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Gasoline Engine Economy as Affected by the Time of Ignition

by George Jay Hopkins

1907

Submitted to the University of Kansas in partial fulfillment of the requirements for the Degree of Bachelor of Science

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GASOLINE ENGINE ECONOMY

as Affected by

the Time of Ignition.

A Thesis

Submitted to the Faculty of the

University of Kansas

by

George Jay Hopkins,

For the Degree of B.S. in Mechanical Engineering.

Lawrence

The author desires to make grateful acknowledgment of the friendly aid and advice of Professor P. F. Walker M.M.E., Professor of Mechanical Engineering at the University of Kansas, to which much of the value of this work is due.

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G. J. Hopkins.

Lawrence, Kansas.

June 1, 1907.

Gasoline Engine Economy as Affected by Time of Ignition.

In the face of the conclusions arrived at by almost every manufacturer of internal combustion engines, the value of such a discussion as this might be questoned by the casual observer. But the vagueness in the practice of adjusting the ignition apparatus, and the divergence of opinions as to the effect of speed and mixture on the time allowed for lead, made it evident that more refinement in this line is not only possible, but in most cases profitable.

Considering the almost infinite variety of uses to which the internal combustion engine is put, it is manifestly impossible to set any one angle of advance, at which the maximum economy will be obtained in all cases. The field of investigation, therefore, is as broad as there is variety of engines, but we have limited this to a certain extent by assuming a definite fuel, and attempting to deal only with gasoline.

That the breadth of the subject is still considerable, is seen from the fact that in 1903, after running, under approximately the same conditions-- a series of 346 tests covering a period of six years, Prof. Robertson, lately of Purdue University, withheld data for further consideration, from his article in the Transactions of the American Society of Mechanical Engoneers Vol. 24, Page 1097. (Prof. Robertson used Natural gas instead of gasoline.)

In this article he has considered the following variables;-- speed, load, point of ignition, mixture and jacket temperature. Considering any three of these five fixed, the other two will be inter-dependent. In view of this sensitiveness of one variable to changes of any other, it is fortunately possible to set the load somewhere near the engine's rating, and the jacket temperature between limits found common in practice, without materially narrowing the field of investigation, and at the same time effect a great saving in the labor of collecting data.

In justification of this, it is evident that if a number of values be taken for any variable, the series, to be complete, must be entirely repeated for each value, changing each of the other conditions in order, thus multyplying the work in direct proportion to the number of values taken for any variable.

The point of view during this investigation has been at all times merely a financial one and consequently the curves will be found to relate to the gasoline consumption per unit of power. For the same reason, that is, to make the results commercially useful and comparable to usual practice, the running conditions have been kept as near those ordinarily surrounding actual running en-

gines, and as constant as possible.

The engine used is one installed in the mechanical laboratory of the University of Kansas;-- a seven by ten "Olds", rated at eight H.P. at a speed of about 300 R.P.M.

It's equipment is the same as that supplied commercially and of which the description follows, except that three beads were supplied for the cylinder to give 60, 80, and 100 pounds compression respectively. However, it was found impossible to use any but the lowest for gasoline without serious backfiring, though the engine ran well at 100 pounds on natural gas. (Almost pure CH4 in this region.)

The valve mechanism, to which the explosion counter is attached, is controlled by the governor which holds open the exhaust valve and closes the intake during miss shots. The effect of this will be noticed on some of the cards. The cylinder being better scavenged the mixture was cooler and perhaps somewhat leaner,--due in part to the lag of the fuel valve after being allowed to seat,and consequently slower burning and less powerful, giving both an inclined explosion line and reduced area.

The exhaust temperature was taken in the line from an auxiliary exhaust port consisting of four $3/8^{*}$ holes situated near the end of stroke and communicating with the muffler through a pad connection screwed to the side of the cylinder.

Both intake and exhaust valves are of the "mushroom" type, the intake being automatic. The gasoline valve is of the plain needle variety, having on the same stem, a light screen which is acted upon by the inrushing air to lift the valve from its seat. It's lift is adjust able by a threaded sleeve and lock nut. The position of which was indicated by numbers stamped on the faces of the nut.

The ignition is accomplished by a mechanically operated break spark device, the points of which are pushed together and released, when they immediately fly apart under the action of a strong coil spring.

The ignition apparatus is situated in the top of the valve chamber, which is bolted to the side of the cylinder opposite the auxiliary exhaust. Current was supplied through a spark coil by a set of six dry batteries, which being used but once a week, gave an almost constant current of six amperes and nine volts.

The load was applied by an interchangable rope prony brake fitted to either one of the fly wheels, and read by a platform scale. A constant pressure of 70 pounds was maintained, resulting, at an arm of 1.83 feet in a load of about three fourths rating except in the case of varying speed when it became necessary to chaange the load to keep the power constant.

The indicated power was recorded by a Crosby Indicator using a 300 pound spring and actuated by a light

wooden reciprocating device connected to a small crank on the end of the shaft. The speed was taken with a revolution counter.

The inclosed diagramatic sketch will give an idea of the arrangement of apparatus and manner of carrying out tests.

A small high speed steam engine connected to a three foot fan blower was used to drive air into the large tanks to the right, through the valve system shown. They have a capacity of something more than 100 cubit feet each, and are controlled by a set of valves arranged to allow the contents of one to be used while the other is being filled. (In the sketch the tank X is rising while Y is supplying the engine; the crossed valves being closed.)

They were both weighted to a pressure of 3 inches of water and the air used by the engine was measured by taking the difference of the readings of the pointer P before and after emptying. The cord being connected in the center of the tank reads accurately, regardless of tilting.

The regulator illustrated, was interposed to approximate the condition of constant air supply. Its action is as follows: the part A, floating up under the influence of the air from the large tank, raises the lever L which closes the cock C, shutting off the inflow, thus regulating the pressure with reasonable accuracy since A

has a content of about five cubic feet and the cylinder much less than one.

The thermometer, T_i gave the temperature of the incoming air while the exhaust temperature was taken after it has expanded to atmospheric pressure in a chamber of brick laid up loosely.

The temperature of the discharged jacket water was read at T. (much difficulty was experienced in keeping this constant, but an attempt was made to average about 150). Another thermometer was used to measure its incoming temperature, and the discharge was caught in a calibrated tank and its weight read.

The calibrated glass jar, G, contains the gasoline, which is automatically pumped up and returned through an overflow; evaporation being prevented by a tight stopper, perforated to receive the pipes.

All readings, including indicator cards, but excepting jacket water were taken at 5 minutes intervals. Most of the runs were of 20 minutes duration. Care was taken, however, to get all running conditions constant before starting any test, and since facilities were at hand for doing this as perfectly as possible under any conditions, the short tests have been given the same value as longer ones. Indeed, long duplicates of short tests have given quite uniform results.

Three persons were necessary to run a test, since one man's time was almost wholly occupied with the

tanks and steam engine.

The observations made were:

1 Speed

2 Load

3 Explosions per min.

4 Gasoline valve setting

5 Angle of ignition advance

6 Amount of air (cu.ft.)

7 Amount of Fuel (pts)

8 Temp. entering jacket water

9 Temp. leaving jacket water

10 Weight jacket water

11 Indicator cards and

12 Barometer.

From this data it is possible to make a complete mechanical and thermal analysis of the engine's performance.

In this paper, however, only the following quantities have been calculated:

1 Gasoline per B.H.P. per hour

2 Gasoline per I.H.P. per hour and

3 Ratio of Air to fuel, by weight, in the mixture Curves have been plotted showing:

I. Variation of fuel consumption per I.H.P. per hour with various angles of advance: -- at two constant sp speeds.

II. Same per B.H.P.

III. Variation of fuel consumption with varying mixture, the angle of advance being held constant:- for 3 angles. The constants and formulae used in calculating these are as follows,

I.H.P. = .000918 X M.E.P. X Explosions P.M.

B.H.P. = .02238 X R.P.M. (at 70 pounds brake load) B.H.P. = .01753 X R.P.M. (at 55 pounds brake load) One pint of gasoline weighs .77067 pounds.

For the weight of one cubic foot of air the following formulae from Kent's hand book was used; $W = \frac{1.3253 \text{ X Barometer}}{459.2}$ Temperature but since the barometer varied so slightly, its average, 28.8" was taken for all cases.

The average of the shots in a Parr Caldrimeter gave a heat value of 19,300 British Thermal Units per pound of the gasoline used. The samples were taken at various times during the time occupied by the tests and the quality ran very constant.

Conclusions.

Series A, being first and containing a large number of tests, occupied more time than all the other series attempted. This would not have been true, but for the fact that in repeating some of the runs that looked doubtful when plotted, it was noticed that the points were coming quite regularly higher, which necessitated an entire repetition of the series. Both curves are given, as there appeared no way of deciding that either one was better than the other. The

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logical conclusion seems to be that the conditions of the engine changed between the first running of the test and its repetition, so as to require a greater consumption of gasoline.

Although a slight difference seems to exist between the shape of the B.H.P. and I.H.P. curves both show a minimum of consumption between 11° and 13° for 305 R.P.M.

Series B.C. and D. were run under the belief that the mixture might be made so lean that the increased number of shots resulting would result in an actual increase of fuel consumption, σ in other words that the mixture curves would rise. But during this series this condition was not attained, and it seems that in this engine the leanest mixture that will run well, is the most economical.

Series F.- A consideration of the data of these runs shows only what every engineer knows: that the efficiency of a gas engine varies with the compression. Since the engine would not run at 100# compression, only two points were possible and it was not thought worth while to plot these.

Series G. corresponds to Series A except in speed, which was 350 R.P.M. The curves have about the same shape but the minimum point comes a little above 17[°] More points would have made this curve more complete but lack of time prevented.

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				Series	A.			
	Compressi	on 60 [#]	except v	there no	oted, in	all foll	owing-	
1	No. ofTest	; 1	· 1 a	1 b	10	. 1 d .	8	3 a
2	Duration- Min.	10	20	20	20	20	15	30
3	Ignition							
	Angle of Advance	14.8	14.8	14.8	14.8	14.8	14.8	11.2
4	Jacket	245	129	133	137	135	120	196
-	Water pds.	01	61	80	86	90 E	00	00
Da	ALF ALF	OL	91	180 91	181	172	181	258
7	Jacket In	53	57	57	54	58	53	56
8	2 Water Out	147.3	154.6	146	149.6	145	151.2	152
9	Total			2	and the second s			
	Explosions	1138	2302	2311	2169	2255	1580	3421
10	Explosions							
	per minute	113.8	115.1	115.56	108.45	112.75	106	114
11	M.E.P.	83.3	82	83.4	87.2	75.6	82.9	79.51
12	I.H.P.	9.1	8.53	9.27	9.1	8.25	8.454	8.719
13	R.P.M.	306.5	306.5	304.75	295.25	307	304	304.3
14	B.H.P.	6.86	6.86	6.82	6.6	6.87	6.8	6.80
15	Total Air							
	Cubic Ft.		381	381	-	393	355	557
16	Total Gas-							
	oline pts.	1.00	3.61	3.64	3.53	3.44	2.15	5.10
17	Mixture		9.67	9.57		9.7	14.8	8.45
	Ratio Air Fuel							
18	Pts. per	.66	1.27	1,178	1.163	1.253	1.02	1.17
	I.H.P.							
	per Hr.							
19	Pts. per	.87	1.58	1.60	1.605	1.503	1.265	1.503
	Der Hr.							
20	Pts.ner							
~	Explo-							
	aion	.000878	.00157	.00157	.00163	.001525	.00135	.00149
21	Satting of			1				
~	DOUNTIR OI							
	FUEL VELVE							

Brak-load 70[#] Gasoline Valve 7

1	3 b	30	3 d	4	4 a	4 b
2	25	20	20	15	20	20
3	17.3	17.3	17.3	20.2	20.2	202
4	160	155	125	90	137	135
5	81	86	87	81	80	86.3
6	185	158	191	205	150(?)	174.7
7	60	58	57	53	57	58.3
8	150.5	141.4	157.6	147.5	145.8	146.4
9	2711	2275	2305	1609	2279	2286
10	108.4	113.75	115.2	107.3	114	114.3
11	79.5	77.8	78	79.5	81.25	77.8
12	8.3	8.52	8.07	8.206	8.37	8.56
13	299	305	307	256	307.25	307
14	6.69	6.83	6.87	5.73	6.87	6.87
15	438	391	377	233	397	411
16	4.18	3.45	3.73	2.35	3.52	3.49
17	8.05	8.58	7.65	9.2	10.38	10.7
18	1.206	1.216	1.386	1.16	1.26	1.222
19	1.478	1.517	1.63	1.64	1.54	1.524
20	.00149	.00152	.00162	.00146	.00155	.001526

1	4 0	5	5 a	5 b	6	6 a
8	80	15	15	20	85	30
8	20.2	13	1.3	13	10.3	10.3
4	150	88	125	128	155	214
5	85.5	87	78	85.5	81.6	84.3
8	190	215	862	166 (🕈)	823	219.7
7	57	80	54	62	58	59.5
8	150	180	136.2	152	151	145
9	8349	1840	1671	2877	8874	3407
10	112.45	109.5	111.4	114	115	113.6
11	72.8	81	82.7	74.8	78.83	79
12	8.23	8.5	8.86	8.8	8.71	8.41
13	307	2977	301.3	306.6	298	804-8
14	6.87	8.66	6.74	6.86	6.67	6.80
15	383		251	385		562
18	8.77	8-45	8.53	3.58	4.4	5.1
17	9.00		9.2	9.78	-	10
18	1.374	1,15	1.45	1.3	1.21	1.2
19	1.646	1.47	1.5	1.55	1.58	1.508
20	.001605	.001495	.00157	.00157	.00153	.0015

1	6 b	7	7 8	8	88	9	
8	20	30	20	20	20	20	
3	10.3	8,7	8.7	5,6	5.6	23.8	
4	140	320	122	145	135	160	
5	86	75	85.3	76	88	87	
8	190	260	194	269	198	195	
7	59.5	54	58.5	56	57	57	
8	142.6	136.1	149.8	149.5	148.4	147.8	
9	2291	3409	2329	2308	2369	2269	
10	114.5	113.6	116.4	115.4	118.4	113.5	
11	78.6	82.1	73	80.8	74.6	73.2	
12	86.05	8.97	8.18	8.97	8.5	8	
13	307.7 5	304	307	304.5	307.5	307.75	
14	6.88	6.8	6.87	6,81	6,88	6.88	
15	408	553	393		398	-	
18	5.59	5.14	3.66	3.47	3.9	3.5	
17	6.65	9,95	9.75	_	9.43		
18	1.844	1.145	1.34	1.16	1.376	1.318	
19	1.56	1.51	1.596	1.53	1.70	1.525	
20	.00175	.00151	.00157	.001605	.00164	.00154	

Series B

1	1	8	3	4	1	8
2	20	20	15	20	20	20
3	13	13	13	13	14.8	14.8
4	148	133	128	128	130	134
5	76	78,5	72.6	85.5	78.3	81
6	190	211	208	166 (?)	212	223
7	55	55	66.5	62	55	55
8	151.8	154.8	151.5	152	152.2	153
9	2305	2348	1929	8277	2320	2874
10	115,2	117.4	128.6	114	116	118.7
11	75.8	78	76.75	74.8	76.4	77 .4
12	8.32	8,82	9.495	8.8	8.63	8.84
13	308.25	308.75	307.6	306,6	309.85	308.75
14	6,71	6.92	6.88	6.86	6.92	6.92
15	367	388	299	385	390	384
16	3.8	2.84	2.02	3.58	2.78	2.71
17	10.6	12.6	18.7	9,76	12.6	13.1
18	1.153	.96	.852	1.3	.978	.92
19	1.39	1.23	1.175	1.55	1.205	1.175
20	.00139	.00121	.00105	.00157	.00120	.00114
21	6	5.75	5	ас. * 8. * Жатар	5,75	5.33

Varying Mixture

1	3	4	5	1	8	3	4
8	20	20	20	20	20	20	10
8	14.8	14.8	14.8	17.3	17.3	17.3	17.3
4	140	142	129	135	139	126	
5	98	101.5	81	101.7	101	100	73.3
6	197	827	****	827.7	226.2	225	204
7	69	69.3	57	70	70	69.7	61.6
8	158.2	162.2	154.6	166	160	162.2	144
9	2348	8487	2302	2339	2352	2381	1143
10	1174	121.3	115.1	117	117.6	119	114.5
11	71	71	82	71	69.8	70.8	77.55
12	8,03	8.29	8.53	8,88	7.88	8.1	8.61
13	308.8	308.75	306.5	309.7 5	309.3	310	310.6
14	6.92	6.98	6,86	6.93	6,92	6,95	6.95
15	387	387	381	376	387	378	201
16	3.38	8.62	3.61	2.59	3.35	3.81	1.76
17	10.2	13.12	9.67	12.8	10.2	8,65	10.6
18	1.29	. 948	1.27	. 972	1.277	1.41	1.225
19	1.495	1.137	1,58	1.12	1.452	1.65	1.52
20	.00144	.00108	.00157	.00111	.00406	.0016	.00154
21	6.25	5.75	_		6	6.75	6.33

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	4				U .			
		80# cm	mp res- sion	Gasoli Brake Comp.	ne valve load 55# 60#	5.5		
1	5	1	2	1	2	3	3a.	4
2	20	20	20	20	20	15	15	15
3	17.3	14.8	14.8	13	17.3	14.8	14.8	2.02
4	155	130	142	166	132	108	100	105
5	86	77	1015	73.2	84	83	83	83
6	158	223	227	221	211	213	224	229
7	58	71	69.3	61	62.5	60	60	60
8	141.4	156.8	162.2	146.8	151.6	147	146.7	147.7
9	2275	2541	2427	2569	2470	1884	1882	1856
10	113.75	127	121.3	128.4	123.5	126.2	126.1	123.7
11	77.8	70.6	71	75.2	75	73	71	69.7
12	8.52	8.48	8.29	9.29	8.91	8.86	8.61	8.29
13	305	307	308.75	343.2	344.2	342.6	344	246.3
14	6.83	6.82	6.92	6.02	6.05	6.01	6.04	6.08
15	391	420	385	310	360	266	271	263
16	3.45	2.38	2.62	3.68	3.47	2.75	2.72	27
17	8.58	16.3	13	7.85	9.44	9.74	9.1	8.9
18	1.216	.842	.948	1.19	1.17	1.24	1.265	1.303
19	1.517	1.04	1.137	1.835	1.725	1.83	1.84	1.78
20.	00152 .	000937.	00108 .	00143	.001405	.00146	.001445	.001456
21		4.33	5.75					
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20. 21	1 5 20 3 17.3 155 5 86 6 158 7 58 8 141.4 9 2275 10 113.75 11 77.8 12 8.52 13 305 14 6.83 15 391 16 3.45 17 8.58 18 1.216 19 1.517 20.00152 . 21	151220203 17.3 14.8 4 155 130 5 86 77 6 158 223 7 58 71 8 141.4 156.8 9 2275 2541 10 113.75 127 11 77.8 70.6 12 8.52 8.48 13 305 307 14 6.83 6.82 15 391 420 16 3.45 2.38 17 8.58 16.3 18 1.216 $.842$ 19 1.517 1.04 20.00152.000937.21 4.33	151222020203 17.3 14.8 14.8 4 155 130 142 5 86 77 1015 6 158 223 227 7 58 71 69.3 8 141.4 156.8 162.2 9 2275 2541 2427 10 113.75 127 121.3 11 77.8 70.6 71 12 8.52 8.48 8.29 13 305 307 308.78 14 6.83 6.82 6.92 15 391 420 388 16 3.45 2.38 2.62 17 8.58 16.3 13 18 1.216 $.842$ $.948$ 19 1.517 1.04 1.137 20.00152 $.000937.00108$ 21	151212202020203 17.3 14.8 14.8 13 4 155 130 142 166 5 86 77 1015 73.2 6 158 223 227 221 7 58 71 69.3 61 8 141.4 156.8 162.2 146.8 9 2275 2541 2427 2569 10 113.75 127 121.3 128.4 11 77.8 70.6 71 75.2 12 8.52 8.48 8.29 9.29 13 305 307 308.75 343.2 14 6.83 6.82 6.92 6.02 15 391 420 386 310 16 3.45 2.38 2.62 3.68 17 8.58 16.3 13 7.85 18 1.216 $.842$ $.948$ 1.19 19 1.517 1.04 1.137 1.835 20.00152 $.000937.00108$ $.00143$ 21 4.33 5.75	151212220202020203 17.3 14.8 14.8 13 17.3 4 155 130 142 166 132 5 86 77 1015 73.2 84 6 158 223 227 221 211 7 58 71 69.3 61 62.5 8 141.4 156.8 162.2 146.8 151.6 9 2275 2541 2427 2569 2470 10 113.75 127 121.3 128.4 123.5 11 77.8 70.6 71 75.2 75 12 8.52 8.48 8.29 9.29 8.91 13 305 307 308.75 343.2 244.2 14 6.83 6.82 6.92 6.02 6.05 15 391 420 388 310 360 16 3.45 2.38 2.62 3.68 3.47 17 8.58 16.3 13 7.85 9.44 18 1.216 $.842$ $.948$ 1.19 1.17 19 1.517 1.04 1.137 1.835 1.725 20.00152 $.000937.00108$ $.00143$ $.001405$ 21 4.33 5.75	15121232202020202015317.314.814.81317.314.8415513014216613210858677101573.2848361582232272212112137587169.36162.5608141.4156.8162.2146.8151.6147922752541242725692470188410113.75127121.3128.4123.5126.21177.870.67175.27573128.528.488.299.298.918.8613305307308.75343.2244.2342.6146.836.826.926.026.056.0115391420388310360266163.452.382.623.683.472.75178.5816.3137.859.449.74181.216.842.9481.191.171.24191.5171.041.1371.8351.7251.8320.00152.000937.00108.00143.001405.00146214.335.7514.335.7514.33	15121233a220202020201515317.314.814.81317.314.814.8415513014216613210810058677101573.284838361582232272212112132247587169.36162.560608141.4156.8162.2146.8151.6147146.79227525412427256924701884188210113.75127121.3128.4123.5126.2126.11177.870.67175.2757371128.528.488.299.298.918.868.6113305307308.75343.2244.2342.6344146.636.826.926.026.056.016.0415391420388310360266271163.452.382.623.683.472.752.72178.5816.3137.859.449.749.1181.216.842.9481.191.171.241.265191.5171.041.1371.8351.7251.831.84 <t< td=""></t<>













Sample Gards

SCALE. 3 7 Piston Diameter %... CROSBY STEAM ENGINE INDICATOR, CROSBY STEAM GAGE & VALVE CO 147, QUEEN VICTORIA ST., LONDON, E. C. REVS, PER MIN 21-23 WEST LAKE ST., CHICAGO, ILL. 93-95 OLIVER ST., BOSTON, MASS. INDICATOR DIAGRAM Engine Constant. M. E. P. 8.3. Piston Speed.... Piston Stroke... Diagram Area ... Piston Area... I. H. P. 16 DEY ST., NEW YORK. MANUFACTURED SOLELY BY A STORES: (..... lbs. CARD No. Z ins. Taken BOILER PRES Ibs. gage Which Engine Which Cylinder Which End. Temp. Hot Well deg. Pres. in Receiver 2 may alu A1 3 1 3 4 Vac. per gage. REMARKS, &c. By F 374; L 5-06

Run # | Series A

REMARKS, &c. Which End. Which Engine Temp. Hot Well deg Vac. per gage. Pres. in Receiver BOILER PRES lbs, gage Which Cylinder..... At 3,00 Ву..... Taken..... CARD No..... CROSBY STEAM GAGE & VALVE CO CROSBY STEAM ENGINE INDICATOL, 147, QUEEN VICTORIA ST., LONDON, E. C. Mun & Series H 21-23 WEST LAKE ST., CHICAGO, ILL. 93-95 OLIVER ST., BOSTON, MASS. 16 DEY ST., NEW YORK. MANUFACTURED SOLELY BY lbs. TAKEN WITH THE . ins. STORES : REVS. PER MIN..... SCALE..... I. H. P..... M. E. P. 70 Diagram Area Engine Constant. Piston Area... Piston Stroke.... Piston Diameter..... Piston Speed.....

Run #3

Series A

Vac. per gage. {..... lbs. Which End..... Duff ## S-H Temp. Hot Well deg. BOILER PRES lbs. gage CARD No..... REVS. PER MIN. Which Cylinder..... Pres. in Receiver At 2-27 By..... Taken..... Which Engine..... CROSBY STEAM GAGE & VALVE CO LKOSBY STEAM ENGINE INDICATOR, 147, QUEEN VICTORIA ST., LONDON, E. C. 21-23 WEST LAKE ST., CHICAGO, ILL. 93-95 OLIVER ST., BOSTON, MASS. 16 DEY ST., NEW YORK. MANUFACTURED SOLELY BY TAKEN WITH THE STORES : SCALE..... Piston Diameter..... I. H. P..... Diagram Area M. E. P. **8**2 Engine Constant..... Piston Area..... Piston Speed..... Piston Stroke.....

Run#4

SeriesA

м. е. р. 84 CARD No........ REVS. PER MIN...... SCALE...... Piston Stroke..... Piston Speed..... Diagram Area I. H. P. Piston Diameter..... Piston Area..... Engine Constant..... CROSBY STEAM GAGE & VALVE CO. CROSBY STEAM ENGINE INDICATOR, 147, QUEEN VICTORIA ST., LONDON, E. C. 21-23 WEST LAKE ST., CHICAGO, ILL. 93-95 OLIVER ST., BOSTON, MASS. INDICATOR DIAGRAM 16 DEY ST., NEW YORK. MANUFACTURED SOLELY BY TAKEN WITH THE STORES : (..... Ibs. BOILER PRES lbs. gage (..... ins. Which Engine..... Which End. At 12 . 05 2 Which Cylinder..... Pres. in Receiver Temp. Hot Well deg. Taken By..... REMARKS, &c. th of Vac. per gage. F 374: L 5-06

Run#5 2

SeriesA

R DIAGRAM VITH TUR NGINE INDICATOR, ED SOLELY BY AGE & VALVE CO. AGE & VALVE CO. RES: , BOSTON, MASS. NEW YORK. ST., CHICAGO, ILL. ST., CHICAGO, ILL.	REVS. PER MIN SCALE Piston Diameter	Piston Stroke Piston Speed Piston Area Diagram Area M. E. P. 7. 5	Г. Н. Р.
F 374: L 5-06 INDICATOF TAKEN W CROSBY STEAM ET MAKUPACTURI MAKUPACTURI CROSBY STEAM G STO 93-95 OLIVER ST. 21-23 WEST LAKE 147, QUEEN VICTORI	CARD No	At	Vac. per gage. { lbs. Temp. Hot Welldeg. REMARKS, &c.

Taken..... Which Cylinder..... Which Engine At 10, 23 By..... CROSBY STEAM ENGINE INDICATOR, BOILER PRES lbs. gage Which End. Vac. per gage. { lbs. CROSBY STEAM GAGE & VALVE CO. REMARKS, &c. Temp. Hot Well deg. Pres. in Receiver 147, QUEEN VICTORIA ST., LONDON, E. C. 21-23 WEST LAKE ST., CHICAGO, ILL. STORES: 93-95 OLIVER ST., BOSTON, MASS. 16 DEY ST., NEW YORK. # Series # MANUFACTURED SOLELY BY SCALE..... Piston Stroke..... Piston Diameter..... Diagram Area Engine Constant..... Piston Speed..... I. H. P..... M. E. P..... Piston Area.....

SeriesA

Run#7

Run#6

SeriesA

Vac. per gage. $\left\{ \begin{array}{c} \dots & \text{lbs.} \\ \dots & \text{ins.} \end{array} \right.$ BOILER PRES lbs. gage Which End. Which Cylinder..... CARD No..... REVS. PER MIN..... REMARKS, &c. Temp. Hot Well deg. Which Engine Taken..... Pres. in Receiver CROSBY STEAM ENGINE INDICATOR, CROSBY STEAM GAGE & VALVE CO. 147, QUEEN VICTORIA ST., LONDON, E. C. 21-23 WEST LAKE ST., CHICAGO, ILL. 93-95 OLIVER ST., BOSTON, MASS. #8 Series # 16 DEY ST., NEW YORK. MANUFACTURED SOLELY BY TAKEN WITH THE STORES : Diagram Area I. H. P..... Engine Constant..... M. E. P. 9 1.6 Piston Stroke..... SCALE..... Piston Area..... Piston Speed..... Piston Diameter.....

Run #8 SeriesA

SCALE...... Piston Diameter..... Piston Speed..... Engine Constant..... Diagram Area CARD No..... Piston Stroke..... Piston Area..... I. H. P..... CROSBY STEAM GAGE & VALVE CO. CROSBY STEAM ENGINE INDICATOR, 147, QUEEN VICTORIA ST., LONDON, E. C. 21-23 WEST LAKE ST., CHICAGO, ILL. STORES : 93-95 OLIVER ST., BOSTON, MASS. INDICATOR DIAGRAM 16 DEY ST., NEW YORK. MANUFACTURFO SOLELY BY TAKEN WITH THE Vac. per gage. { lbs. Which End..... Which Cylinder BOILER PRES lbs. gage **Taken.....** 1. 6.0 Z Which Engine Pres, in Receiver Temp. Hot Welldeg. REMARKS, &c. F 374; L 5-06

SeriesA

Run*9

Vern #

R DIAGRAM WITH THE INGINE INDICATOR, SIGINE INDICATOR, AGE & VALVE CO ORES: C. BOSTON, MASS. , NEW YORK. ST., CHICAGO, ILL.	REVS. PER MIN	Piston Diameter	Piston Speed	Engine Constant	м. Е. Р. 79. 7.3	
F 374; L.5-06 INDICATO TAKEN CROSBY STEAM F MANUPACTU CROSBY STEAM (93-95 OLIVER ST 16 DEY ST. 21-23 WEST LAKE 147, QUEEN VICTOR	CARD No/	By 2.12 8	Which Engine	Which End	Pres. in Receiver	Temp. Hot Well deg. REMARKS, &c.

Run#1 SeriesB

CROSBY STEAM GAGE & VALVE CO. CROSBY STEAM ENGINE INDICATOR, Piston Diameter REVS. PER MIN. 303 147, QUEEN VICTORIA ST., LONDON, E. C. Engine Constant..... Diagram Area SCALE..... 21-23 WEST LAKE ST., CHICAGO, ILL. Piston Area..... Piston Speed 93-95 OLIVER ST., BOSTON, MASS. INDICATOR DIAGRAM Piston Stroke.... 16 DEY ST., NEW YORK. MANUFACTURED SOLELY BY TAKEN WITH THE STORES : Tere ins. lbs. Taken..... By..... AL 3,08 Which Engine..... Which End. BOILER PRES Ibs. gage Temp. Hot Welldeg. Which Cylinder Pres. in Receiver REMARKS, &c. Vac. per gage. F 374; L 5-06 # 2

Run #2 Series B

F 374F L 5-06 INDICATOR DIAGRAM TAKEN WITH THE CROSBY STEAM ENGINE INDICATOR, MANUFACTURED SOLEN IN CROSBY STEAM GAGE & VALVE CO. STORES: 93-95 OLIVER ST., BOSTON, MASS.	16 DEY ST., NEW YORK. 21-23 WEST LAKE ST., CHICAGO, 11J. 147, QUEEN VICTORIA ST., LONDON, E. C. CARD No	Taken ScALE ScALE By By Piston Diameter By At Siton Stroke Which Engine Piston Stroke Which Engine Piston Stroke Which Engine Piston Stroke Which Engine Piston Stroke Which End Piston Area Which End Piston Area Which End Diagram Area Pres. in Receiver M. E. P. ZSS Vac. per gage I. H. P. PRMADYCS RO I. H. P.	L B 2
	Run#	3 Series B	
F 374; L 5-06 INDICATOR DIAGRAM TAKEN WITH THE CROSBY STEAM ENGINE INDICATOR, MANUFACTURED SOLELV EV CROSBY STEAM GAGE & VALVE GO.	storts: 93-95 OLLVER ST., BOSTON, MASS. 16 DEY ST., NEW YORK. 21-23 WEST LAKE ST., CHICAGO, ILL. 147, QUEEN VICTORIA ST., LONDON, E. C.	CARD No	Temp. Hot Welldeg. REMARKS, &c. Jerris C
	Run	#1 SeriesC	

R DIAGRAM TTH THE VIGINE INDICATOR, ED SOLETV BV AGE & VALVE CO, RES: , BOSTON, MASS, ST., CHICAGO, ILL, A ST., LONDON, E. C.	REVS. PER MIN	
F 374: 'L 5-06 INDICATOF TAKEN W CROSBY STEAM EI MANUFACTUR OCROSBY STEAM G 93-95 OLIVER ST. 16 DEY ST. 21-23 WEST LAKE 147, QUEEN VICTORI	CARD No	Ren - 2 Serie C

Run#2 Series C

M. E. P. 72 I. H. P. SCALE ... 3. 0.D. Piston Diameter Piston Stroke..... Piston Area..... Engine Constant..... Diagram Area CROSBY STEAM GAGE & VALVE CO. Piston Speed..... CROSBY STEAM ENGINE INDICATOR, 147, QUEEN VICTORIA ST., LONDON, E. C. 21-23 WEST LAKE ST., CHICAGO, ILL. STORES : 93-95 OLIVER ST., BOSTON, MASS. INDICATOR DIAGRAM 16 DEY ST., NEW YORK. MANUFACTURED SOLELY BY TAKEN WITH THE (..... ins. Taken At 1,12 Which Engine..... Which End..... BOILER PRES Ibs. gage By..... Which Cylinder (..... Ibs. Pres. in Receiver Temp. Hot Welldeg. REMARKS, &c. Vac. per gage. F 374; L 5-06

Run#3 Series C

Serie C Rever 3

	Pun 4
	REMARKS, &c.
	Temp. Hot Welldeg.
I. H. P	Vac. per gage. { lbs ins.
M. E. P. 77/	Pres. in Receiver
Diagram Area	BOILER PRES livs. gage
Piston Area	Which Cylinder
Piston Speed	Which Engine
Piston Stroke	M / 1 5 0
Piston Diameter	By
SCALE 3.70	Taken
REVS. PER MIN	CARD No.
ST., CHICAGO, ILL. A ST., LONDON, E. C.	21-23 WEST LAKE : 147. QUEEN VICTORL
NEW YORK.	16 DEY ST.,
BOSTON, MASS.	\$100 93-95 OLIVER ST.
AGE & VALVE CO.	CROSBY STEAM G.
VGINE INDICATOR,	CROSBY STEAM E
TTH THR	TAREN

Run #4 Series C

Serie

Piston Speed..... Diagram Area SCALE . 3 07 Piston Diameter Piston Area..... м. Е. Р. 7.0 Piston Stroke..... Engine Constant..... I. H. P. CROSBY STEAM ENGINE INDICATOR, CROSBY STEAM GAGE & VALVE CO. 21-23 WEST LAKE ST., CHICAGO, IIL. 147, QUEEN VICTORIA ST., LONDON, E. C. STORES: 93-95 OLIVER ST., BOSTON, MASS. INDICATOR DIAGRAM 16 DEY ST., NEW YORK. MANUFACTURED SOLELY BY TAKEN WITH THE Ren / Serie D By 21, 35 Taken..... Which Engine..... Vac. per gage. {..... lbs. Which Cylinder..... Which End. BOILER PRES lbs. gage Pres. in Receiver Femp. Hot Welldeg. REMARKS, &c. F 374: L 5-06 Run *1 Series \mathcal{D}

F 374: L 5-06	INDICATOR DIAGRAM TAKEN WITH THE	CROSBY STEAM ENGINE INDICATOR, MANUFACTURED SOLELY BY CROSRY STEAM GAGE & VALVE CO.	93-95 OLIVER ST., BOSTON, MASS. 16 DEY ST., NEW YORK. 21-23 WEST LAKE ST., CHICAGO, ILL. 147, QUEEN VICTORIA ST., LONDON, E. C.	CARD No	By By Piston Diameter	Which Engine Piston Speed	BOILER PRESlbs. gage Diagram Area Pres. in Receiver M. E. P. 7.0	Vac. per gage. { lbs.]. H. P Temp. Hot Welldeg.	REMARKS, &c.	Jenne J	
Run*2 Series D											

DIAGRAM TH THE GGINE INDICATOR, D SOLELY BY AGE & VALVE CO.	BOSTON, MASS. NEW YORK. ST., CHICAGO, ILL. A ST., LONDON, E. C. REVS. PER MIN	SCALE	Piston Speed Piston Area Engine Constant Diagram Area M. E. P	ÂH Â
F 374: L 5-06 INDICATOR TAKEN W CROSBY STEAM EN MANUFACTURE CROSBY STEAM G	93-95 OLIVER ST., 16 DEY ST., 21-23 WEST LAKE 9 147, QUEEN VICTORL	Taken By f. 0f	Which Engine Which Cylinder Which End BOILER PRESlbs. gage Pres. in Receiver	Vac. per gage. { ins. Temp. Hot Welldeg. REMARKS, &c.
	Rur	ı * 3	Series	зIJ

DIAGRAM TH THE IGINE INDICATOR, BOURLY BY AGE & VALVE CO. ES: BOSTON, MASS. VEW YORK. TT, CHICAGO, ILL.	REVS. PER MIN SCALE3 の	Piston Diameter Piston Stroke Piston Stroke	гион эрееа. Piston Area Diagram Area M. Е. Р. У. У. С. I. H. P.	
F 374: L 5-06 INDICATOR TAKEN WI CROSBY STEAM EN MANUFACTURE OROSBY STEAM G4 5708 93-95 OLIVER ST., 1 16 DEY ST., 1 21-23 WEST LAKE S 147, QUEEN VICTORIA	CARD No	By	Which Cylinder	Temp. Hot Welldeg. REMARKS, &c.
/1	1 n	# 4	Deries	D

 DIAGRAM THH THE VGINE INDICATOR, assure by AGE & VALVE CO. AGE & VALVE CO. ABOSTON, MASS. NEW YORK. ST., CHICAGO, ILL. A ST., LONDON, E. C. 	REVS, PER MIN	Piston Diameter	Piston Speed	Engine Constant Diagram Area M. E. P. 72	Н. Р.	
F 374: L 5:06 INDICATOR TAKEN W CROSBY STEAM ET MANUFACTURI MANUFACTURI MANUFACTURI MANUFACTURI MANUFACTURI MANUFACTURI STEAM G STEAM C STEAM	CARD No	By 2,20	Which Engine	Which End	Vac. per gage. { lba. Vac. per gage. ? ina. Temp. Hot Well deg. REMARKS, &c.	
Ŧ	201	۱ <i>۳</i>	-	Ser	iesf	-

gen 1 Len . H. F

Rem 4

DIAGRAM FIN THE GINE INDICATOR, GINE INDICATOR, SOLELY BY (GE & VALVE CO. ES: BOSTON, MASS. IEW YORK. T., CHICAGO, ILL. T., CHICAGO, ILL.	REVS. PER MIN	Piston Diameter. Piston Speed Piston Area Engine Constant Diagram Area M. E. P. 7. 7. Æ I. H. P.	
F 374; L 5-06 INDICATOR TAKEN WI CROSBY STEAM EN MANUFACTUREI MANUFACTUREI MANUFACTUREI BAUF GA STORI 93-95 OLIVER ST., N 16 DEY ST., N 21-23 WEST LAKE S 147, QUEEN VICTORIA	CARD NoG	By	Dun / Den /

Run#1 SeriesG

Platon Diameter Platon Stroke..... Piston Speed CROSBY STEAM GAGE & VALVE CO. CROSBY STEAM ENGINE INDICATOR, 93-95 OLIVER ST., BOSTON, MASS. 18 DEY ST., NEW YORK. 21-23 WEST LAKE ST., CHICAGO, ILL. 147, QUEEN VICTORIA ST., LONDON, E. C. SCALE . 3 00. REVS. PER MIN..... 5 INDICATOR DIAGRAM Kagine Constan Islagram Arri Piston Area N K P. MANUFACTURED SOLELY BY L. H. P. TAKEN WITH THE - and STORES : N 1 BOILER PRES ... BM. KAKT ž ž 1, 9, 5 3 Which Engine Which Cylinder Which End Taken Tomp. Hes Well KEMAKKS, &c. Pres in Kerdere Var per 640°. F 374; L 5-06 Run#2 Series G

DIAGRAM TH THE GINE INDICATOR, a solutive by AGE & VALVE CO, tes: BOSTON, MASS, VEW YORK, IT, CHICAGO, ILL, ST,, LONDON, E. C,	REVS, PER MIN. SCALE J DJ Piston Diameter Piston Stroke. Piston Area Engine Constant Diagram Area M. E. P. YA F M. E. P. I. H. P.	e, z
F 374: L 5-06 INDICATOR TAKEN WI TAKEN WI TAKEN WI TAKEN WI ANNUFACTUREN MANUFACTUREN MANUFACTUREN CROSBY STEAM 64 8700 16 DEY ST., P 21-23 WEST LAKE 5 147, QUEEN VICTORIA	CARD No	Ren See
R	un#3 SeriesG	

R DIAGRAM THT THE VGINE INDICATOR, BE SOLELY BY AGE & VALVE CO. AGE & VALVE CO. RES: BOSTON, MASS. NEW YORK. ST., CHICAGO, ILL. A ST., LONDON, E. C.	REVS. PER MIN	Piston Diameter Piston Stroke Piston Speed	Piston Area Engine Constant. Diagram Area M. E. P	2 0
F 374; L 506 INDICATOR TAKEN W CROSBY STEAM ET MANUFACTURI CROSBY STEAM G 570 93-95 OLIVER ST., 21-23 WEST LAKE 147, QUEEN VICTORI	CARD No	By At	Which Cylinder	Temp. Hot Welldeg. REMARKS, &c. A. M. M.

Run#3a SeriesG

C. J ~ .

NEP 687 Г. Н. Р. Piston Stroke Piston Diameter Piston Speed Engine Constant CROSBY STEAM GAGE & VALVE CO. SCALE J.M CROSBY STEAM ENGINE INDICATOR, Piston Area 147, QUEEN VICTORIA ST., LONDON, E. C. CARD No. 3 REVS. PER MIN. 21-23 WEST LAKE ST., CHICAGO, ILL. BI-95 OLIVER ST., BOSTON, MASS. INDICATOR DIAGRAM Frigram Area 16 DEY ST., NEW YORK. MANUFACTURED SOLELY BY TAKBN WITH THE BOILER PRES La. KAGE 101 -Taken h, 6.07 Temp. Hut Well der. Which Engine Which Cylinder Which End KEMARKS, **A**G Pres. in Kectiver Var per gage F 3741 .L 5-06 Kun#4 Series G.

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