by two things only. First, the steam chest pressure might become excessive, thus causing undue friction in the valve gear. Second, the steam might be expanded down to the point where condensation would begin. Judging from the temperature of the exhaust, this would not occur with a cutoff over 10% of the stroke. With full gear the exhaust was superheated 74 degrees; with a 20% cutoff this was reduced to 29°. The steam chest


lbs.
31
30
29
28
27
26
25
24
23
22
B.T.U.
600
550
500
450
lbs.
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
16
19
15
17
20
Water per H.P. hr.
Test No's. in red
Gasoline per H.P. hr.
B. T. U. per H.P. per min.
70
60
50
40
30
20
Cut-off in percent of Stroke

pressure was increased from 43 to 115 pounds. Thus it is seen that each pound of steam gives up much more heat with the short cutoff, with the result that the water consumption is reduced 27%. Owing to less waste heat at exhaust, the gasoline saving was proportionately greater, amounting to about 31.5%.

With the Stanley boiler, the temperature of the steam delivered to the engine may be raised by increasing the steam pressure, or by increasing the amount of superheating surface. To obtain a group of tests with different degrees of superheat, a series of runs were made at varying boiler pressures, with three distinct systems of superheating. The first used was the system ordinarily used in a Stanley car. This is known as the "double superheater." The course of the steam is shown in Fig. 8 page 64. It is seen that the steam passes through the boiler four times and through the fire box twice. The system next tested is known as the "single superheater." As shown in Fig. 9, this is constructed in the same manner as the "double superheater," but the steam passes only twice through the boiler and once through the fire box. Tests No. 30, 31, 32 and 33 were made this form of superheater.

In making the tests it was observed that with both the "single" and "double" systems, the temperature of the steam at the engine was greater than the boiler temperature. It was therefore evident that the high temperature of the steam was due to the coil in the fire box, and that the steam on passing through the boiler the last time, must be cooled to a certain

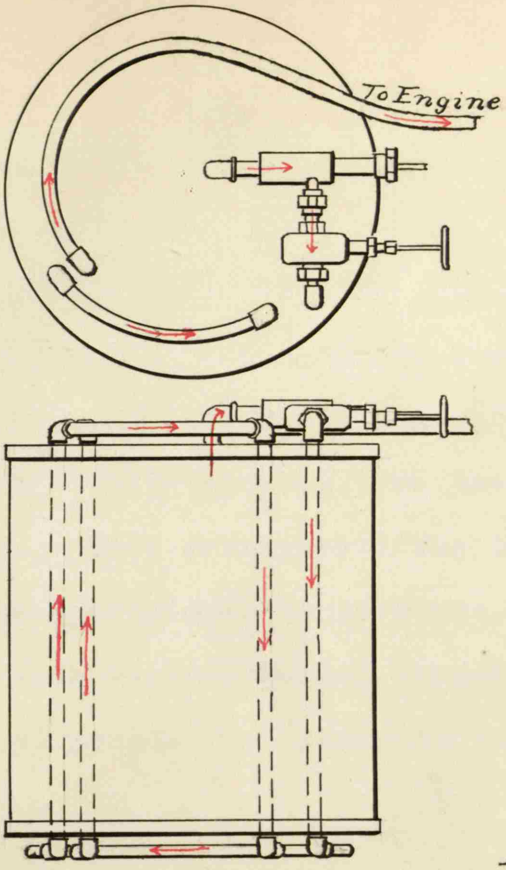


Fig. 8

Fig. 9

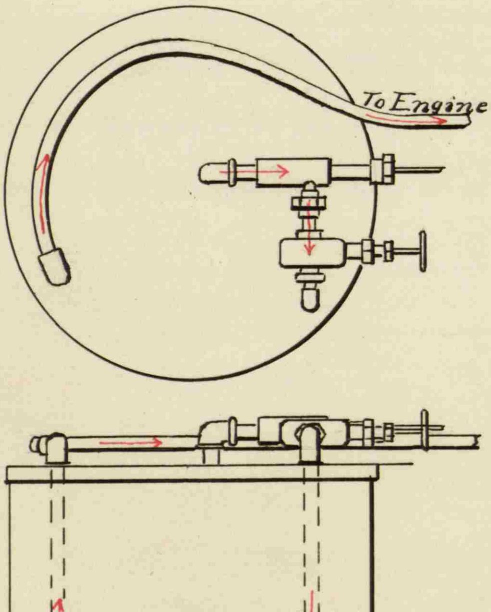
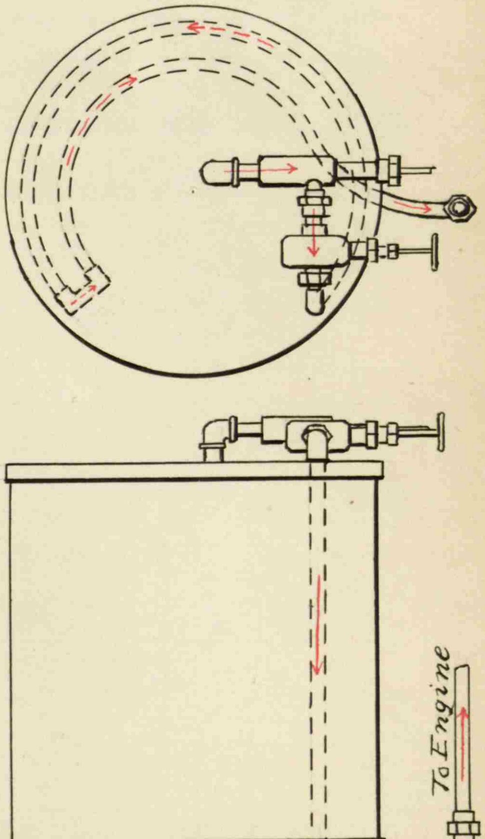


Fig. 10

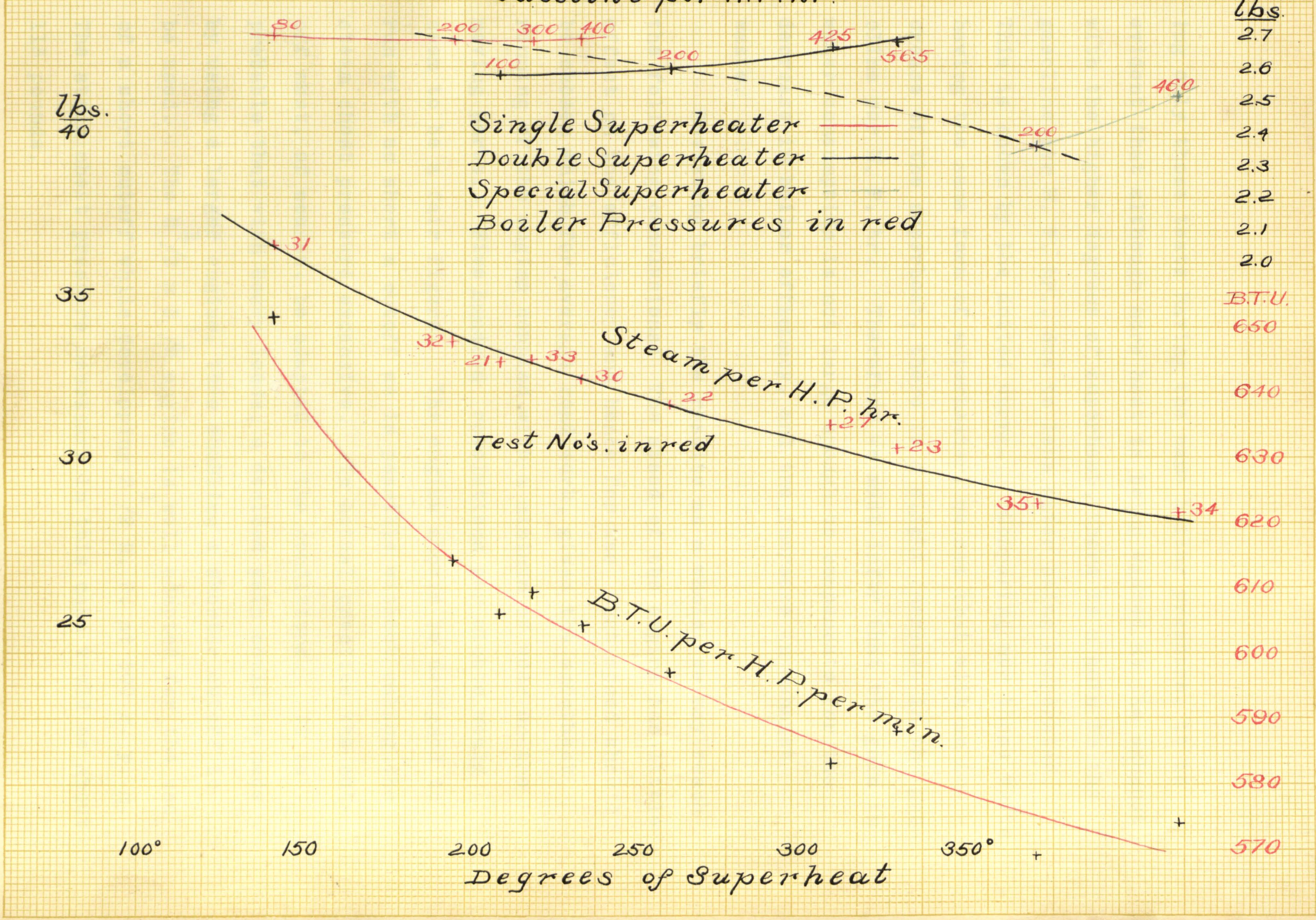


extent. On this account it was decided to try a superheater of the form shown in Fig. 10. The steam passed through the boiler only once, but the coil in the fire box had practically the same length as the two coils in the double superheater. From the fire box the steam was led directly to the engine through a pipe covered first with asbestos, and then with a thick layer of hair felt. This arrangement was only used in the last two tests. The approximate temperature of the steam at the engine, obtained with various boiler pressures, and a steam chest pressure of 45 pounds, is shown in the following table.

Form of Superheater	Single				Double					Special	
Boiler Pressure	100	200	300	400	100	200	300	425	550	200	460
Temp. of Steam	450	490	510	525	500	550	575	600	625	670	710

Before considering the results of the tests, we will first show the loss in boiler efficiency with higher pressures, due to the greater temperature of the flue gases. The results of tests in which the equivalent evaporation was the same, have been plotted on Page 61 (curve B). It is seen that the efficiency was directly proportional to the boiler pressure, and that a gain of about 15 percent was made in going from 500 to 100 pounds. It is evident that if we are obliged to raise the boiler pressure, in order to obtain a higher degree of superheat, the gain in the engine efficiency must be very great to offset the loss in boiler efficiency. The results of the tests are plotted on Page 67. The water consumption and the B. T. U. per H. P. may be directly compared, for although a slight difference in conditions was introduced on account of the engine doing additional work in pumping against a higher boiler pressure in some of the tests, this affects the results so slightly that it may be left out of consideration. This probably accounts, however, for the fact that tests No. 27 and 23, having high pressures, lie above the curve. The additional work done in pumping water necessary in the average test against 500 pounds pressure instead of 100 pounds, would, neglecting friction amount to about 2.3 percent. It is seen from the curve that there was a marked gain in economy, which, however, becomes slightly less as the superheat becomes very high.

Looking at the plotted gasoline consumption, and compar-


lbs.
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
80
200
300
400
100
200
425
565
200
460
Single Superheater
Double Superheater
Special Superheater
Boiler Pressures in red
lbs.
40
35
30
25
B.T.U.
650
640
630
620
610
600
590
580
570
31
32
21
33
30
22
27
23
35
34
Steam per H.P. hr.
Test No's. in red
B.T.U. per H.P. per min.
100°
150
200
250
300
350°
Degrees of Superheat

ing only those tests having the same boiler pressure, it is evident that although more heat is being wasted at the exhaust with the higher degrees of superheat, there is a gain in the gasoline per H. P. hr., due to less water being evaporated. This is shown by the dotted curve. Comparing now those tests having the same form of superheater, we see that with an increase of the superheat, there is a slight increase in the gasoline per H. P. hr. Therefore we must infer that the gain in water consumption is not large enough to compensate for the decrease in boiler efficiency, and the increase in exhaust waste.

Reviewing briefly the results as a whole, we may reach the following conclusions: The speed of the engine has little effect on the efficiency and hence for use that speed should be chosen which, for average road work, gives the smoothest running of the engine coupled with a minimum of wear on the moving parts. Five hundred revolutions per minute would seem to be a fair figure. The engine should be designed to run with as short a cutoff as is possible without making the steam chest pressure excessive. In actual practice the cutoff must, of course, be adapted to the conditions. It is probable that with heavy loads, a decided gain could be made by using a larger engine, thus enabling a shorter cutoff to be used. The $2\frac{1}{2} \times 3\frac{1}{2}$ engine is well adapted for the use of a short cutoff while developing $2\frac{1}{2}$ H. P. at 500 r. p. m. The steam chest pressure necessary in this case would be about 115 pounds.

Superheating the steam results in a great saving in water consumption. Whether or not it is advisable to obtain the superheat by raising the boiler pressure at a sacrifice of efficiency, depends on the conditions under which the carriage is operated. It has been shown to be uneconomical in regard to fuel in the testing machine, but on the road with a fluctuating load and a rapidly changing boiler pressure, this might not hold true. In any case, the ideal way would be to choose a boiler pressure sufficiently high to provide an ample reserve of energy, and then to obtain, by increasing the superheating surface in the fire box, as high a temperature as it is possible to use without injury to the engine, or without causing the too rapid burning out of superheaters. The heat wasted at exhaust amounts to a very small percentage of the whole. Under average conditions, developing 2.5 H. P. with a 20 percent cutoff, it would only require an increase of 3 percent in the gasoline per H. P.hr. to superheat the exhaust 100 degrees instead of 30 degrees, as is the case with a double superheater.

From the boiler efficiency curve on Page 61 it is clear that a boiler sufficiently large should be provided, so that it would never be necessary to force it beyond its point of maximum efficiency. Under ordinary conditions, the efficiency of the boiler is very high. Practically perfect combustion is obtained, and the temperature of the gases on leaving the tubes is but little above boiler temperature. With an actual evaporation of about 75 pounds per hour, and a boiler pressure of 400, the average efficiency is 82 percent. The maximum efficiency of 88.1 percent was obtained with a boiler pressure of 82 pounds. The equivalent evaporation in this case was 17.14 pounds of water per pound gasoline. Taking the heat of combustion of coal at 14,000, this would be equivalent to an evaporation of 12.78 pounds per pound coal. The equivalent evaporation per square foot of heating surface was 3.75 pounds. With the engine running in full gear, and the boiler pressure at 400 pounds, the 14" boiler was capable of furnishing, without being forced beyond the point of maximum efficiency, steam enough to develop 2.5 H. P. By shortening the cutoff to 20 percent, this could be increased to 3.2 H. P.

The maximum power developed in any test was 4.859 H. P. (test No. 29). The water per H. P. hr., was in this case 21.3 pounds. It should be noted that the feed water in all the tests was very cold, whereas under actual conditions it reaches 120 degrees. Had the feed water been at this temperature during this test, the power developed could have been increased to 5.08 H. P.

The lowest consumption in gasoline was reached in test No. 20, with a cutoff of 20 percent, and developing 2.64 H. P. The result obtained was 1.905 pounds per H. P. hr. This is equivalent to .328 gallons per H. P. hr. Taking the price of gasoline at .15 per gallon, we have 4.92 cts. as the cost per H. P. per hour. It should be noted that test No. 20 was made under ordinary conditions, with a high boiler pressure and a double superheater. Had a similar test been run with a pressure of 100, and the special superheater, the gasoline per H. P. hr. would have been reduced to at least 1.65 pounds, and the cost per H. P. hr. to 4.26 cts.

In conclusion, a word should be said in regard to ball bearings. The engine used in testing was new when set up. During the work of testing, it made 1,888,150 revolutions, which would in the automobile be equivalent to 1046 miles. It developed an average of 2.50 H. P. at 515 r. p. m., which would be equal to a speed of 17.1 miles per hour on the road. At the end of the tests, the engine was in perfect condition. No bearings were adjusted during the tests, and but little looseness or play was observed at the end.