THESIS

COMPRESSION TESTS ELYRIA GAS ENGINE

A. H. NICHOL G. W. OSGOOD
H. G. SOMMER

1917

Determination of the Most Efficient Compression Pressure for the Elyria Gas Engine

A Thesis Submitted to

The Faculty of

MICHIGAN AGRICULTURAL COLLEGE

by

A.H. Nichol G.W. Osgood

H.G. Sommer

Candidates for the Degree of

Bachelor of Science

June, 1917

THESIS

ACKNOWLEDGMENT

We wish to express our appreciation to the Mechanical Engineering Department for the use of the apparatus on which this test was made, also for the services of the mechanic who kept the engine in running order.

Signed,

The Authors

The R.E. Olds Hall of Engineering

PREFACE

During the last few years the internal combustion engines, in both the stationary and portable types, have reached, as regards the mechanical construction, a high degree of development. The simplified construction and the attendant reduction of the first cost has brought about a marked increase in the use of this type of prime mover. Coincident with the large use of internal combustion engines has arisen a problem of efficiency.

In all kinds of internal combustion engines the compression pressure plays an important part in the efficiency derived from that engine. The theoretical effect of increasing the compression, and the commercial limits to this increase are very important. In running test to determine the most efficient compression pressure the problem of economy is dealt with only as a minor subject. The subject matter of thermal and mechanical efficiency is of prime importance.

Different fuels will stand varied degrees of compression but we are limiting our test s to the use of illuminating gas. It is our problem to determine the most efficient compression pressure, all other things being as nearly constant as possible.

GENERAL DESCRIPTION

The object of this thesis was to determine the most efficient pressure for the Elyria Gas Engine in the M.A.C. Mechanical Engineering Laboratory by running efficiency tests under constant conditions. The different compression pressures were to be obtained by changing the length of the connecting rod.

The engine on which this test was made is the "Little Big Engine", of the tandem, single acting type, built by the Elyria Gas Engine Company. Elyria, Ohio. It has a twelve inch stroke and two cylinders of 8.5" diameter, each. It developes 35 H.P. at 325 R.P.M. The piston rod which is 2" in diameter runs through the front cylinder to the rear, thus reducing the piston area of the front cylinder by 3.1416 sq. in.

The connecting rod is so made that it can be lengthened by inserting shims near the crank pin box. For lower compressions there is a connecting rod 1.25 inches shorter than the first. By means of these two rods and several shims the compression can be changed from 70 pounds to 190 pounds.

A good idea of the external appearance of this engine may be had from the accompaning photograph.

The speed of this engine is controlled by a constant quality governor which is guaranteed to govern within two per cent of the mean speed.

As fuel the engine burns a mixture of air and illuminating gas. The gas was taken from the mains of the Lansing Gas Co. Before the gas enters the manifold it passes thru an Equitable gas meter which registers tenths of cubic feet. Manometers in the gas line at the entrance and exit of the meter show the drop of pressure of the gas as it passes t hru. Two thermometers register the temperature of the gas as i t enters and leaves the meter.

To determine the amount of air used as fuel a special measuring device was built. This device consisted of a long cylindrical tank fitted with two 2" orfices in o ne end and connected from the other end to a 3" pipe leading to the manifold. A manometer measures the drop in pressure between the air outside and the air inside of the tank. The tank is also equiped with a thermometer. The method just described is known as the R.J Durley's method.

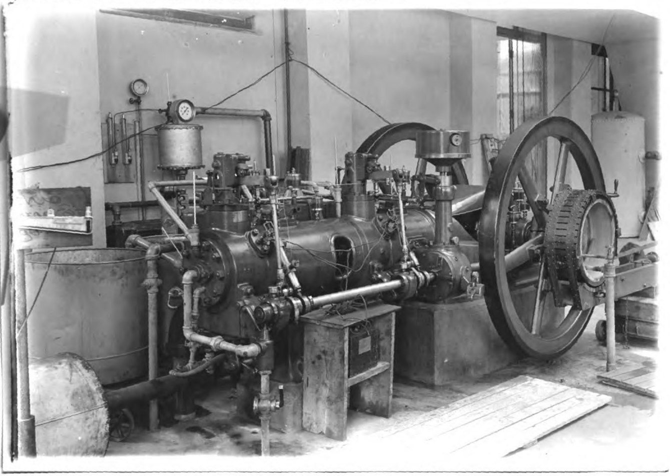
The indicators used in connection with this test were Crosby outside spring indicators.

An ordinary prony brake was used to maintain a constant load on the engine.

For starting, compressed air is admitted to the rear cylinder at regular intervals by a cam mechanism which turns over the engine until it is operated on gas.

Seven thermometers were used to aid in regulating the temperature of the cooling water.

Other auxiliary apparatus which was useful in this test was: a watch, foot rule, engineer's scale, speed counter, log boards and weighing scales.



The Elyria gas engine on which the test was made

It has been stated by good authority that very few tests of this nature have been run without any mishaps. We found no exception to this rule. After numerous delays such as burned out bearings, worn packing, bent piston rod, etc, we succeeded in finishing the experiment. We have, however, endeavored to use due care in performing these tests so that the results can be relied on.

To determine the most efficient compression, five tests were made, a different length of connecting rod being used with each test. Each test was composed of a series of runs, five in number, one for each load. These runs covered a period of twenty minutes during which the load was kept constant by a prony brake. The different loads were, zero, quarter, half, three-quarter, and full load.

Before starting the engine we noted carefully that everything was in running order, such as bearings, oil cups, cooling system, etc. Then the engine was set so that when compressed air was admitted to the rear cylinder it would start the engine. The engine was allowed to run for several minutes so that it would be properly warmed up when the first readings would be taken. In the meantime the indicators were attached, the temperature of the cooling water was regulated by the adjustment of valves provided for that purpose, and a trial reading of R.P.M. was taken. As the greatest efficiency can be had when the engine is running at a high temperature, just enough cooling water was allowed to pass thru

the jackets to prevent over-heating. We first made a preliminary run to determine the range of load that the engine would carry without the speed falling below 2% of the mean R.P.M.

The first run was made with the brake entirely loose. At a predetermined instant the "no load" test was begun. Two men took the following readings: Gas meter reading, pressure and temperature of gas entering and leaving the meter, cooling water temperatures, manometer readings on the air meter, and temperature of air passing thru the meter. The weight of cooling water used was also obtained. The third man took indicator cards and recorded the R.P.M. Ten minutes later a similar set of readings were taken again. At the end of twenty minutes the final readings were recorded and the brake was set to maintain the next higher load.

When the readings and cards had been taken for the five different loads, we obtained compression cards in the following manner: At full load the spark was cut off by holding down the push rod of the spark breaking mechanism so that the cam would not touch it. During this interval a card was taken, the indicator drum being operated by hand. The cards thus obtained, instead of looking like ordinary cards, resembled a series of peaks and valleys. The distance between the atmospheric line and one drawn thru the peaks, when reduced to scale, will equal the compression pressure at full load. As a precaution

against error several cards were taken for each cylinder. We used 100# and 150# indicator springs for this purpose.

For no load and quarter load a 100# spring was used. 150# and 200# springs were inserted for the respective remaining loads.

The only preparation necessary for the next test was the lengthening of the connecting rod. This was done by inserting a half inch shim. The second test was run in a similar manner as the first. We however, had trouble with the ignition. At times the engine failed to carry its load because of misfiring. We remedied this trouble by adjusting the locknuts on the ignition push rods.

To obtain the desired compression for the third test we inserted a quarter inch shim, which, with the half inch shim already in use, reduced the clearance volume by .75 times the piston area. This test was run without any mishaps.

For the fourth and fifth tests the shorter connecting rod was used. Three quarter inch of shims were used to bring about the desired compression in the fifth test. All barometric pressures were obtained from the U.S. weather bureau, at East Lansing, Mich.

The heating value of the gas was obtained from the records of the chemical engineering department at M.A.C.

Osgood Nichol Sommer

CONCLUSIONS

The tests which were made will hereafter be referred to, as, A, B, C, D, E, whose respective compression pressures are 120#, 145#, 155#, 70#, 93#.

As has been stated before we have endeavored to use due care in performing these tests so that the results can relied upon for comparative purposes.

After a careful examination of the curves and tabulated results we have come to the conclusion that the engine runs most efficiently with the compression ranging from 93# to 120#. At first sight it is difficult to decide which of the two compressions gives the better results. When using a 120# compression pressure, a far better mechanical efficiency is obtained. In the other hand, the average thermal efficiency is higher and the engine consumes less fuel per B.H.P. Hr. when a 93# compression is maintained.

When the engine is pulling a 25 H.P. load, a 93# compression is best, because the efficiencies are comparatively high within that range.

A 120# compression is best for a 35 H.P. load because of the following reasons:

a. In this test the engine developed 33 H.P. without the speed falling 2% below the mean R.P.M.

b. The thermal and mechanical efficiencies are practically as high as they were in test E in which only 28H.P. was developed.

c. The engine consumes only a small amount of more gas per B.H.P. Hr. for a 33 H.P. load than it does for a 22 H.P. load.

In general the curves obtained are fairly smooth and regular. In the case of test B any irregularities in the curves are due to the trouble which we encountered with the ignition. For the fluctuations of the R.P.M. we placed the blame on the governor which was not sensitive enough to meet the emergency.

In all of the tests the highest thermal efficiencies are about the same. Apparently they do not seem to increase with the compression pressure. In comparing the thermal efficiency curves, we find that they differ only in the relative time in which they reach a constant value. In tests A and E they rise quickly at the start, while in the other tests the slope is more gradual at first. In tests B and D the thermal efficiency curves fall after the 20 H.P. point has been passed.

The air and gas ratio should remain constant for light and heavy loads because the engine is equipped with a constant quality governor. In this matter we found some discrepances; the ratio drops from 10 - 1 at no load to 6 - 1 at full load. This is due to the inadequate design of the governor.

It was our intentions to make a more exhaustive test than we have. But, because of the shortened term and because of engine trouble, we are unable to give more complete results.

CONSTANTS

NICHOL
OSGOOD
SOMMER

ITEM		
HEATING VALUE OF GAS / C.F.	B.T.U.	535
BRAKE CONSTANT		.0006
TARE OF BRAKE	LBS.	25.5
FRONT CYLINDER CONSTANT		.001625
REAR " "		.00172
DIA. OF CYLINDER	"	$8\frac{1}{2}$
STROKE	"	12
PISTON ROD DIA.	"	2.
DIA. OF AIR ORIFICES	"	2

Test No (A)

Tabulated Data

Nichol
Osgood
Sommer

Item		Run 1	2	3	4	5
Gross Brake Load	Lbs.	25.5	70	115	160	200
Time of Test	Min.	20	20	20	20	20
Temperature of Gas	°F	66.6	68.2	69.3	69.5	69
Press. in Gas Mains	" H_2O	4.29	4.25	4.095	3.58	2.7
Quantity of Gas used	C.F.	84.5	127	179.2	250.5	323.5
Rev. per Min.	"	306	312	300	299	292
Barometer Press.	" Hg.	29.03	29.03	29.03	29.03	29.03
Temperature of Air	°F	65.4	67	68	68.7	69
Pressure of Air Vac.	" H_2O	.168	.212	.363	.613	.841

TEST (B)

TABULATED DATA

NICHOL
OSGOOD
SOMMER

ITEM		RUN 1	2	3	4	5
GROSS BRAKE LOAD	LBS.	25.5	70	115	135	170
TIME of TEST	MIN.	20	20	20	20	20
TEMPERATURE of GAS	°F.	68.8	70.7	70.5	71.6	69.8
PRESS. IN GAS MAINS	"H_2O	4.27	4.23	4.15	4.07	3.36
QUANTITY of GAS USED	C.F.	91.8	154.7	189.9	218.4	224.5
R.P.M.		312	301	296	302	290
BAROMETER PRESSURE	"HG.	28.98	28.98	28.98	28.98	28.98
TEMP. OF AIR	°F	71	71.7	69.4	68	67.7
PRESS. OF AIR VAC.	"H_2O	177	.237	.380	.523	.700

TEST No. ©

TABULATED DATA

ITEM		RUN 1	2	3	4	5
GROSS BRAKE LOAD	LBS.	25.5	65	100	135	170
TIME OF TEST	MIN.	20	20	20	20	20
TEMP. OF GAS	°F	65.9	67.2	68.0	67.51	67.0
PRESS. IN GAS MAINS	" H_2O	4.405	4.775	4.075	4.233	3.75
QUANTITY OF GAS USED	C.F.	86.7	116.4	156.5	212.0	255.7
R.P.M.		316	310	304	304	296
BAROMETRIC PRESS.	"Hg.	29.0	29.0	29.0	29.0	29.0
TEMP. OF AIR	°F	67	69	67	66.3	66.3
PRESS. OF AIR VAC.	" H_2O	.173	.245	.356	.543	.630

NICHOL | OSGOOD | SOMMER

TEST No (D)

TABULATED DATA

NICHOL
OSGOOD
SOMMER

ITEM		RUN 1	2	3	4	5
GROSS BRAKE LOAD	LBS.	25.5	70	110	145	170
TIME OF TEST	MIN.	20	20	20	20	20
TEMP. OF GAS	°F	78.4	79	79	79.5	79.2
PRESS. IN GAS MAINS	"H_2O	4.35	4.325	4.15	3.79	3.48
C.F. OF GAS USED		81.1	132.3	186.0	227.5	277.8
R.P.M.		304	316	310	296	290
BAROMETER PRESS.	"Hg.	28.95	28.95	28.95	28.95	28.95
TEMP. OF AIR	°F	76.7	78	80	80	80
PRESS. OF AIR VAC.	"H_2O	.154	.250	.402	.540	.745

Run No. (E)

Tabulated Data

Nichol
Osgood
Sommer

Item		Run 1	Run 2	Run 3	Run 4	Run 5
Gross Brake Load	Lbs.	25.5	70	110	145	180
Time of Test	Min.	20	20	20	20	20
Temp. of Gas	°F	84	83.3	83.5	83.1	82.3
Press. in Gas Mains	" H_2O	4.48	4.125	4.225	3.85	3.325
Quantity of Gas used	C.F.	72	125.5	164.5	216.8	283
R.P.M.		289	315	292	291	288
Barometer Pressure	" Hg.	28.95	28.95	28.95	28.95	28.95
Temp. of Air	°F.	85.3	85	84.7	84.7	84
Press. of Air vac.	" H_2O	.113	.276	.381	.551	.729

TEST "A" JUNE '17

MEP DATA

CARD LENGTH = 2.75

LOAD	CYL	SPRING	CARD AREA	MEAN HGT.	MEP	AV. MEP
25.5	R	100	.87	.32	32	
	R		.62	.23	23	27.5
	F		.82	.30	30	
	F		.82	.30	30	30
70	R		.94	.34	34	
	R		.94	.34	34	34
	F		1.00	.36	36	
	F		1.00	.36	36	36
115	R		1.24	.45	45	
	R		1.23	.45	45	45
	F		1.12	.41	41	
	F		1.23	.45	45	43
160	R	200	.82	.30	60	
	R		.87	.32	64	62
	F		.83	.30	60	
	F		.92	.33	66	65
200	R		1.05	.38	76.5	
	R		1.00	.36	75	75.7
	F		1.12	.41	82	
	F		1.14	.41	82	82

NICHOL
OSGOOD
SOMMER

Test "B" June '17

MEP Data

Card length = 2.75

Load	Cyl	Spring	Card Area	Mean Hgt.	MEP	Av. MEP
25.5	R	150	.50	.182	27.3	
	R		.44	.160	24.0	25.65
	F		.40	.145	21.8	
	F		.30	.109	16.4	19.1
70	R		.73	.265	39.8	
	R		.80	.291	43.6	41.7
	F		.48	.174	26.2	
	F		.50	.182	27.3	26.75
115	R	150	.96	.349	52.4	
	R	200	.80	.291	58.2	55.3
	F	150	.62	.226	33.8	
	F	200	.57	.207	41.4	37.6
135	R	200	.85	.309	61.75	
	R		.89	.32	64.0	63.23
	F		.60	.218	43.6	
	F		.64	.2325	46.5.	45.05
170	R		1.00	.363	72.6	
	R		1.00	.363	72.6	72.6
	F		.73	.269	53.8	
	F		.75	.2725	54.5	54.15

Nichol
Osgood
Sommer

TEST "C" JUNE '17

MEP DATA

CARD LENGTH = 2.75

LOAD	CYL	SPRING	CARD AREA	MEAN HGT.	MEP	AV. MEP
25.5	R	150	.48	.18	27	
	R		.45	.16	24	25.3
	F		.43	.16	24	
	F		.43	.16	24	24
65	R		.72	.26	39	
	R		.78	.28	42	40.5
	F		.62	.23	34.5	
	F		.61	.22	33	33.75
100	R		.92	.33	49.5	
	R		.98	.36	54	51.75
	F		.82	.30	45	
	F		.78	.28	42	43.5
135	R	200	.92	.33	66	
	R		.88	.32	64	65
	F		.74	.27	54	
	F		.65	.24	48	51
170	R		1.18	.43	86	
	R		1.22	.44	88	87
	F		.95	.35	70	
	F		.98	.36	72	71

NICHOL
OSGOOD
SOMMER

TEST "D" JUNE '17

MEP DATA

CARD LENGTH = 2.85

LOAD	CYL	SPRING	CARD AREA	MEAN HGT.	MEP	AV. MEP
22.5	R	100	.66	.231	23.1	
	R		.65	.228	22.8	22.9
	F		.58	.204	20.4	
	F		.64	.225	22.5	22.5
70	R		1.07	.375	37.5	
	R		1.03	.362	36.2	36.8
	F		1.02	.358	35.8	
	F		.92	.323	32.3	34.1
110	R		1.43	.505	50.5	
	R		1.43	.503	50.3	50.4
	F		1.38	.485	48.5	
	F		1.35	.473	47.3	47.9
145	R	150	1.27	.445	66.8	
	R		1.21	.423	63.6	65.2
	F		1.02	.358	53.7	
	F		1.01	.354	53.1	53.4
175	R		1.31	.458	68.8	
	R		1.32	.463	69.4	69.1
	F		1.22	.426	63.8	
	F		1.18	.414	62.2	63.0
						NICHOL OSGOOD SOMMER

TEST "E"

JUNE 17

MEP DATA

CARD LENGTH = 2.8

LOAD	CYL	SPRING	CARD AREA	MEAN HGT.	MEP	AV. MEP
25.5	R	100	.53	.189	18.9	
	R		.46	.164	16.4	17.65
	F		.48	.1715	17.15	
	F		.50	.1785	17.85	17.5
70	R		1.10	.393	39.3	
	R		1.10	.393	39.3	39.3
	F		.79	.282	28.2	
	F		.88	.314	31.4	29.8
110	R	150	1.05	.375	56.25	
	R		.98	.350	52.5	54.38
	F		.65	.232	34.8	
	F		.70	.250	37.5	36.15
145	R		1.22	.433	65.0	
	R		1.20	.43	64.5	64.75
	F		.90	.322	48.3	
	F		.88	.314	47.1	47.7
180	R	200	1.08	.386	77.2	
	R		1.10	.393	78.6	77.9
	F		.87	.311	62.2	
	F		.87	.311	62.2	62.2

NICHOL
OSGOOD
SOMMER

TEST No (A)

TABULATED RESULTS

NICHOL
OSGOOD
SOMMER

ITEM		RUN 1	2	3	4	5
NET BRAKE LOAD	LBS.	0	44.5	89.5	134.5	174.5
B.H.P.		0	8.33	16.1	24.2	30.3
I.H.P. FRONT CYLINDER		7.45	9.15	11.0	15.3	19.5
" REAR "		8.42	9.10	11.1	15.9	19.1
TOTAL I.H.P.		15.87	18.25	22.1	31.2	38.6
MECH. EFF.	%	0	45.65	72.8	77	78.25
C.F. STD. GAS / HOUR		243.6	364.5	513.9	717	924
" " " / B.H.P. HR.		—	42.6	31.9	29.6	30.46
THERMAL EFF.	%	0	11.13	14.9	16.04	15.5
C.F. STD. AIR / HR.		2550	2868	3788	4812	5580
AIR TO GAS RATIO		10.5	7.9	7.2	6.7	6
COMPRESSION PRESS.	#/□"	—	—	—	—	120
B.T.U. SUPPLIED/B.H.P.-HR.		—	22800	17060	15850	16370

TEST (B)

TABULATED RESULTS

NICHOL
OSGOOD
SOMMER

ITEM		RUN 1	2	3	4	5
NET BRAKE LOAD	LBS.	0	44.5	89.5	109.5	144.5
B. H. P.		0	8.05	15.9	19.85	23.4
I. H. P. FRONT CYLINDER		4.84	6.55	9.05	11.07	12.75
" REAR "		6.87	10.80	14.1	16.4	18.1
TOTAL I. H. P.		11.71	17.35	23.15	27.47	30.85
MECH. EFFICIENCY	%	0	46.4	68.75	72.25	76
C.F. STD. GAS / HR.		263.1	441	541.5	621.6	785.4
" " " / B.H.P. HR.		—	54.8	34.0	31.3	33.6
B.T.U. SUPPLIED / " "		—	29380	18170	16750	18000
THERMAL EFFICIENCY	%	0	8.66	14.0	15.20	14.15
C.F. STD. AIR / HR.		2592	2988	3828	4452	4800
COMPRESSION PRESS.	#/□	—	—	—	—	145

TEST No. (C)

TABULATED RESULTS

ITEM	RUN 1	2	3	4	5
NET BRAKE LOAD LBS.	0	39.5	74.5	109.5	144.5
B.H.P.	0	7.35	13.6	20.0	24.8
I.H.P. FRONT CYL.	6.15	8.5	10.75	12.6	17.1
" REAR "	6.93	10.80	13.5	17.0	22.15
TOTAL I.H.P.	13.08	19.30	24.25	29.60	39.25
MECH. EFFICIENCY %	0	38.1	56.1	67.6	63.2
C.F. STD. GAS / HR.	249.6	333.9	448.2	607.2	732.9
" " " / B.H.P. HR.	—	45.4	32.96	30.36	29.64
B.T.U SUPPLIED / " "	—	24,260	17630	16230	15,850
AIR TO GAS RATIO	10.45	9.14	8.52	7.68	6.65
COMPRESSION PRESS. #/□"	—	—	—	—	155
C.F. STD. AIR / HR.	2580	3054	3690	4668	4884
THERMAL EFFICIENCY %	0	10.5	14.43	15.65	16.05

NICHOL OSGOOD SOMMER

Test No. (D)

Tabulated Results

Nichol
Osgood
Sommer

Item		Run 1	2	3	4	5
Net Brake Load	Lbs.	0	44.5	84.5	119.5	144.5
B.H.P.		0	8.45	15.7	21.2	25.2
I.H.P. Front Cyl.		5.55	8.75	12.1	12.8	14.85
" Rear "		5.9	10.0	13.4	16.6	17.25
Total I.H.P.		11.45	18.75	25.5	29.4	32.10
Mech. Efficiency	%	0	45	61.5	72.2	81
C.F. Std. Gas / Hr.		234.6	378.9	537.6	655.5	798
" " " / B.H.P. Hr.		—	44.8	34.9	30.9	31.7
B.T.U. Supplied / " "		—	23950	18650	16550	16900
Thermal Efficiency	%	0	10.63	13.65	15.36	15.05
C.F. Std. Air / Hr.		2400	3082	3864	4464	5238
Air to Gas Ratio		10.22	8.11	7.18	6.8	6.57
Compression Pressure	#/□"	—	—	—	—	70

Test No (E)

Tabulated Results

Nichol
Osgood
Sommer

Item		Run 1	2	3	4	5
Net Brake Load	Lbs.	0	44.5	84.5	119.5	154.5
B.H.P.		0	8.4	14.7	20.9	26.7
I.H.P. Front Cyl.		4.38	10.65	13.65	16.2	19.3
" Rear "		4.12	7.63	8.35	11.3	14.6
Total I.H.P.		8.5	18.28	22.0	27.5	33.9
Mech. Eff.	%	0	46.2	66.8	76.0	78.8
C.F. Std. Gas / Hr.		203.1	349.5	456.6	600	789
" " " / B.H.P. Hr.		—	41.6	31.1	29.63	29.6
B.T.U. supplied / B.H.P. Hr.		—	22200	16630	15980	15830
Thermal Efficiency	%	0	11.48	15.3	15.95	16.06
C.F. Std. Air / Hr.		2046	3192	3744	4476	5160
Air to Gas Ratio		10.08	9.14	8.2	7.46	6.54
Compression Press.	#/□	—	—	—	—	93

TEST A - RUN 2

JUNE '17

SAMPLE COMPUTATIONS

NICHOL
OSGOOD
SOMMER

$$BHP = K \cdot RPM \cdot \text{NET BRAKE LOAD}$$

$$= .0006 \cdot 312 \cdot 44.5 = 8.33$$

$$IHP = \frac{PLAN}{33000}.$$

$$\text{F. CYL} = .001625 \cdot MEP \cdot \frac{RPM}{2}$$

$$= .001625 \cdot 36 \cdot 156 = 9.15$$

$$\text{R. CYL} = .00172 \cdot MEP \cdot \frac{RPM}{2}$$

$$= .00172 \cdot 34 \cdot 156 = 9.1$$

$$\text{MECH. EFF.} = \frac{BHP}{IHP} = \frac{8.33}{18.25} = 45.65\ \%$$

$$\text{GAS REDUCTION FACTOR} = \frac{PT'}{P'T} = \frac{29.03 \cdot 522}{30 \cdot 528.2} = .956$$

$$\text{CU. FT. STD. GAS per HR.} = 127 \cdot .956 \cdot \frac{60}{20} = 364.5$$

$$\text{CU. FT. STD. GAS per BHP per HR.} = 364.5 \div 8.33 = 42.6$$

BTU SUPPLIED per BHP per HR.

$$= 42.6 \cdot 535 = 22{,}800$$

HGV

Sample Computations

Nichol
Osgood
Sommer

Thermal Eff. $= \frac{2545}{22,800} = 11.13\ \%$

Air — $Wt. = .01369\ d^2 \sqrt{\frac{i\ P}{T}} \cdot C$ #/sec. $C = .600$

$K = .01369 \cdot 2^2 \cdot .600 \cdot 3600 = 120.09$ for one hour

$Wt. = 120.09 \sqrt{\frac{.215\ (2044.8 - 15.2)}{527}} = 109.2$

For two orifices $Wt = 109.2 \cdot 2 = 218.4$

Cu. Ft. Std. Air Used per Hr. $= \frac{218.4}{.07602} = 2868$

Air to Gas Ratio $= \frac{2868}{364.5} = 7.9$

HGV

Test No. (A)

JUNE '17
NICHOL
OSGOOD
SOMMER

LOG SHEET

Load (Gross) Lbs.	Time	Gas					Air		Average R.P.M.	Barometer Rdg. – "Hg.
		Pressure Enter. Meter – "H_2O	Pressure Leav. Meter – "H_2O	Temp. Enter. Meter – °F	Meter Rdg. C.F.	Temp. Leav. Meter – °F	Temp. °F	Press. in Tank Vac. – "H_2O		
25.5	8:45	4.35	4.25	66.2	36069.8	65.5	65	.165		
	8:55	4.34	4.21	67.5	36110.0	66.0	65	.170	306	
	9:05	4.35	4.25	68.0	36153.3	66.5	66	.168		
70	9:10	4.25	4.1	68.5	36183.3	67.0	67	.215		
	9:20	4.4	4.2	69.0	36256.7	67.5	67	.215	312	
	9:30	4.4	4.2	69.2	36370.3	68.0	67	.215		
115	9:35	4.2	3.9	69.5	36364.0	68.0	68	.360		
	9:45	4.3	4.0	70.0	36454.5	69.0	68	.365	300	
	9:55	4.2	3.9	70.0	36543.2	69.0	68	.365		
160	10:00	3.9	3.4	69.5	36603.0	69.5	68	.620		
	10:10	3.7	3.2	69.5	36729.5	69.5	69	.610	299	
	10:20	3.9	3.4	69.4	36853.5	70.0	69	.610		
200	10:30	3.10	2.2	68.5	37008.5	69.8	69	.834		
	10:40	3.15	2.4	68.0	37175.0	69.8	69	.840	292	
	10:50	3.10	2.25	68.0	37331.0	69.8	69	.848		29.03

TEST No (B)

LOG SHEET

JUNE '17
NICHOL 32.
OSGOOD
SOMMER

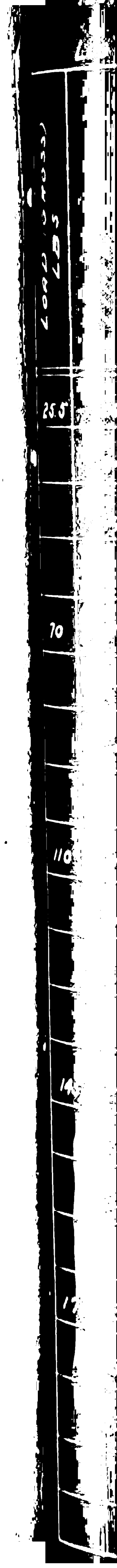
LOAD (GROSS) LBS.	TIME	GAS: PRESSURE ENTER. METER – "H_2O	GAS: PRESS. LEAV. METER – "H_2O	GAS: TEMP. ENTER. METER – °F	GAS: TEMP. LEAV. METER – °F	GAS: METER RDG. C.F.	AIR: TEMP. – °F	AIR: PRESS. IN TANK VAC. – "H_2O	AVERAGE R.P.M.	BAROMETER RDG. – "HG.
25.5	1:25	4.32	4.22	66	69	37758.2	68	.180		
	1:35	4.35	4.2	68	70	37804.3	72	.171	312	
	1:45	4.35	4.2	69	71	37850.0	73	.180		
70	1:52	4.3	4.1	70	72	37902.0	74	.235		
	2:02	4.35	4.12	70	72	37976.4	73	.235	301	
	2:12	4.4	4.15	68	72	38056.7	68	.240		
115	2:19	4.32	4.0	68.5	72	38115.1	68	.395		
	2:29	4.35	4.05	69.0	72.3	38213.0	72	.380	296	
	2:39	4.2	4.0	69.0	72.5	38305.0	68	.385		
135	2:49	3.8	4.2	69	72.5	38812.6	66	.542		
	2:59	3.9	4.3	70	73.5	38927.0	66	.510	302	
	3:09	3.9	4.3	70.5	74.0	39031.0	72	.518		
170	3:16	3.65	3.05	67	72	38441.0	69	.731		
	3:26	3.65	3.1	67	71.5	38579.0	68	.660	290	
	3:36	3.65	3.1	68	72	38715.5	66	.710		28.98

TEST No (C)

LOG SHEET

JUNE '17
NICHOL
OSGOOD
SOMMER

LOAD (GROSS) LBS.	TIME	GAS: PRESS. ENTER. METER – "H_2O	GAS: PRESS. LEAV. METER – "H_2O	GAS: TEMP. ENTER. METER – °F	GAS: TEMP. LEAV. METER – °F	GAS: METER RDG. C.F.	AIR: TEMP. – °F	AIR: PRESS. IN TANK VAC – "H_2O	AVERAGE R.P.M.	BAROMETER RDG. – "HG.
25.5	1:33	4.5	4.32	65	66	39704.8	66	.171		
	1:43	4.5	4.31	66	66	39747.6	66	.175	316	
	1:53	4.5	4.3	66	66	39779.5	69	.173		
65	1:58	4.4	4.15	67	66.5	39820.0	69	.255		
	2:08	4.4	4.15	67	67	39879.3	69	.240	310	
	2:18	4.4	4.15	67.5	68	39936.4	69	.240		
100	2:24	4.4	4.1	68	68	39980.0	68	.362		
	2:34	4.05	4.35	68	68	40059.0	67	.355	304	
	2:44	44	4.1	68	67.5	40136.5	66	.350		
135	2:52	4.3	3.85	68	67.5	402118.0	66	.542		
	3:02	4.3	3.85	68	67.0	40324.2	67	.543	304	
	3:12	4.3	3.85	68	67.0	40430.0	66	.543		
170	3:19	4.1	3.55	68	66.5	40517.8	66	.624		
	3:29	4.0	3.45	68	66.0	40647.0	66	.620	296	29.0
	3:39	4.0	3.4	67.5	66.0	40773.5	67	.645		



LOAD (GROSS)
LBS
25.5
70
110

TEST No. (D)

LOG SHEET

JUNE '17
NICHOL
OSGOOD
SOMMER

34

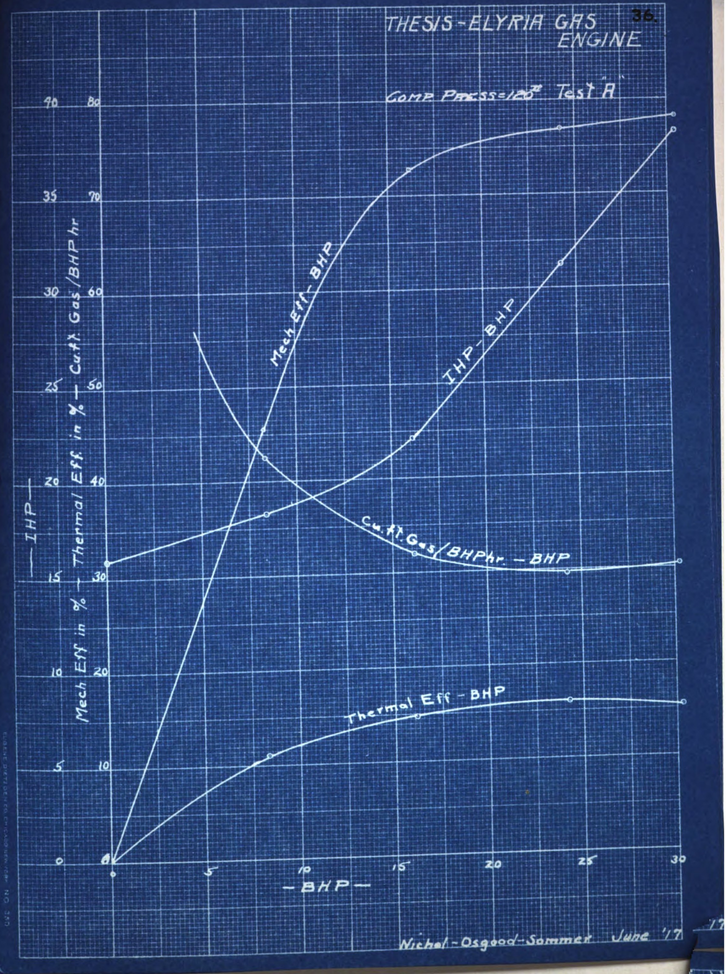
LOAD (GROSS) LBS.	TIME	GAS: PRESS. ENTER. METER - "H2O	GAS: PRESS. LEAV. METER - "H2O	GAS: TEMP. ENTER. METER - °F	GAS: TEMP. LEAV. METER - °F	GAS: METER RDG. C.F.	AIR: TEMP. - °F	AIR: PRESS. IN TANK VAC. - "H2O	AVERAGE R.P.M.	BAROMETER RDG. - "HG.
25.5	1:24	4.45	4.25	77	79	42258.4	76	.151		
	1:34	4.45	4.25	77.5	79	42300.0	77	.153	304	
	1:44	4.45	4.25	78	80	42339.5	77	.158		
70	1:49	4.45	4.2	78	80	42369.7	77	.248		
	1:59	4.45	4.2	78	80	42436.3	78	.252	316	
	2:09	4.45	4.2	78	80	42502.0	79	.251		
110	2:14	4.35	3.95	78	80	42555.7	80	.408		
	2:24	4.35	3.95	78	80	42649.0	80	.395	310	
	2:34	4.35	3.95	78	80	42741.7	80	.403		
145	2:39	4.00	3.45	78.5	80.5	42796.5	80	.538		
	2:49	4.10	3.55	78.5	81.	42907.7	80	.540	296	
	2:59	4.10	3.55	78.	80.5	43024.0	80	.542		
170	3:12	3.8	3.10	77	80	43202.0	80	.748		
	3:22	3.85	3.15	77	80	43343.0	80	.745	290	28.95
	3:32	3.85	3.15	76	80	43479.0	80	.743		

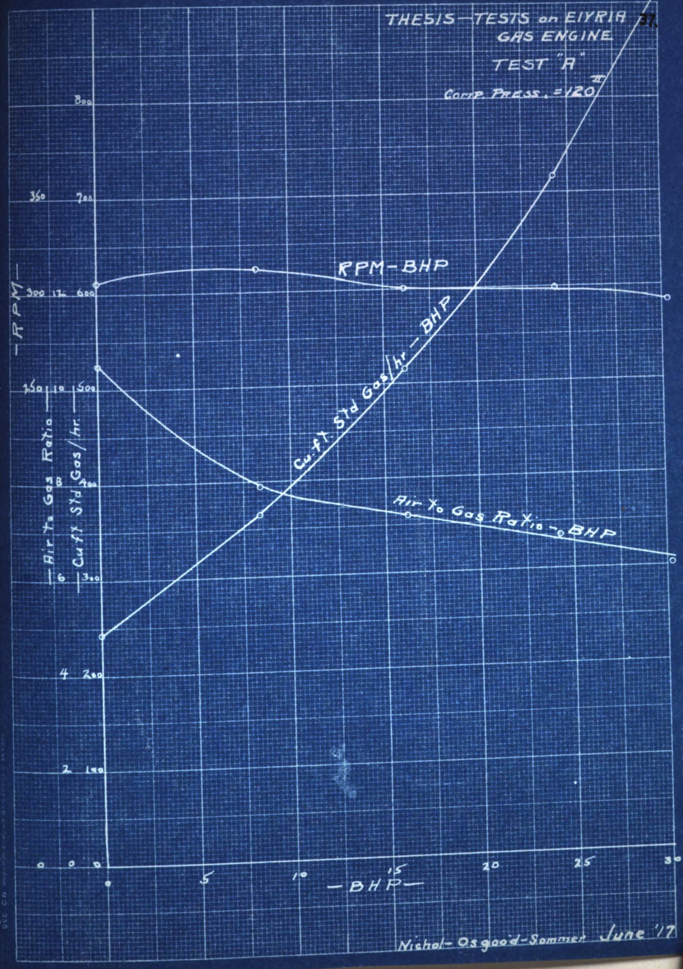
TEST-No. (E)

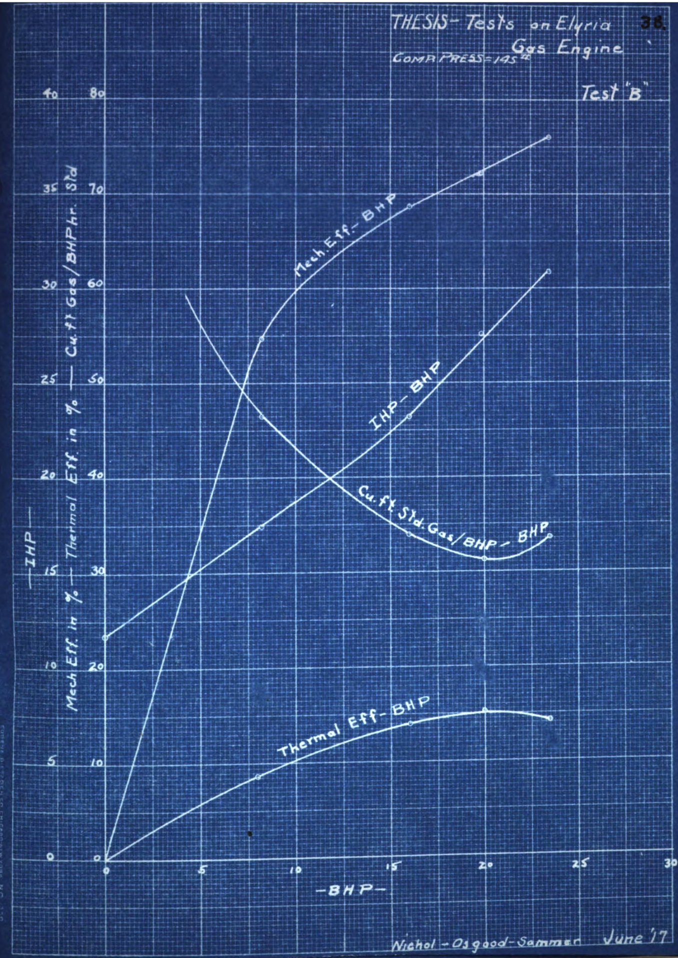
JUNE
NICHOL
OSGOOD
SOMMER

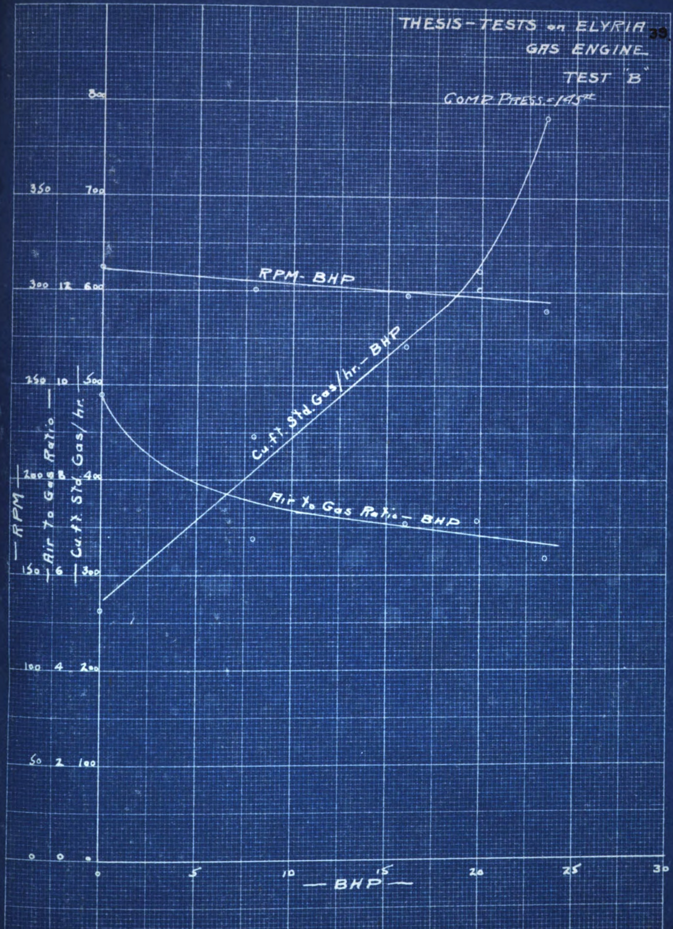
LOG SHEET

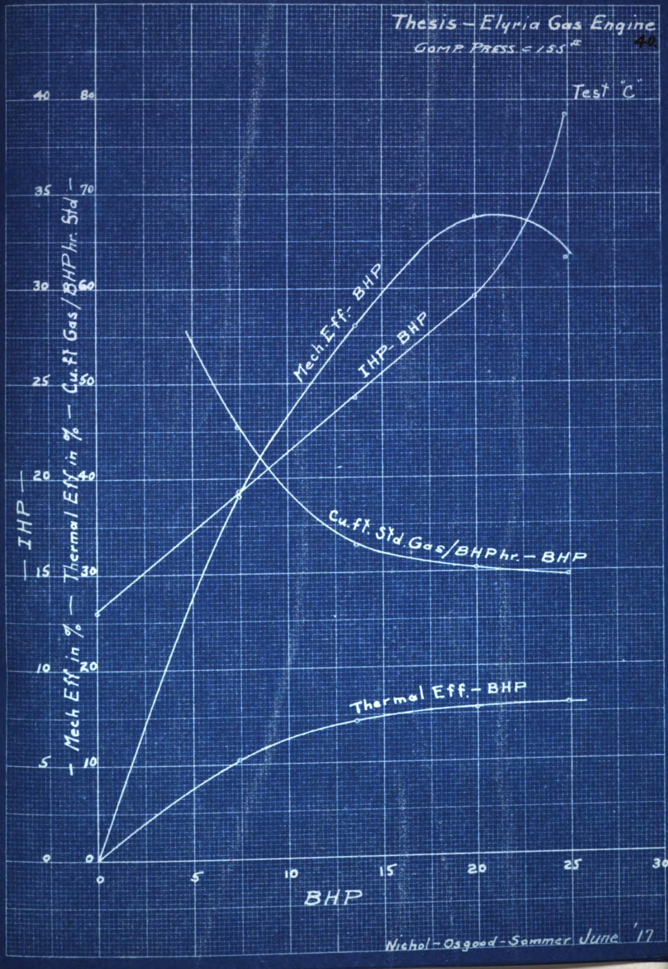
LOAD (GROSS) LBS.	TIME	GAS					AIR		AVERAGE R.P.M.	BAROMETER RDG. – "HG.
		PRESS. ENTER. METER – "H₂O	PRESS. LEAV. METER – "H₂O	TEMP. ENTER. METER °F	TEMP. LEAV. METER °F	METER RDG. C.F.	TEMP. °F	PRESS. IN TANK VAC. – "H₂O		
25.5	2:03	4.6	4.4	83	85	43811.0	86	.113		
	2:13	4.55	4.4	83	85	43850.5	85	.113	289	
	2:23	4.55	4.5	83	85	43883.0	85	.112		
70	2:56	4.25	4.0	83	84	44000.5	85	.271		
	3:06	4.25	4.0	82.5	84	44063.4	85	.280	315	
	3:16	4.25	4.0	82.5	84	44126.0	85	.278		
110	3:21	4.45	4.1	82.5	84.5	44165.0	84	.383		
	3:31	4.35	4.0	82.5	84.5	44248.3	85	.381	292	
	3:41	4.4	4.05	82.5	84.5	44330.0	85	.380		
145	3:48	4.1	3.6	82.0	84.5	44404.4	85	.548		
	3:58	4.1	3.6	82.0	84	44513.6	85	.550	291	
	4:08	4.1	3.6	82.0	84	44621.2	84	.555		
180	4:15	3.55	2.85	81.0	84	44711.0	84	.756		
	4:25	3.8	3.1	80.5	84	44858.2	84	.710	288	
	4:35	3.65	3.0	80.0	84	44994.0	84	.721		28.95

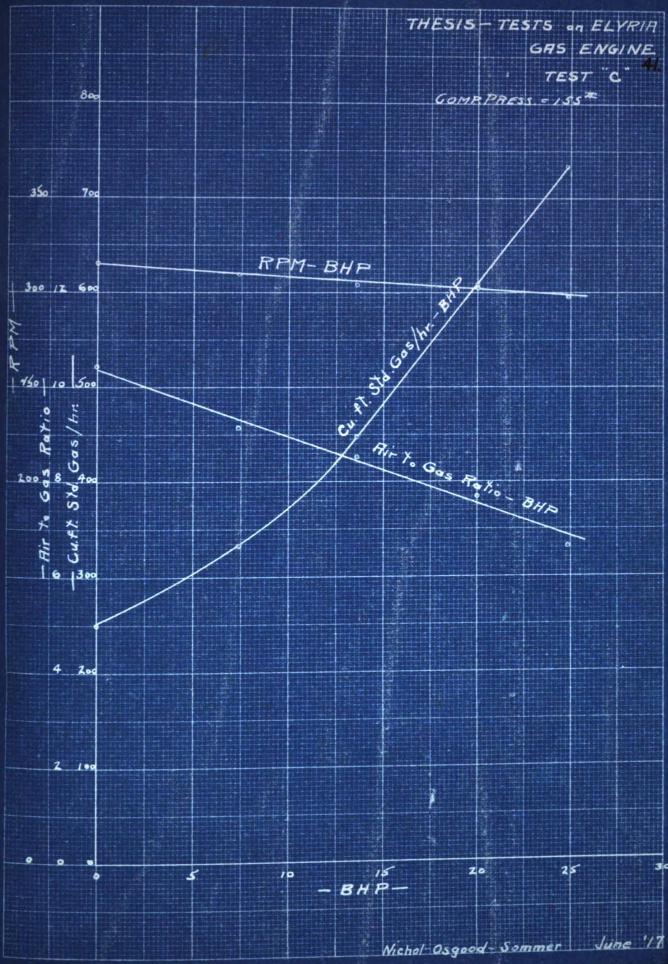

THESIS - ELYRIA GAS ENGINE
COMP PRESS=120# Test "A"
Mech Eff in % - Thermal Eff in % - Cu.ft. Gas/BHP hr
— IHP —
— BHP —
Mech Eff - BHP
IHP - BHP
Cu.ft. Gas/BHPhr. - BHP
Thermal Eff - BHP
0 5 10 15 20 25 30 35 40
0 10 20 30 40 50 60 70 80
0 5 10 15 20 25 30
Nichol-Osgood-Sommer June '17

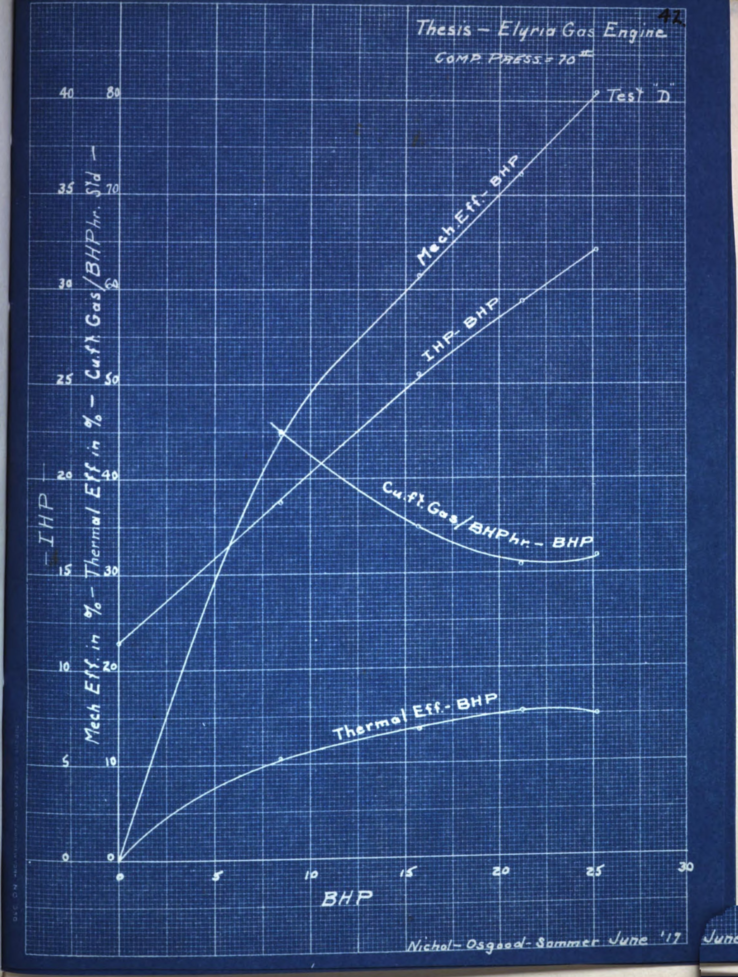

THESIS—TESTS on ELYRIA GAS ENGINE
37.
TEST "A"
Comp. Press. = 120#
RPM-BHP
Cu ft Std Gas/hr — BHP
Air to Gas Ratio — BHP
— RPM —
— Air to Gas Ratio —
— Cu ft Std Gas/hr —
— BHP —
Nichol-Osgood-Sommer June '17

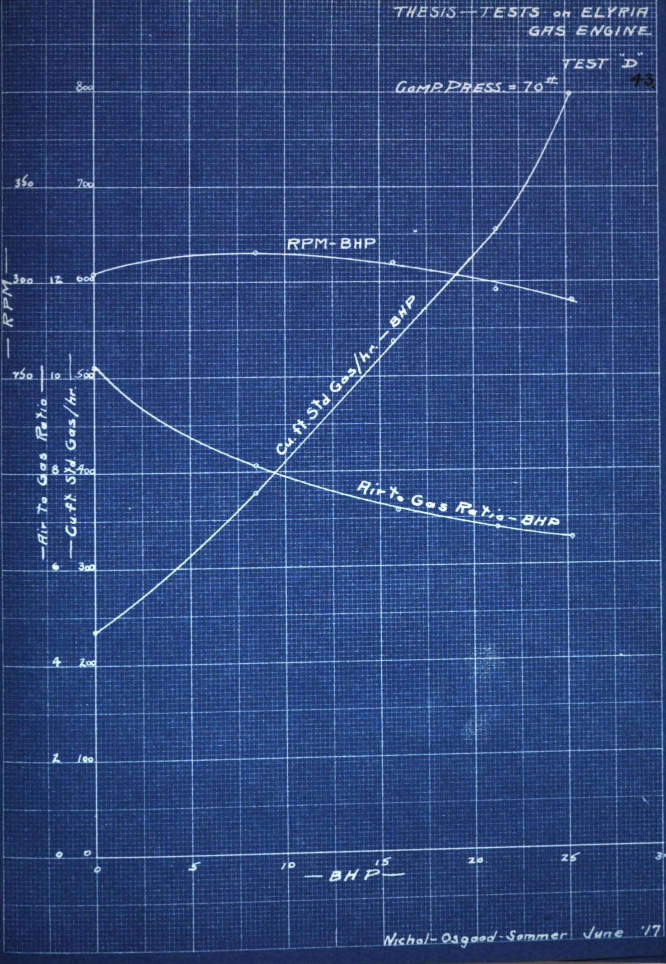

THESIS - Tests on Elyria Gas Engine
COMP. PRESS = 145#
Test "B"
Mech. Eff. in % — Thermal Eff. in % — Cu. ft. Gas/BHP hr. Std
— IHP —
Mech. Eff. - BHP
IHP - BHP
Cu. ft. Std. Gas/BHP - BHP
Thermal Eff. - BHP
- BHP -
Nichol - Osgood - Sammer
June '17

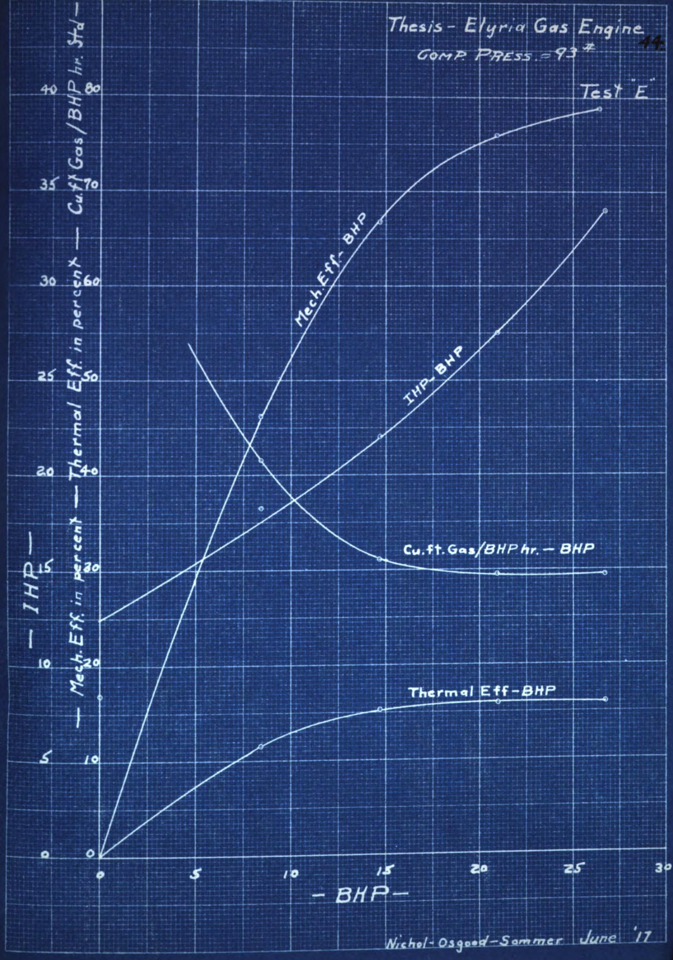

THESIS-TESTS on ELYRIA GAS ENGINE
TEST "B"
COMP. PRESS.=145#
RPM-BHP
Cu. ft. Std. Gas/hr.-BHP
Air to Gas Ratio-BHP
— RPM — Air to Gas Ratio — Cu. ft. Std. Gas/hr.
800
350 700
300 12 600
250 10 500
200 8 400
150 6 300
100 4 200
50 2 100
0 0 0
0 5 10 15 20 25 30
— BHP —
Nichol-Osgood-Sommer June '11

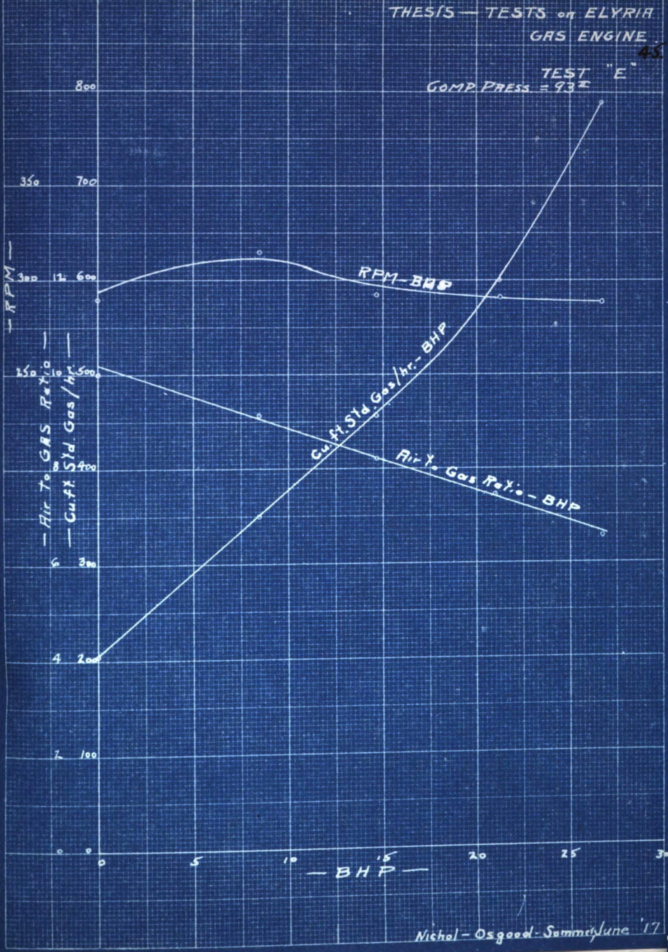

Thesis – Elyria Gas Engine
Comp. Press = 155#
Test "C"
Mech. Eff. - BHP
IHP - BHP
Cu. ft. Std. Gas/BHP hr. - BHP
Thermal Eff. - BHP
— IHP —
– Mech Eff in % – Thermal Eff in % – Cu. ft Gas/BHP hr. Std –
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
BHP
Nichol - Osgood - Sommer June '17


THESIS – TESTS on ELYRIA
GAS ENGINE
TEST "C"
COMP PRESS. = 155#
41.
RPM - BHP
Cu. ft. Std. Gas/hr. - BHP
Air to Gas Ratio - BHP
RPM
Air to Gas Ratio
Cu. ft. Std. Gas/hr.
800
350
700
300
12
600
250
10
500
200
8
400
6
300
4
200
2
100
0
5
10
15
20
25
30
- BHP -
Nichol - Osgood - Sommer
June '17


Thesis – Elyria Gas Engine
COMP. PRESS = 70#
Test "D"
Mech. Eff. – BHP
IHP – BHP
Cu. ft. Gas/BHP hr. – BHP
Thermal Eff. – BHP
– IHP –
Mech Eff. in % – Thermal Eff. in % – Cu. ft. Gas/BHP hr. Std –
40 80
35 70
30 60
25 50
20 40
15 30
10 20
5 10
0 0
0 5 10 15 20 25 30
BHP
Nichol – Osgood – Sommer June '17


THESIS — TESTS on ELYRIA GAS ENGINE
TEST "D"
43
COMP. PRESS. = 70#
RPM-BHP
Cu. ft. Std Gas/hr. — BHP
Air to Gas Ratio — BHP
— RPM —
— Air To Gas Ratio —
— Cu. ft. Std. Gas/hr.
350
300
250
12
10
8
6
4
2
0
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
— BHP —
Nichol - Osgood - Sommer June '17


Thesis - Elyria Gas Engine
COMP. PRESS. = 93#
Test "E"
Mech. Eff. - BHP
IHP - BHP
Cu. ft. Gas/BHP hr. - BHP
Thermal Eff - BHP
- IHP -
- Mech. Eff. in percent - Thermal Eff. in percent - Cu. ft. Gas/BHP hr. Std -
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
- BHP -
Nichol - Osgood - Sommer June '17


THESIS — TESTS on ELYRIA GAS ENGINE.
TEST "E"
COMP. PRESS = 93#
RPM-BHP
Cu.ft. Std. Gas/hr. - BHP
Air to Gas Ratio - BHP
— RPM —
— Air To GAS Ratio —
— Cu.ft. Std. Gas/hr. —
— BHP —
800
700
600
500
400
300
200
100
350
300
250
12
10
8
6
4
2
0
5
10
15
20
25
30
Nichol - Osgood - Sommers June '17