THESIS

AN EFFICIENCY COMPARISON
BETWEEN
A SCAVENGING AND NON-SCAVENGING
GASOLINE MOTOR

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M. A. C.

SPRING TERM 1911

Re-written May, 1917.

This thesis was contributed by

Mr. C. P. Thomas Mr. R. E. Brightup

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OBJECT OF TESTS:-

First, - To determine the brake horse power of the motor, its thermal efficiency, the gasolene used per brake horse power per hour, and a heat balance for different angles of ignition and throttle openings with the motor running on a four stroke cycle.

Second, - To design the required cams and gears for changing to a six stroke scavenging cycle and repeat the first series of tests as nearly as possible in order to obtain a comparison of results from the use of the different cycles.

M O T O R:-

The motor used was of the two cylinder, vertical, water cooled, high speed type and was built by the REO MOTOR COMPANY for experimental work. It was of four and one fourth inch bore and five inch stroke with mechanically operated poppet valves for both intake and exhaust.

Ignition was by means of a jump spark system, using dry batteries and a separate vibrator coil for each cylinder. Timing of the spark was obtained by means of a cummutator revolving at the same speed as the cam shaft and containing a contact point for each cylinder.

The motor was hand governed by the use of the throttle and commutator levers.

The carburetor was of the float feed type and was provided with fuel and air adjustments besides a variable gate throttle.

APPARATUS AND METHODS:-

The brake horse power was determined by means of a rope brake shown in Plate I. It consisted of a strong wooden frame set over the pulley and resting on platform scales. A double rope, which was attached to the bottom of the frame, passed once around a water cooled pulley, which was arranged on the engine for this purpose, and thence to a tightener at the top of the frame.

With the brake wheel revolving as shown in the figure, the net pull at the rim of the wheel was read directly on the scale beam after deducting the weight of the brake. Therefore, $B.H.P. = \frac{W.C.N.}{33000}$ where W = the net pull in pounds, C = circumference of the wheel in feet, and N = the revolutions per minute.

According to some authorities, this would not give the correct horse power, as the pull is delivered to the frame through the center of the rope and, therefore, half the diameter of the rope should be added to the radius of the wheel in computing the circumference. However correct this may be, the diameter of the rope would, due to wear, not remain constant, and it was decided, that since the object of these tests was essentially a comparison, better results would be obtained by using the actual radius of the wheel in the computations, as this would remain constant throughout all the tests.

The total number of revolutions of the cam shaft during each test, was registered by an automatic counter, which was so arranged that it could be stopped whenever it was so desired. By this arrangement, it was possible to take the initial and final readings of the counter without having to read it while in motion.

The number of revolutions of the crank shaft was obtained by multiplying those of the cam shaft by two for the four cycle tests and by three for the six cycle tests.

Cooling water was taken directly from the mains and entered the cylinder jackets near the bottom, while the outlet was at the top. The initial and final temperatures were taken by calibrated thermometers and the readings were taken at intervals of five minutes during each test. The final temperatures were kept as nearly constant as possible by adjusting the quantity of water used. This was done in order to prevent any variation in efficiency which might arise due to different cylinder temperatures. The water was collected in a tank and weighed on platform scales at the end of each test.

For the gasolene supply, two tanks were used. One rested on platform scales, which weighed to one one-hundredth of a pound and furnished the supply while the test was being run. It was connected to the pipe leading to the carburetor by a flexible rubber hose, which provided for accurate and free action of the scales. The other tank was used to furnish the fuel between tests and while obtaining proper running conditions. Either or both of the tanks could be shut off from the carburetor by turning a stop cock. By this method, the changing of the source of fuel from one tank to the other on beginning or ending a test, was very easily and accurately accomplished. In setting the valves, which was done for both cycles, the proper points for the different events were laid off on the flywheel and suitably marked with reference to a pointer attached to the crank case. Then, with the cam shaft gear in proper mesh with the one on the crank shaft, thin shims were placed beneath the caps, with which the valve push rods were equipped, till the valve movements checked with the corresponding events marked on the flywheel. This setting was checked occasionally during the tests to guard against any changes which might occur.

The four cycle valve setting was obtained from the construction drawings of the motor as designed by the builders. The lay-out of the cams is shown in Plates II and III.

The valve setting for the six stroke cycle was one which had been found to give the best results by the REO

COMPANY.

The necessary cams to give these events were designed as a part of the work and are shown in Plates IV and V.

The diagrams used in placing the cams on the shaft are shown in Plate VI.

In changing from the four to six stroke cycle, it was necessary to arrange for a three to one reduction for the cam shaft. The two gears designed for the purpose are shown in Plates VII and VIII. All the cams and gears were made in the College shops.

The timing the spark was obtained by laying out the degrees, on each side of dead center, on the flywheel. With the spark circuit closed, and by turning the flywheel slowly by hand until contact occurred as evidenced by the sound of the vibrator, the position of the commutator was noted and marked permanently on an arc of tin around which a pointer, fastened to the commutator, moved. This gave the point of ignition when the wheel was turned by hand, but as is well known, the lag of the spark coil is very great, especially at high speeds and to say that the spark was set at forty degrees ahead of center when the R. P. M. was eight hundred does not mean that the ignition was actually occurring forty degrees ahead. This method simply provided a means whereby a former commutator setting could be accurately duplicated at any time and must not be understood in the tests to give the real time of ignition.

The throttle gate opening on the carburetor was divided into four equal parts for use in duplicating throttle settings.

The motor exhaust was very little muffled, it passing through about five feet of one and one-fourth inch pipe from each cylinder and then through a long four inch pipe to the open air.

The extra two strokes on the six stroke cycle were used for the purpose of scavenging the cylinders of burned gases. An automatic poppet valve was attached to the exhaust pipe of each cylinder near the exhaust valve, to allow fresh air to enter during the suction scavenging stroke instead of drawing in the burned gases again from the exhaust pipe. The inertia of the gases moving up the pipe tended to help the piston suction to open these valves and during the exhaust stroke they remained closed, and forced the exhaust gases and the scavenging charge to pass up the exhaust pipe.

Compression cards were taken from each cylinder before starting both series of tests. To obtain these an indicator was attached in place of the spark plug and the engine cranked by hand while the cord was drawn out slowly, giving the diagrams as shown in Plate IX. These diagrams were taken only for the purpose of showing any difference of compression in the cylinders for the two series of tests.

Calibration tests were made on the scales and thermometers used and correction curves plotted for the thermometers and gasolene scales. The brake scales and those used in weighing water were found to be correct and, therefore, needed no curves.

METHOD USED IN MAKING TESTS.

Before starting the engine, the cooling water and the gasolene in the supply tank were turned on and the gasolene weighing tank scales were balanced. The brake scales were balanced before the rope was put on the wheel. After the motor was started, the spark and throttle were set at the desired angle and opening respectively and as much load applied as the engine would carry without too great a reduction of speed. These conditions were held constant for about ten minutes before starting the test proper. At the moment of starting the test, whoever was tending the brake took the initial reading of the counter while the timekeeper changed the gasolene supply from the supply tank to the weighing tank and closed the outlet of the cooling water tank. Readings of the initial and final cooling water temperatures were taken every five minutes during the test, the final temperature being kept as nearly constant as possible by adjusting the amount of water used. At the

TEST NUMBER	WEIGHT OF GASOLENE	RISE IN TEMPERATURE	CORRECTION FOR FUSE & CHEMICAL	CORRECTED TEMT. RISE	HEAT VALUE B.T.U. PER LB.	AVERAGE HEAT VALUE
1	.245 gr.	3.245° F.	.248° F.	2.997° F.	19049	
2	.2634 gr.	3.35° F.	.110° F.	3.24° F.	19160	
3	.2298 gr.	2.85° F.	.110° F.	2.74° F.	18580	
						18930 B.T.U

TEST CONSTANTS

Diam. of cylinders - 4¼" Stroke 5"

Circum. of flywheel - 53 1/8" 1" on the rim of flywheel = 6.77.

Circumference of brake wheel - 47"

Brake Constant

B.H.P. = R.P.M. x load x K.

$$K = \text{Brake constant} = \frac{47}{12 \times 33000} = .000118$$

VALVE SETTINGS

4 CYCLE

Inlet opens 18 10' late

Inlet closes 36 20' late

Exhaust opens 54 30' early

Exhaust closes 7 20' late

6 CYCLE

Inlet opens 17 late.

Inlet closes 34 late.

Exhaust opens 40 31' early.

Exhaust closes 13 31' late.

	TEST #1	TEST #2	TEST #3	TEST #4	TEST #5
(A) Duration in minutes	30	30	30	30	30
(B) Angle of Ignition	x15°	x15°	x15°	x25°	x25°
(C) Throttle opening	½	½	Full	½	Full
(D) R. P. M.	476	516	676	565	687
(E) Net load on scales	75#	75#	80#	75#	90#
(F) Brake Horse Power	4.22	4.57	6.38	5.00	7.30
(G) Lbs. gasolene used	3.20	3.41	3.915	3.47	4.255
(H) " " " per hr.	6.40	6.82	7.83	6.94	8.51
(I) " " per B.H.P. hr.	1.52	1.49	1.225	1.385	1.166
(J) B.T.U. per lb. gasolene	18930	18930	18930	18930	18930
(K) B.T.U. supplied per B. H. P. hour	28773	28205	23189	26218	21632
(L) Initial Temp. of water (average)	53.3°	55.2°	56.1°	62.2°	60.2°
(M) Final Temp. of water (average)	104.1°	102.1°	103.1°	105.7°	107.9°
(N) Temperature change	50.8°	46.9°	47.0°	43.5°	47.7°
(O) Weight of water used in test	301	318	488	384	411
(P) Weight of water used per hour	602	636	976	768	822
(Q) B.T.U. absorbed by water per hour	30581	29828	45872	33408	39209
(R) B.T.U. absorbed per B.H. P. hour	7230	6530	7180	6680	5375
(S) Percent of heat in useful work	8.85%	9.02%	10.98	9.7%	11.75%
(T) Percent of heat absorbed by cooling water	25.1%	23.1%	31.0%	25.4%	24.8%
(U) Per cent of heat given to exhaust rad. & friction	66.05	67.88	58.02	64.9	63.45

	TEST #6	TEST #7	TEST #8	TEST #9	TEST #10
(A)	30	14	30	30	20
(B)	x35°	x35°	x35°	x45°	x45°
(C)	1/2	full	full	1/2	full
(D)	645	728	761	666	738
(E)	60	90	90	70	90
(F)	4.57	7.73	8.08	5.50	7.83
(G)	4.535	2.289	4.385	3.863	2.72
(H)	9.07	9.84	8.77	7.726	8.16
(I)	1.985	1.272	1.085	1.405	1.042
(J)	18.930	18.930	18930	18930	18930
(K)	37576	24079	20539	26596	19725
(L)	60.8°	60.9°	60.4°	71°	69.2°
(M)	101.1°	105.2°	108.0°	117.6°	115.5°
(N)	40.3°	44.3°	47.6°	46.6°	46.3°
(O)	369	239	521	407	369
(P)	738	1025	1042	814	1107
(Q)	29741	45407	49599	37932	51254
(R)	6510	5870	6130	6890	6540
(S)	6.78%	10.57%	12.4%	9.57%	12.9%
(T)	17.4%	24.4%	29.8%	25.9%	33.1%
(U)	75.82%	65.03%	57.8%	64.53%	54.0%

	TEST #11	TEST #12	TEST #13	TEST #14
(A)	17	15	20	20
(B)	x55°	x55°	x65°	x65°
(C)	1/2	full	1/2	full
(D)	622	841	700	806
(E)	65	80	55	70
(F)	4.77	7.95	4.54	6.66
(G)	2.045	2.307	2.70	3.02
(H)	7.21	9.228	8.10	9.06
(I)	1.511	1.161	1.783	1.36
(J)	18930	18930	18930	18930
(K)	28603	21978	33752	25745
(L)	70.3	53.1°	53.9°	53.6°
(M)	107.2°	107.2°	103.3°	106.6°
(N)	36.9°	54.1°	49.4°	53.0°
(O)	283	258	244	359
(P)	998	1032	732	1077
(Q)	36826	54799	36160	57081
(R)	7730	6880	7950	8560
(S)	8.88%	11.6%	7.54%	9.88%
(T)	27.0%	31.4%	23.5%	31.2%
(U)	64.12%	57%	68.96%	58.92%

SIX CYCLE COMPUTATIONS

	TEST #1	TEST #2	TEST #3	TEST #4	TEST #5
a	30	30	30	30	20
b	x15°	x15°	x25°	x25°	x35°
c	1/2	full	1/2	full	1/2
d	481	479	513	539	561
e	60	60	60	60	60
f	3.4	3.39	3.65	3.82	3.98
g	1.935	2.26	1.935	2.26	1.235
h	2.87	4.52	2.87	4.52	3.705
i	.844	1.334	.79	1.182	.931
j	18930	18930	18930	18930	18930
k	15976	25252	14954	22375	17623
l	56.7°	55.8°	56.0°	55.8°	57.7°
m	109.2°	109.7°	109.3°	112.9°	108.7°
n	52.5°	53.9°	53.3°	57.1°	51.0°
o	304	295	314	305	230
p	608	590	628	610	690
q	31920	31801	33472	34831	35190
r	9380	9390	9220	9120	8840
s	15.95%	10.01%	17.01%	11.4%	14.4%
t	58.7%	36.8%	61.6%	40.8%	50.2%
u	25.3%	53.19%	21.39%	47.8%	35.4%

SIX CYCLE
C O M P U T A T I O N S

	TEST #6	TEST #7
a	20	20
b	x35°	x45°
c	full	1/2
d	65	55
e	655	489
f	5.02	3.18
g	1.655	1.435
h	4.965	4.305
i	.989	1.355
j	18930	18930
k	18722	25650
l	56.3°	56.3°
m	113.5°	109.9°
n	57.2°	53.6°
o	235	187
p	705	561
q	40326	30069
r	8025	9450
s	13.6%	9.93%
t	42.8%	36.8%
u	43.6%	53.27%

SAMPLE SET OF COMPUTATIONS

Test #1 Four Cycle Series.

Item a --- From Log Sheet - 30 minutes.

b --- " " " - x 15°

c --- " " " - 1/2 open

d --- Total number of revolutions -- duration - R.P.M. or 14288 -- 30 min. -- 476 R.P.M.

e --- From Log Sheet - 75#

f --- B.H.P. - R.P.M. x load x K - where K - .000118, or B.H.P. - 476 x 75# x .000118 - 4.22 B.H.P.

g --- From Log Sheet - 3.20#

h --- Lbs. used per hour $\frac{\text{Lbs. used in test}}{\text{DURATION}}$ x 60 min.

$$= \frac{3.20}{30} \times 60 = 6.4\# \text{ per hr.}$$

i --- Lbs. used per B.H.P. hr. = $\frac{\text{Lbs. per hr}}{\text{B.H.P.}} = \frac{6.4}{4.22} = 1.52\#$

j --- B.T.U. per # gasolene = 18930 from an average of the Parr Calorimeter tests.

k --- B.T.U. supplied per B.H.P. hr. = # of gasoline per B.H.P. hour x B.T.U. per hr. = 1.52 x 18930 B.T.U. = 28773 B.T.U.

l --- Initial temperature of H_2O = Avge. from log sheet = 53.3° F.

m --- Final temperature H_2O = Avge. from log sheet 104.1° F.

n --- Temp. change = Item (m) - Item l = $(104.1^\circ - 53.3^\circ)$ = 50.8° F.

o --- Wght. of H_2O used in test (from Log Sheet) = 301#.

p --- Weight of H_2O per hr. = $\frac{\text{Item (o)}}{\text{Item (n)}}$ x 60 min. = $\frac{301}{30}$ x 60 = 602#.

q --- B.T.U. absorbed by H_2O per hr. = Item (p) x Item (m) = 602# x 50.8 = 30581 B. T. U.

r --- B.T.U. absorbed per B.H.P. hr. = Item (q) ÷ Item (f) = 30581 B.T.U. ÷ 4.22 B.H.P. = 7230 B.T.U.

HEAT BALANCE

s --- Percent of heat in useful work = B.T.U. equivalent of 1 B.H.P. hr. ÷ Item (k) = 2545 B.T.U. ÷ 28773 B.T.U. = 8.85%

t --- Percent of heat absorbed by cooling water = Item (r) ÷ Item (k) = 7230 B.T.U. ÷ 28773 B.T.U. = 25.1%

u --- Percent of heat given to exhaust, radiation and engine friction = 100% - (Item s) plus Item (t) = 66.05%.

CONCLUSION

The results of the foregoing tests show very conclusively that there was a marked increase in thermal efficiency due to the change from four to six stroke cycle. Taking the average of all the efficiencies obtained from the four cycle tests, which is 9.96%, from the average of those obtained from the six cycle tests, which is 13.18%, gives an increase of 3.22%. This is a 32.3% increase in efficiency and compares very favorably with the results obtained by others in the experiments of the same character. The efficiencies obtained, although seeming rather low, are about what would be expected of the common high-speed automobile motor. They would have been slightly higher had the diameter of the brake rope been taken into consideration in computing the B. H. P., as explained in our introduction. The motor ran very well under the six stroke cycle, with the exception that the carburetor could not be adjusted to give the proper mixture at all throttle openings and had to be readjusted with each throttle change. There was a very great decrease in the vibration of the motor, when changed to six cycle, due to the explosions being balanced, while they were unbalanced under the four stroke cycle since the cranks were 180° apart. The six cycle B. H. P. was quite a little less than the four cycle, as would be expected.

APPENDIX

OUTLINE OF PROPOSED WORK.

The object of the test is to obtain a comparison of the mechanical and thermal efficiencies of a two cylinder gasolene motor having a scavenging stroke in addition to the regular four stroke cycle, with those of the same motor without that stroke.

The load will be applied by means of a prong brake and measured by platform scales. The speed will be taken either by a tachometer, checked occasionally by a hand counter, or by a hand counter over a period of several minutes.

The jacket cooling water used will be taken from the mains and weighed in tanks after using, the temperature being taken just before entering and as it leaves the cylinder jacket.

The I.H.P. will be obtained by indicator up to as high a speed as is found possible and it is proposed to take all cards above that speed by monograph, or to compute the M.E.P. from Grover's formulae (M.E.P. = I.C. - .01C^2) if it is found to be fairly accurate by trial. In this case the compression would be obtained by taking compression cards at the various speeds. Since the motor is hand governed, it is thought best to make a series of tests at various angles of ignition, the throttle being adjusted to give the best running conditions of the motor under that angle of ignition. The number of tests will have to be determined by the angle through which the ignition may be varied, which is not known at present. This series will be run on the motor when using a four stroke cycle and all the conditions duplicated as nearly as possible in running the same series using a six stroke cycle.

The length of the tests will depend upon the difficulty found in keeping constant conditions, but will be made long enough to give time to take the required cards, and at the same time, to use considerable fuel in order to reduce the danger of error in the weighing of it and in the depending computations.

The best value of the fuel will be obtained from a calorimeter test made on the gasolene used.

The items to be recorded on the running log will be as follows:

(1) Time

(2) Angle of Ignition

(3) Brake load (constant during each test)

(4) R.P.M. (readings at certain intervals)

(5) Initial temp. of cooling water (readings at intervals).

(6) Final temp. of cooling water (readings at intervals).

(7) Weight of cooling water.

(8) Weight of gasolene used.

(9) Room temperature.

(10) Barometer.

This will give the readings to be taken at intervals during the test besides indicator cards.

Item 8 and probably Item 7 will be obtained at the end of the test.

ITEMS TO BE COMPUTED.

1. No. of test.
2. Duration of test (minutes).
3. Angle of ignition.
4. R. P. M.
5. B. H. P. = K x W x R. P. M. K - Brake constant.
   W - Net scale reading.
6. Explosions per cylinder per minute.
7. Average M.E.P. cyl # 1.
8. Average M.E.P. # 2.
9. 1 H.P.cyl. #1
10. 1 H.P. " #2
11. Total I. H. P. (9) plus (10)
12. Friction H. P. = 1 H P - B H P.
13. Mech. Eff. = Item 5 ÷ Item 11.
14. Pounds of gasolene used during test.
15. Pounds of gasolene used per hour.
16. Pounds of gasolene used per 1 H P hour.

17. Pounds of gasolene used per B. H. P. hour.

18. B. T. U. per pound of gasolene. (Calorimeter)

19. B. T. U. supplied per I. H. P. hour.

20. B. T. U. supplied per B. H. P. "

21. Initial temperature of jacket water.

22. Final temperature of jacket water.

23. Temperature change of jacket water.

24. Weight of jacket water used during test.

25. Weight of jacket water used per hour.

26. B. T. U. absorbed by jacket water per hour.

HEAT BALANCE

27. Heat equivalent of useful work $\left(\frac{2545 \times \text{item } 5}{\text{item } 20}\right)$

28. Heat equivalent of engine friction $\left(\frac{2545 \times \text{item } 10}{\text{item } 20}\right)$

29. Heat absorbed by jacket water $\left(\frac{\text{Item } 26}{\text{Item } 15 \times \text{item } 18}\right)$

30. Heat to exhaust and radiation = I - (item 27 plus item 28 plus item 29).

BIBLIOGRAPHY OF MATERIAL READ.

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theoretical cards for this stroke.

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Scavenging. (text book by Jones)

Scavenging. (text book by Donkin)

"Testing Gas Engines & Motors" (E. S. Frost - POWER, Dec. 29, '08. Methods used in making trials and in keeping the running log, also for finding results. Test on a four cycle, four cylinder automobile motor by prony brake and indicators.

Cards and tabulated results given.

"The Exhaust of The Internal Combustion Engine." (POWER, February 25, 1908). Taking up the effects on the color, smell and sound of exhaust, of the mixture, governing, ignition, valve setting, etc.

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"Griffin Three Cycle (six stroke cycle) Enclosed Gas Engine." (ENGINEERING, December 4th, 1908.) Description of this engine with discussion of scavenging stroke.

"The Effect of Mixture, Strength and Scavenging upon Thermal Efficiency." (Prof. Hopkinson, ENGINEERING, Vol. 85, - '08 (Pages 520, 630, 665, 558, 658.)

Extracts from paper given before the I. of M. E. with discussions by Mr. Atkinson, Mr. J. H. Hamilton and others. Results and conclusions from a number of tests.

SUMMARY OF PROGRESS REPORTS.

Mar. 24. Work was started in preparation for the tests to be made and much time was spent in setting up and cleaning the engine and in piping for the exhaust, water and gasolene.

Apr. 8.
93 hrs. The four cycle series of tests was begun, and five half-hour tests had been completed when, due to the water pressure being shut off at the power house, one cylinder was so badly cracked as to require new ones.

Apr. 11
101 hrs. This required considerable work and the engine was not in running shape again until April 20th.

Apr. 20
120 hrs. The series of tests was begun over again and progressed very well until it was decided to

stop with fourteen tests completed.

Apr. 26
142 hrs.

The work of designing and making the six cycle cams and reduction gears was now taken up and good progress was made, with the exception that after the reduction gears had been finished, the distance between centers was found to be greater than that given by the engine blue print book. This necessitated a new pair of gears being made. After setting valves, etc., the engine was started and found to run very satisfactorily.

May 27
198 hrs.

Tests were begun and the work progressed very well until during the eighth one both cylinders cracked and loosened from the crank case, bringing the work to an end.

May 30
211 hrs.

The work of obtaining the heating value of the fuel samples was then undertaken with the Parr Calorimeter. The remainder of the computations and drawings were finished and the report handed in for correction.

June 5
233 hrs.

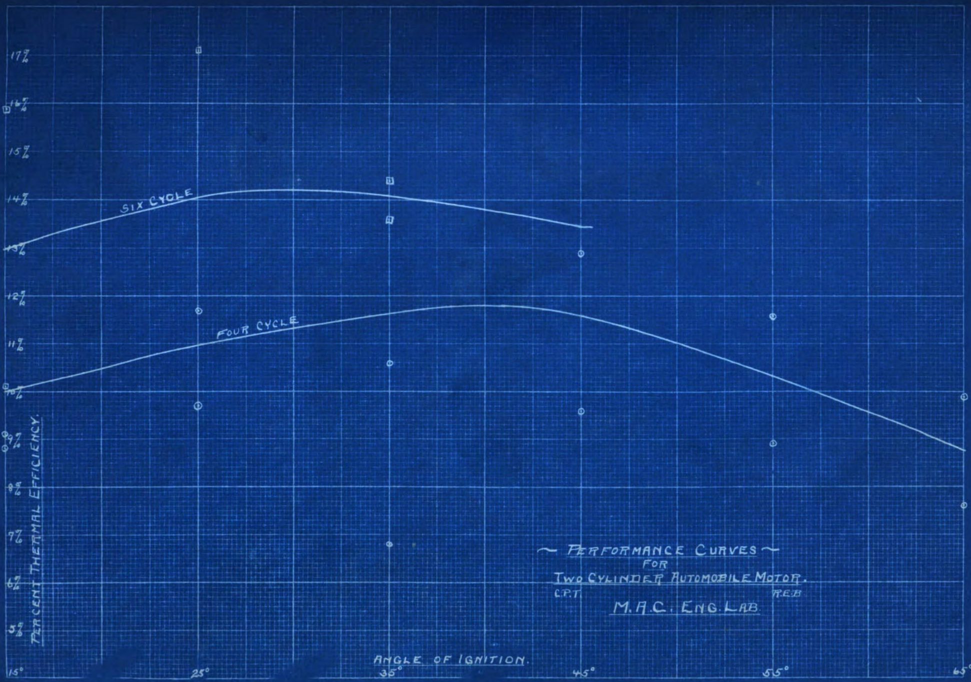
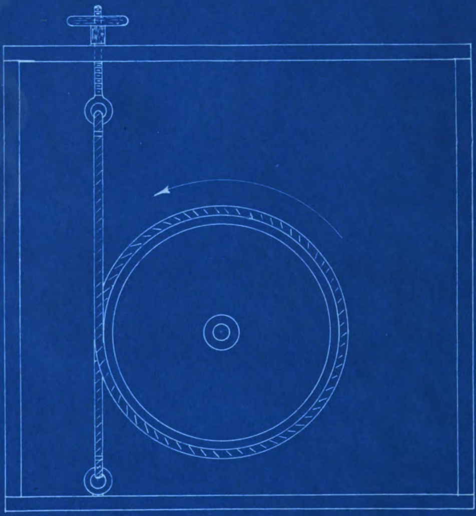
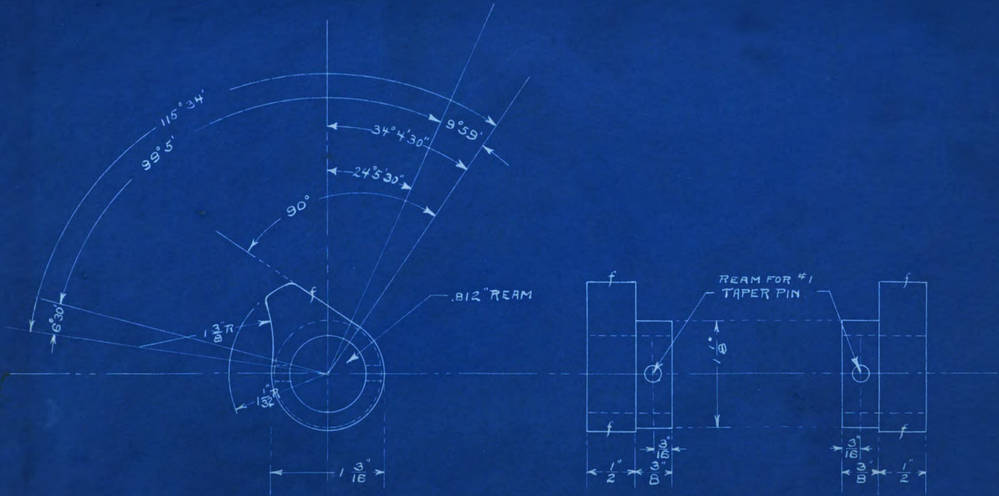

~ PERFORMANCE CURVES ~
FOR
TWO CYLINDER AUTOMOBILE MOTOR.
C.P.T.
R.E.B.
M.A.C. ENG. LAB.
SIX CYCLE
FOUR CYCLE
PERCENT THERMAL EFFICIENCY.
ANGLE OF IGNITION.
17%
16%
15%
14%
13%
12%
11%
10%
9%
8%
7%
6%
5%
15°
25°
35°
45°
55°
65°

PLATE 1.

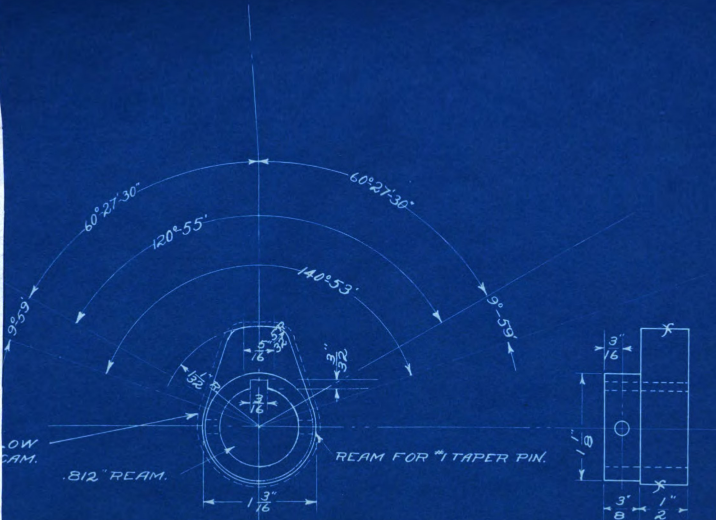


ROPE BRAKE USED IN TESTS.



FOR FRONT CYLINDER. FOR REAR CYLINDER.

FOUR CYCLE INLET CAMS.

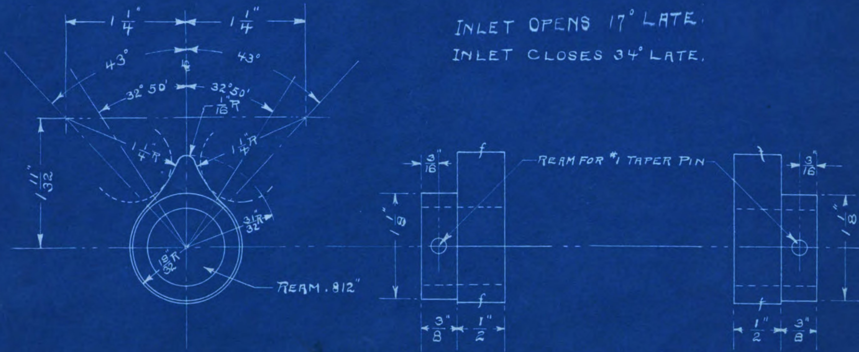


CARBONIZE .030" DEEP & HARDEN.

NOTE:- IN
ALLOW FIN

3DA10- A GRADE D.F. 4 WANTED.

INLET OPENS 17° LATE.
INLET CLOSES 34° LATE.



FOR REAR CYLINDER.

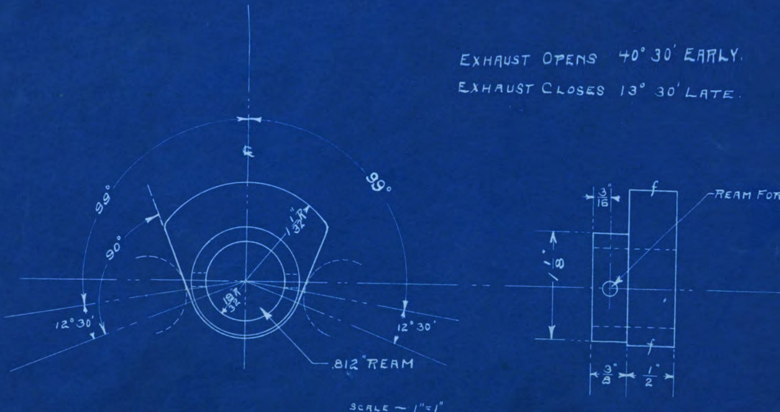
FOR FRONT CYLINDER.

SCALE ~ 1" = 1"

SIX CYCLE CAM (INLET)

PLA7

EXHAUST OPENS 40° 30' EARLY.
EXHAUST CLOSES 13° 30' LATE.



SIX CYCLE EXHAUST CAM.
TWO WANTED.

PLATE

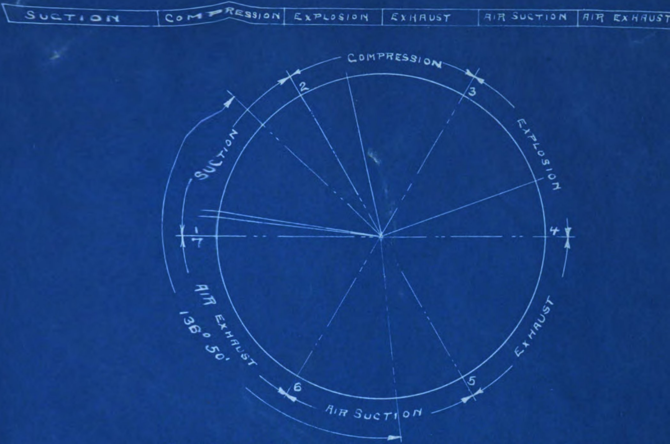


DIAGRAM OF CAM SETTING FOR SIX-STROKE CYCLE.

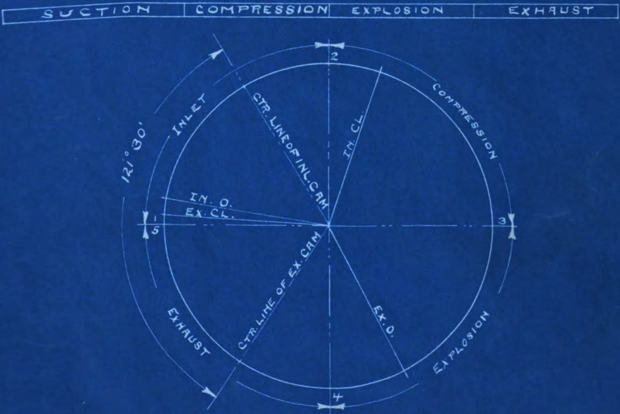
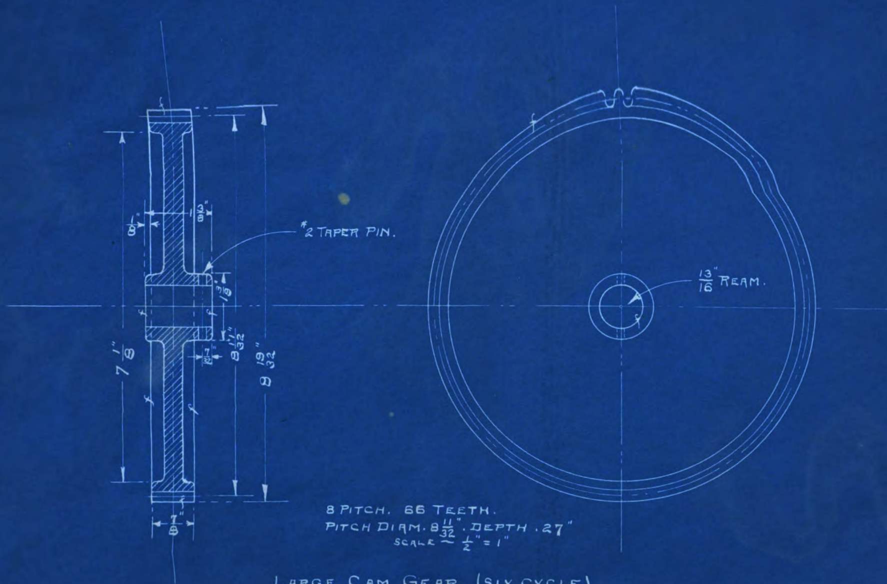


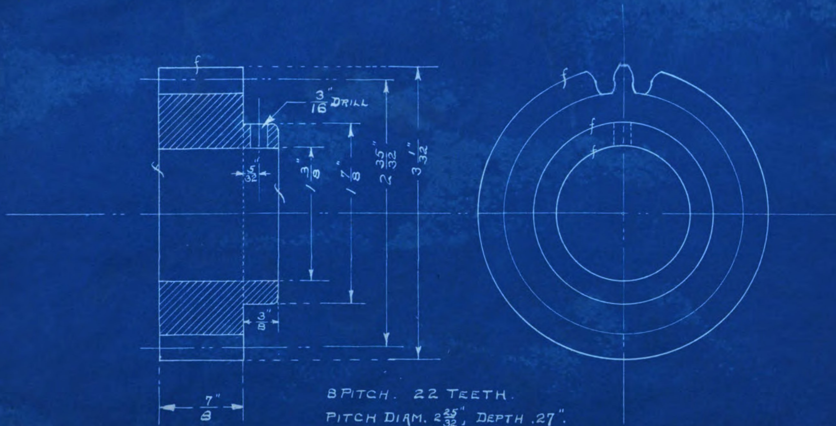
DIAGRAM OF CAM SETTING FOR FOUR-STROKE CYCLE.



8 PITCH. 66 TEETH.
PITCH DIAM. 8 11/32". DEPTH .27"
SCALE ~ 1/2" = 1"

LARGE CAM GEAR. (SIX CYCLE)

PLATE



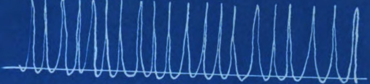
8 PITCH. 22 TEETH.

PITCH DIAM. $2\frac{25}{32}$", DEPTH .27".

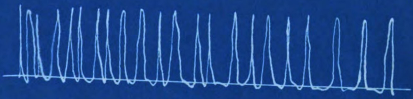
SCALE ~ 1"=1"

SMALL CAM GEAR (SIX CYCLE).

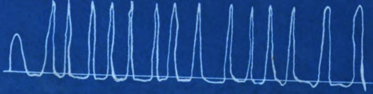
PLATE



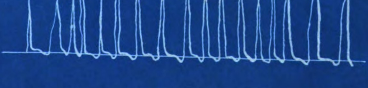
CYLINDER
FOUR CYC
APR. 20, 1
COMP. — 4



CYLINDER
FOUR CYC
APR. 20, 1
COMP. 4

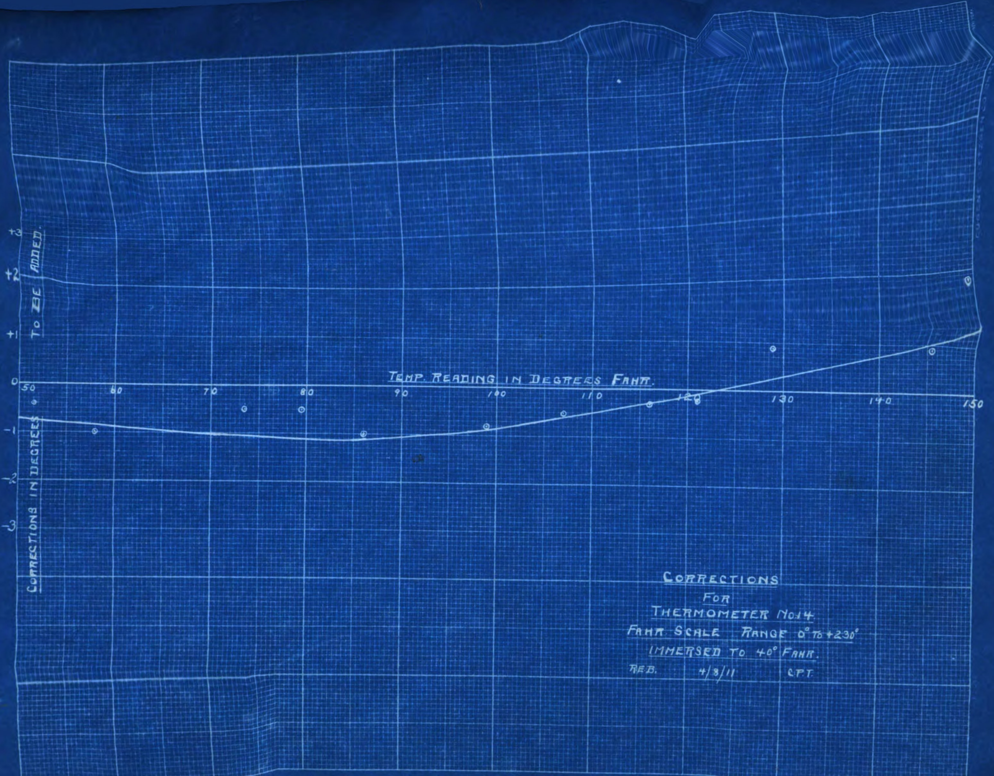


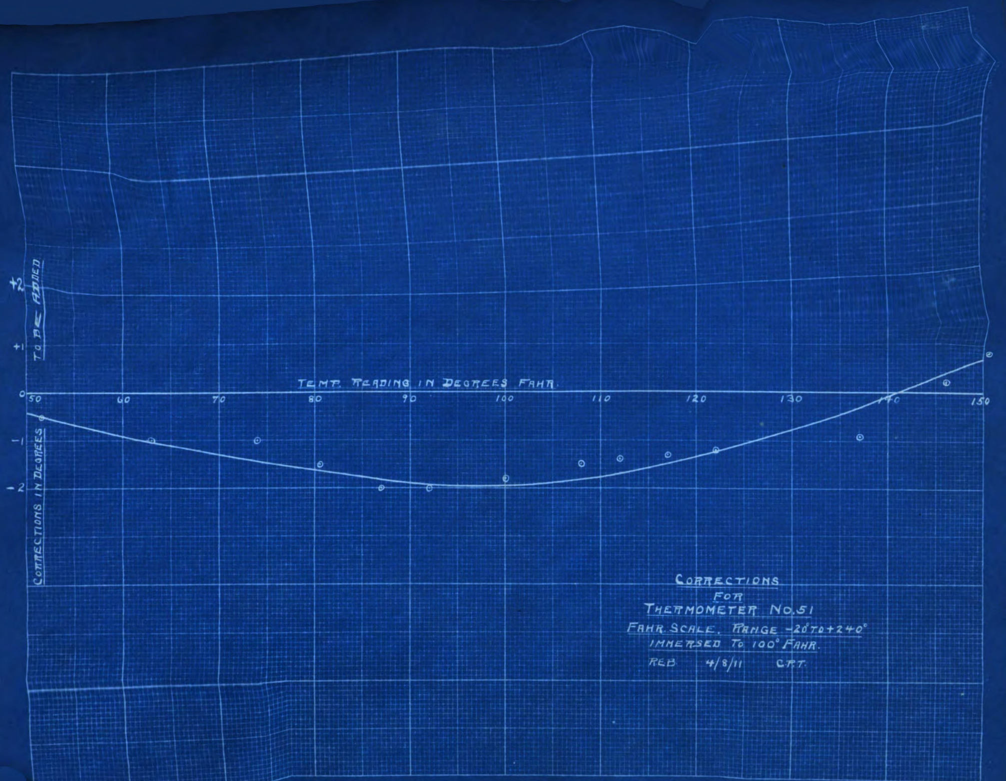
CYLINDER A
SIX CYCLE
MAY 30, 1911
COMP. 46#

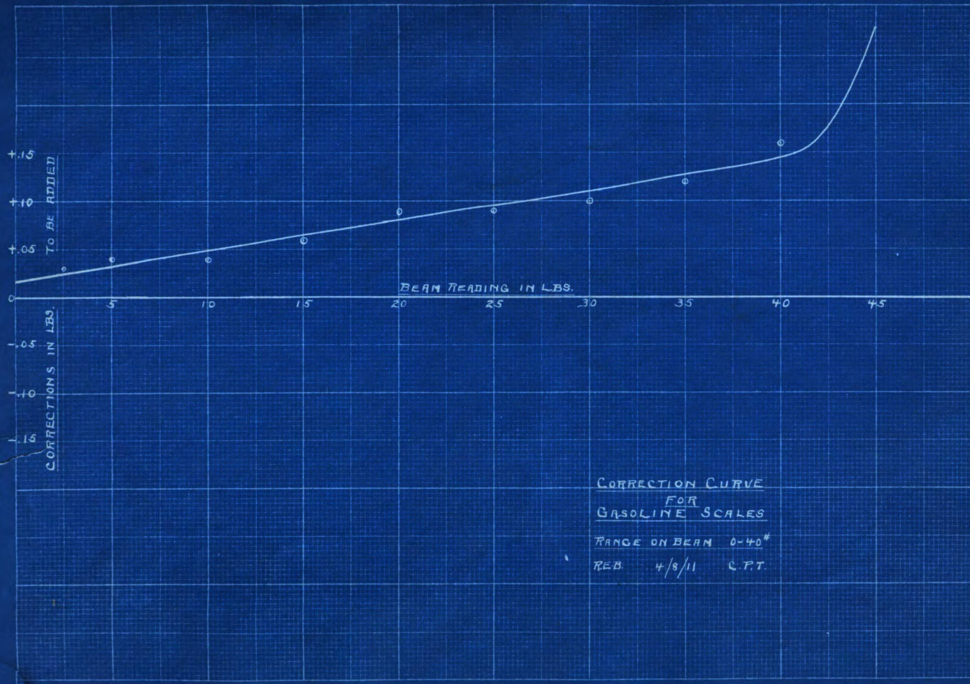


CYLINDER B
SIX CYCLE
MAY 30. 191
COMP. 42

COMPRESSION CARDS.
60# SPRING.


TEMP. READING IN DEGREES FAHR.
50
60
70
80
90
100
110
120
130
140
150
CORRECTIONS IN DEGREES TO BE ADDED.
+3
+2
+1
0
-1
-2
-3
CORRECTIONS
FOR
THERMOMETER No.14.
FAHR. SCALE RANGE 0° TO +230°
IMMERSED TO 40° FAHR.
R.E.B. 4/8/11 C.P.T.


CORRECTIONS
FOR
THERMOMETER NO.51
FAHR. SCALE. RANGE -20° TO +240°
IMMERSED TO 100° FAHR.
REB 4/8/11 C.R.T.
TEMP. READING IN DEGREES FAHR.
CORRECTIONS IN DEGREES
TO BE ADDED
+2
+1
0
-1
-2
50
60
70
80
90
100
110
120
130
140
150



+.15
+.10
+.05
0
-.05
-.10
-.15
TO BE ADDED
CORRECTIONS IN LBS.
BEAM READING IN LBS.
5
10
15
20
25
30
35
40
45
CORRECTION CURVE
FOR
GASOLINE SCALES
RANGE ON BEAM 0-40#
R.E.B. 4/8/11 C.P.T.