

OPERATION OF CAMS FOR THE VALVE - GEAR  
OF A WESTINGHOUSE GAS ENGINE

BY

W. PATERSON

L. W. A. BUNGE

ARMOUR INSTITUTE OF TECHNOLOGY

1915

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P 27



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Design, installation and  
operation of cams for the

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DESIGN, INSTALLATION AND OPERA-  
TION OF CAMS FOR THE VALVE-GEAR  
OF A THREE-CYLINDER, 8 x 10 IN.  
WESTINGHOUSE GAS ENGINE

A THESIS

PRESENTED BY

WILLIAM PATERSON  
LUDWIG W. A. BUNGE

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

MAY 27, 1915

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Preface

The work described in this paper was undertaken with a view to making a much more thorough analysis of the engine performance both before and after the installation of the new cams than is here presented. Very much to the regret however to the writers the limits set by the time available has made any complete thermodynamic study impossible. Many interesting problems present themselves in an investigation of this kind, any one of which might form the matter of an extended study. It is necessary therefore, to record the results in the present incomplete state in the hope that they might be useful as a starting point for future investigation.

The writers wish to acknowledge their gratitude to Professor Daniel Roesch, under whose direction the work was carried on, for his kind and attentive assistance. Acknowledgement is also due to the other members of the faculty and to those members of the student body whose help has made the work possible.

Chicago, Illinois  
May 22, 1915.

Receipt

I have received of Mr. John Doe the sum of \$100.00 (One Hundred Dollars) for the purpose of the purchase of a new machine for the office. This receipt is valid for all purposes.

The receipt is given in full payment of the amount due for the purchase of the machine.

The receipt is given in full payment of the amount due for the purchase of the machine.

The receipt is given in full payment of the amount due for the purchase of the machine.

John Doe  
 Secretary

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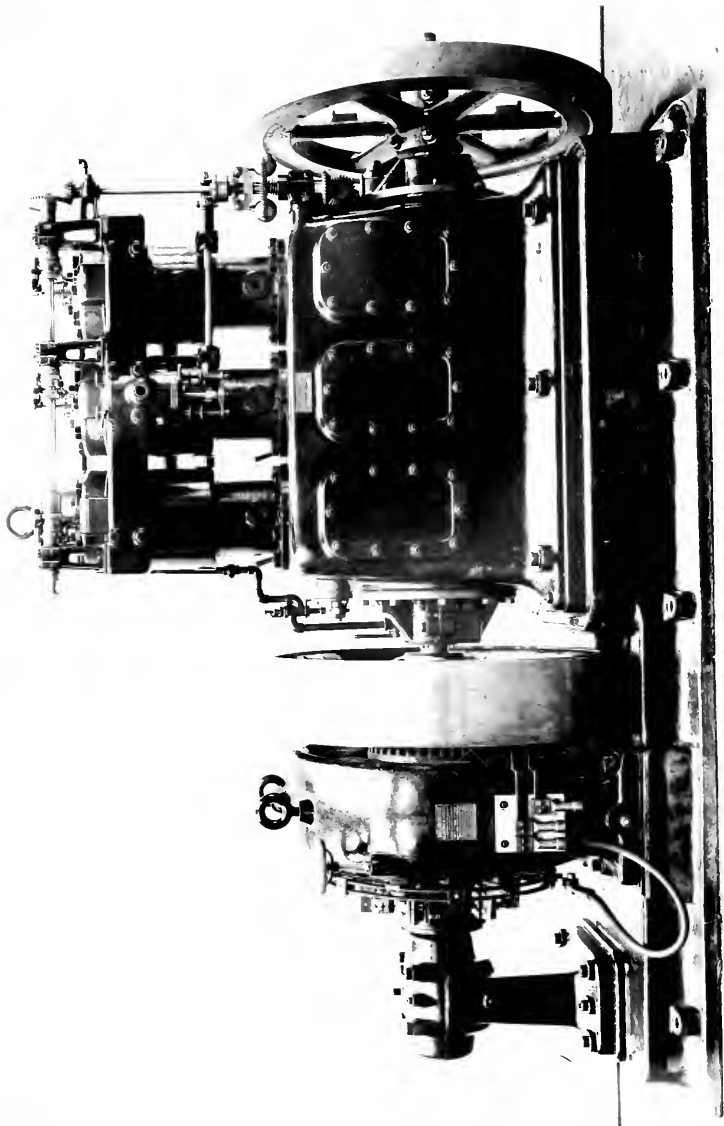


Figure 1





## Introduction

The investigations described in these pages were undertaken with the purpose of studying the effect upon the performance of a Westinghouse gas engine, produced by making certain predetermined changes in the forms of the cams controlling the valve motion.

The engine used in the experiments is a three cylinder, 8" x 10", four cycle, constant volume, vertical machine, made by the Westinghouse Machine Company of East Pittsburgh, Pa. It is rated at 40 horse power and is capable of delivering about 45 brake horse power continuously. It was built about 1902 and owing to the fact that there has been a considerable advance in the matter of cam design since that time, it has been thought possible to increase the maximum output and economy by means of modifying the cams and valve motion. The considerations leading to this conclusion will be discussed in another part of this paper.

## The Engine

The general appearance of the engine is shown in the illustration, Fig.1. During the tests, however, it was fitted with a water cooled Prony brake in place of the generator shown in the photograph. This and the other photographic illustrations were, very kindly, furnished by the manufacturers and although they represent a somewhat later design, embodying some minor changes, in all essentials the construction here shown is the same as that the engine used. Fig. 2 is a very good general representation of the internal construction, being a section through the left cylinder. In referring to the cylinders and corresponding parts, the words left, center and right will be used as indicating the parts in the order named, beginning with those at the governor end of the engine.

The construction of the machine is shown in greater detail in Figs. 3,4, and 5, representing plan and front and end elevation. The bed plate and crank case are cast in

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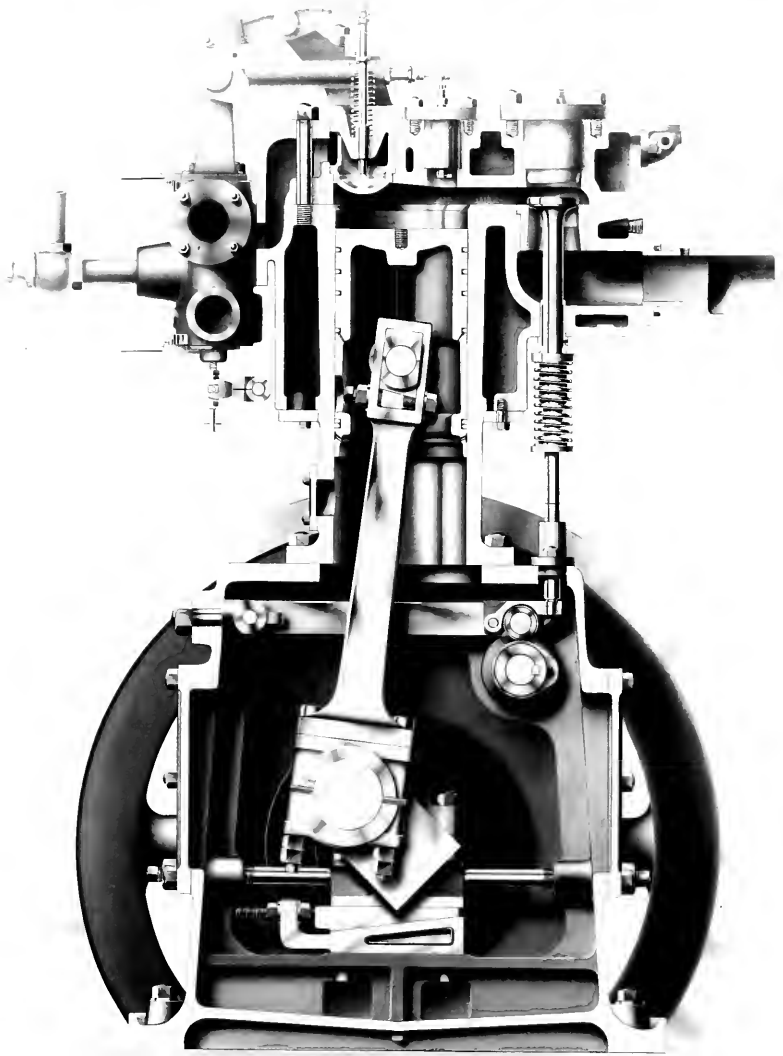


Figure 2



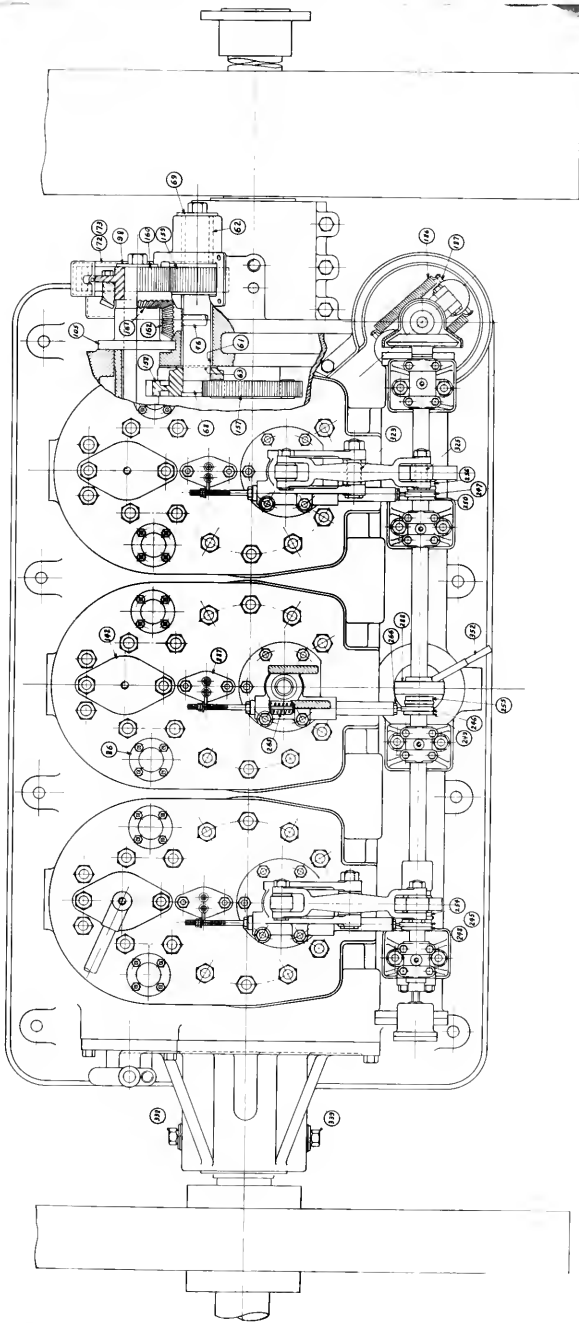
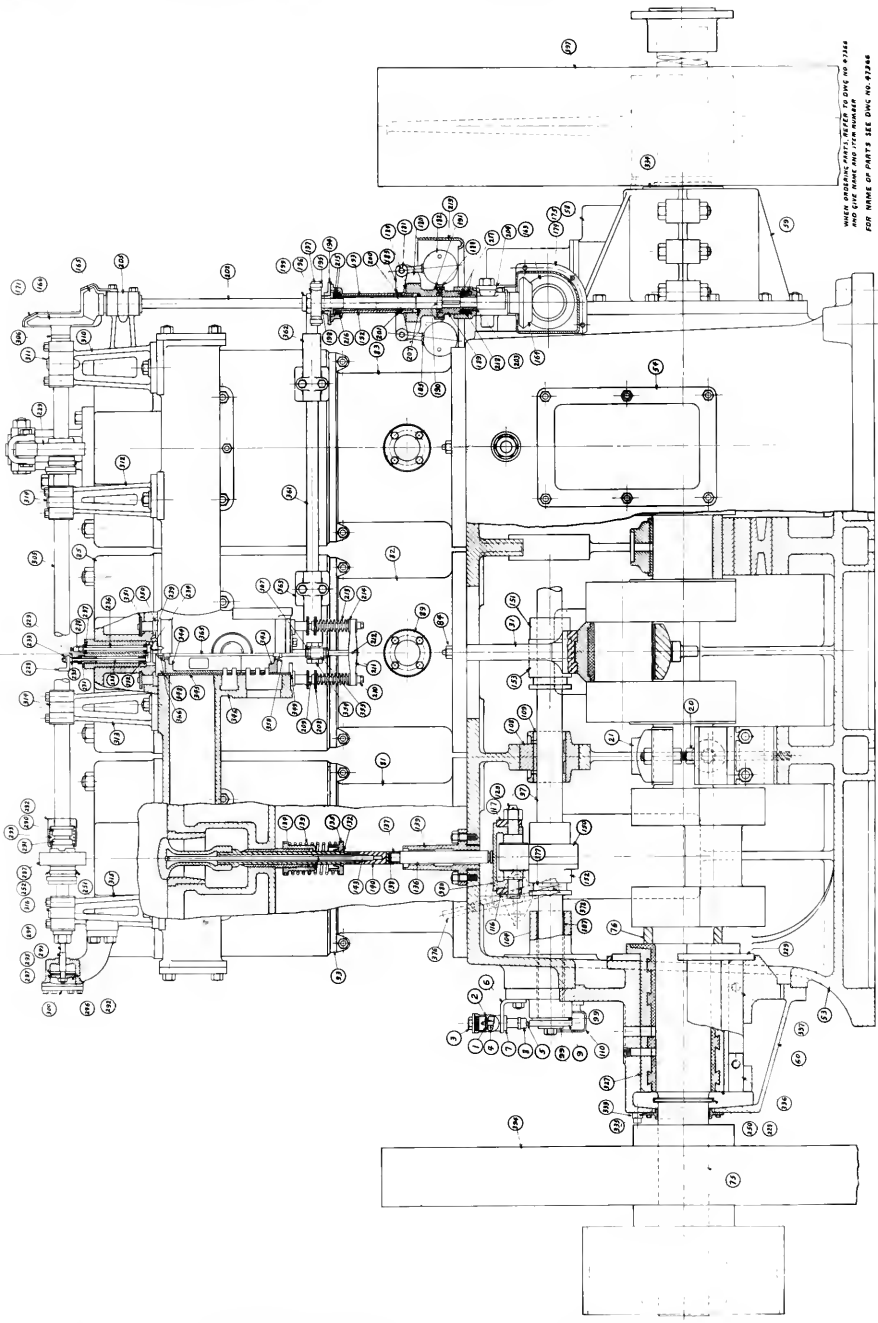


Figure 3





UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES  
AND GRADE SHALL BE AS SHOWN  
FOR NAME OF PARTS SEE Dwg No. 93348

Figure 4





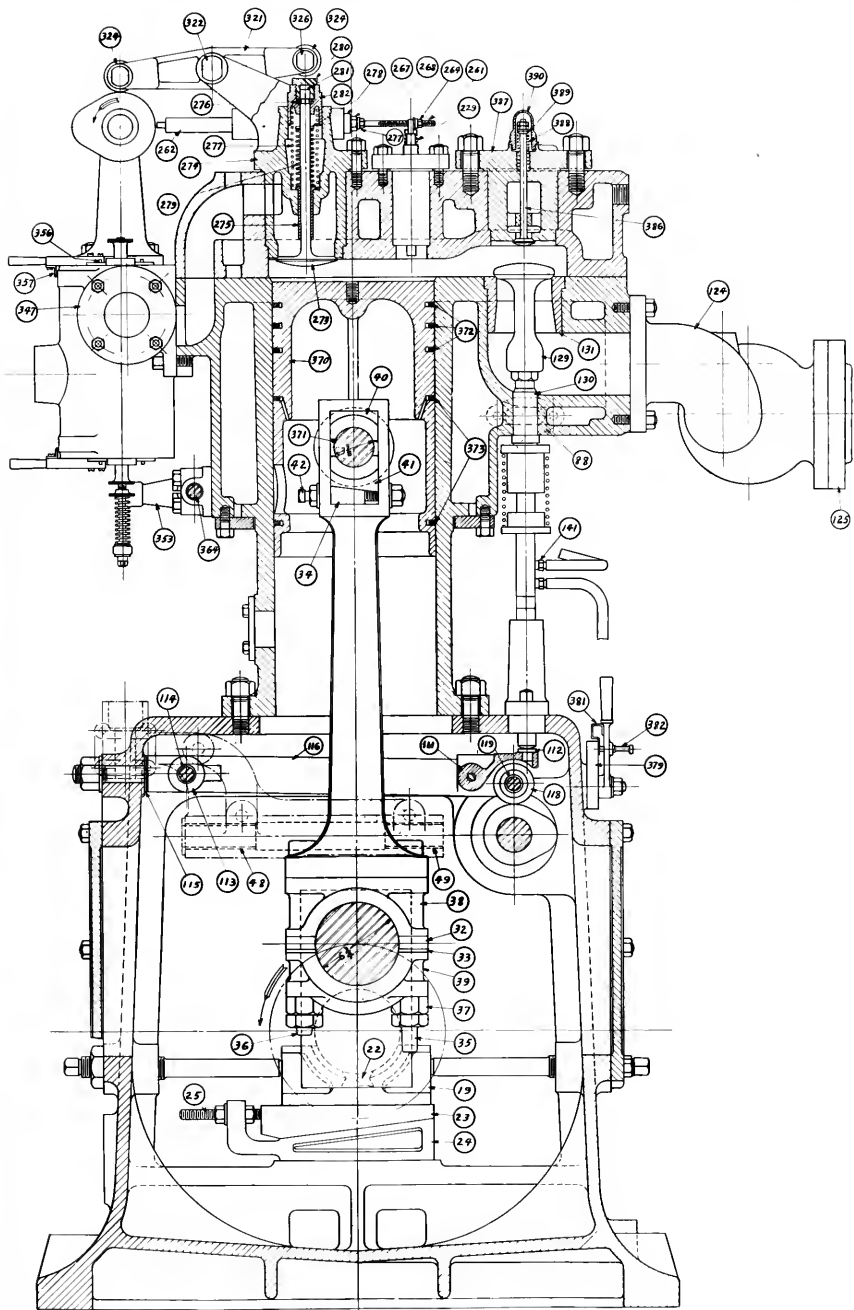


Figure 5



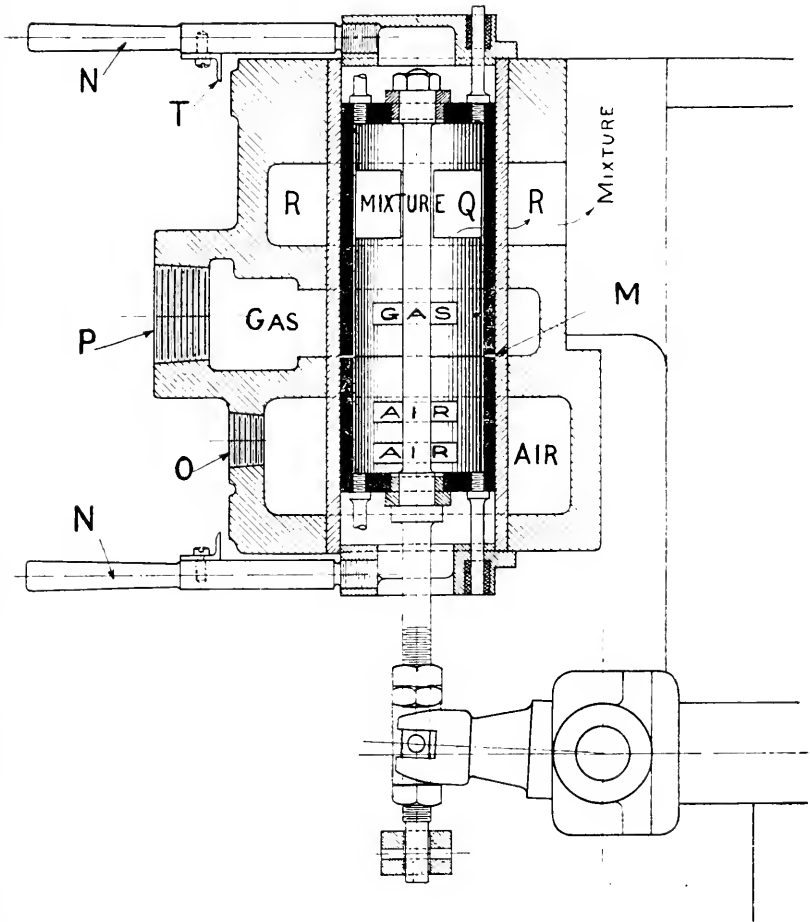


Figure 6



one piece and bolted to a concrete foundation. The three cylinders are separate castings, are water jacketed, and are bolted to the crank case. The valve chambers are bolted to the upper ends of the cylinders. The main shaft and cranks, which are set 120 degrees apart, operate in the crank case. Lubrication is effected by means of large oil cups on the main bearings. The drips from these bearings discharge into the crank case so that the internal working parts are kept flooded by the splash system.

The fuel gas is admitted through the mixing valve shown at 347, Fig. 5 which communicates with the passages connecting with the inlet valves. The details of the mixing valve are shown in Fig. 6. The air inlet is at O and the gas pipe connects at P. Gas and air pass into the valve through ports in the sleeve M, the relative amounts of opening of which are controlled by means of the levers N, N. From the valve the mixture passes into the annular space R and thence into the engine.

The inlet valves are shown at 273 and the exhaust at 129, Fig. 5. The engine is of the ell head type, the inlet valves being located directly above the cylinders and the exhaust in a passage forming an ell toward the back of the engine. Spring poppet valves are used. The inlet valves are operated by means of a set of cams 287, 288, and 289, Figs. 3 and 4, communicating a reciprocating motion to the valve stems 281, through the rocker arms 231, pivoted at 322 and fitted with rollers at 324. A means of timing the events is afforded in the adjustable plungers with lock nut at 326, Fig. 5, in place of the roller shown in the illustration. These plungers make it possible to vary the amount of clearance between the arm and the valve stem.

The exhaust valves are operated by a similar set of cams mounted on a shaft running through the crank case. One of the exhaust cams is shown at 150, Fig. 4 and an end view of it, unnumbered, in Fig. 5. The cam operates in contact with a roller 118 mounted on a lever 116 which is pivoted at 113. The motion is communicated through the shoe 112, Fig. 5 and a plunger 136, Fig. 4, to the valve stem 130 and the valve 129, Fig. 5. Between the plunger and the valve stem proper is a short space in which may be inserted small circular discs

The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry, no matter how small, should be recorded to ensure the integrity of the financial data. This includes not only sales and purchases but also expenses, income, and any other financial activities.

The second part of the document provides a detailed breakdown of the company's revenue. It lists the various products and services sold, along with the corresponding sales figures. This information is crucial for understanding the company's primary sources of income and for identifying areas of growth.

The third part of the document details the company's expenses. It categorizes these into fixed costs, such as rent and salaries, and variable costs, such as materials and utilities. This breakdown helps in understanding the cost structure and in identifying opportunities to reduce costs and improve profitability.

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The sixth part of the document provides a detailed analysis of the company's cash flow. It tracks the inflows and outflows of cash over a specific period, highlighting any periods of cash shortage or surplus. This analysis is critical for ensuring the company's liquidity and for managing its working capital effectively.

The seventh part of the document discusses the company's tax obligations. It outlines the various taxes that the company is required to pay, such as income tax, sales tax, and property tax. It also provides information on the company's tax strategies and on the steps that should be taken to ensure compliance with all applicable tax laws.

The eighth part of the document provides a detailed overview of the company's assets and liabilities. It lists all of the company's assets, including cash, accounts receivable, inventory, and property. It also lists all of the company's liabilities, including accounts payable, loans, and other debts. This information is essential for understanding the company's net worth and for assessing its financial risk.

The ninth part of the document discusses the company's financial ratios. It calculates key ratios such as the current ratio, the debt-to-equity ratio, and the return on assets. These ratios provide a quantitative measure of the company's financial performance and its ability to meet its financial obligations.

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The eleventh part of the document discusses the company's financial controls. It outlines the various controls that the company has in place to ensure the accuracy and reliability of its financial data. These controls include internal audits, reconciliations, and other procedures designed to prevent errors and fraud.

The twelfth part of the document provides a detailed overview of the company's financial reporting process. It describes the steps that are taken to collect, process, and report financial data. This information is essential for understanding the company's financial reporting cycle and for ensuring that all financial information is reported accurately and on time.

The thirteenth part of the document discusses the company's financial risk management. It outlines the various risks that the company faces, such as market risk, credit risk, and liquidity risk. It also describes the strategies that the company has in place to manage these risks and to minimize their potential impact on the company's financial performance.

The fourteenth part of the document provides a detailed overview of the company's financial planning process. It describes the steps that are taken to develop a financial plan for the company, including the identification of financial goals, the analysis of current financial performance, and the development of strategies to achieve these goals.

The fifteenth part of the document discusses the company's financial performance over the long term. It analyzes the company's financial performance over a period of several years, identifying trends and patterns in its financial data. This analysis is essential for understanding the company's long-term financial health and for making informed decisions about its future.

The sixteenth part of the document provides a detailed overview of the company's financial reporting requirements. It outlines the various requirements that the company must follow when reporting its financial performance, including the requirements of the Securities and Exchange Commission (SEC) and other regulatory bodies.

The seventeenth part of the document discusses the company's financial reporting policies. It outlines the various policies that the company has in place to ensure the accuracy and reliability of its financial reporting. These policies include the use of accrual accounting, the use of the cost of sales method, and other procedures designed to ensure the integrity of the financial data.

The eighteenth part of the document provides a detailed overview of the company's financial reporting process. It describes the steps that are taken to collect, process, and report financial data, including the use of accounting software and the involvement of external auditors.

The nineteenth part of the document discusses the company's financial reporting process. It outlines the various steps that are taken to ensure that the company's financial reporting is accurate and reliable, including the use of internal controls and the involvement of external auditors.

The twentieth part of the document provides a detailed overview of the company's financial reporting process. It describes the steps that are taken to collect, process, and report financial data, including the use of accounting software and the involvement of external auditors.

or shims of whatever total thickness the adjustment of clearance between the cam motion and the valve, when seated, requires.

To the end of exhaust cam shaft at 9, Fig. 4 is secured a small auxiliary cam which operates an air valve admitting compressed air to the right cylinder as a means of turning the engine over until it picks up its stroke in starting. In order to make this operation possible a set of three additional auxiliary cams is provided, seen at 152, Fig. 4. These cams are free to slide along the shaft on feathers and are controlled by the hand levers 376, Fig. 4. When in the position shown in the figure, they cause the exhaust valve to open toward the end of every stroke, allowing the air to operate the engine in the manner of a single acting steam engine. When the lever 376 is in a vertical position, they are free of the roller and revolve with the shaft idle.

The cam shafts are run by means of a train of gears from the main shaft, shown in Figs. 3 and 4, 157 to 166.

The governor, which is of the fly ball type, is secured to the vertical shaft 202, Fig. 4. The motion of the governor resulting from speed variations, is communicated through a yoke at 197 to a shaft 361 and thence to the mechanism shown at the lower end of the mixing valve, Fig. 6. An increase in speed results in lowering the valve stem and reducing the quantity of gas admitted. The fuel is ignited by means of the make and break system of electric spark. The sparking plugs are seen at 277, Fig. 3, and are operated by spring controlled plungers, 262, Fig. 5, in contact with adjustable cams on the inlet cam shaft.

#### The Original Cams

An outline of the shape of the admission cams originally furnished with the engine is shown in Fig. 7, and that of the original exhaust cams in Fig. 9. The considerations that led to the adoption of these designs need not be considered here. In Table I are shown the position and sequence of events in each of the three cylinders as operated by the original cams. The measurements were made by means of observing the positions of the cranks as marked in the fly wheel with respect to upper or lower dead center. In Table II are listed the amounts of valve lift in inches and the areas of valve opening in square inches,





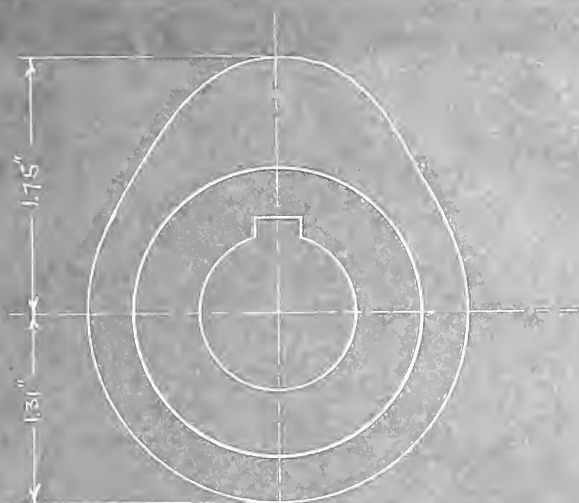


FIGURE 7.

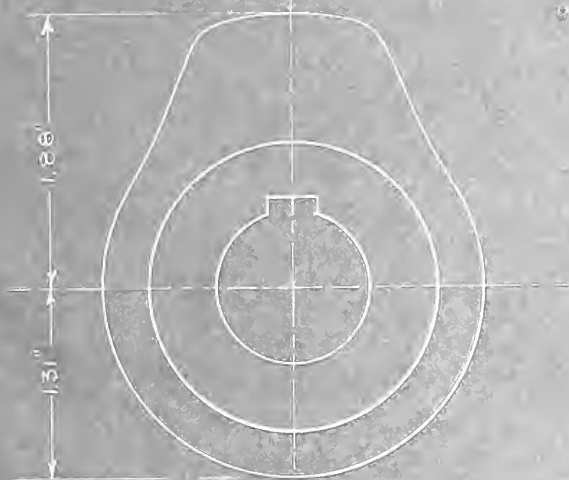
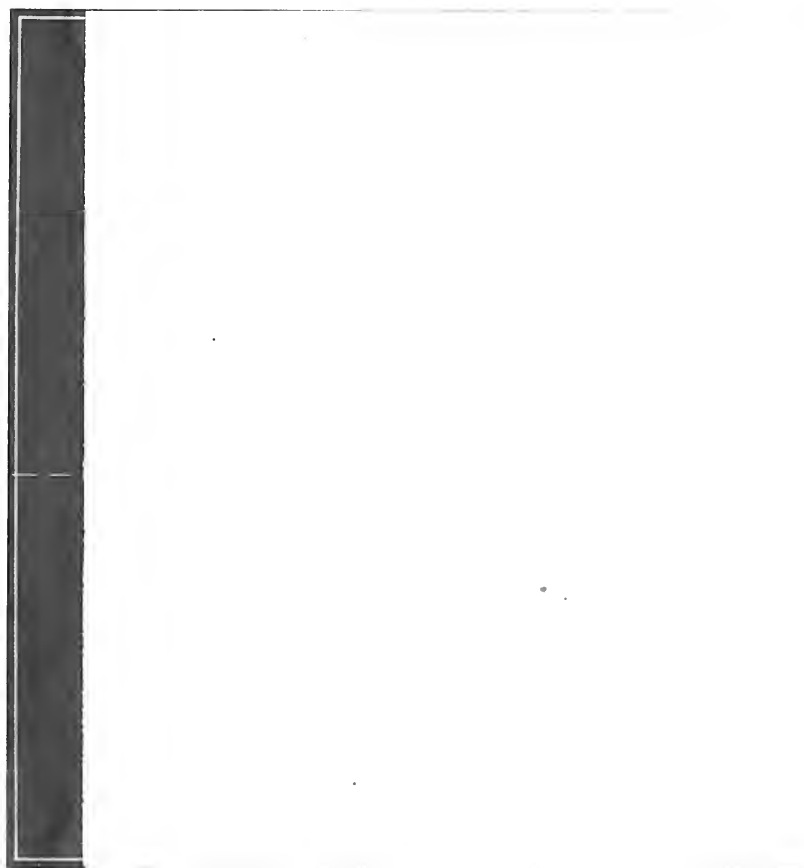


FIGURE 8.









11

100

11

11





Table I

Events	Cylinders		
	Left	Center	Right
Inlet opens	11° early	9° early	14° early
Inlet closes	19° late	12° late	16° late
Ignition	18° early	13° early	16° early
Exhaust opens	22° early	31° early	29° early
Exhaust closes	2° early	5° late	1° early

for every 15 degrees of crank revolution during the time valves are in motion.

#### Preliminary Tests

In order to obtain information upon which to base the design of the new cams as well as to afford a basis of comparison in studying the effect of the new design, a series of tests was made with the original cams set as indicated in the foregoing description. The series consisted of five short runs at loads of approximately 10, 20, 30, 40 and 45 brake horse power. The first four were twenty minutes and the last a quarter of an hour in duration. For testing purposes the engine is equipped with Westinghouse "wet" gas meter reading in cubic feet, provided with a thermometer and an open end manometer for ascertaining the temperature and pressure of the gas supply. Thermometer cups are provided at suitable points in the inlet and outlet jacket water pipes for convenience in taking temperatures. The jacket water discharges through a two way cock into two weighing tanks.

Frequent cards were taken from all three cylinders during the tests and all other observations were made at intervals of five minutes. These observations are recorded in tabulated form in the printed logs 1 to 7 and the results as calculated are given in 8 and 9. Stop motion cards were taken at each load to show more clearly the characteristics of the lower loops. Sample cards from each run are submitted in Figs. 11 to 15. Figs. 16 to 20 are enlarged diagrams made from cards selected from each run as approximating most nearly the average mean effective pressure for the run.

Molecular Weight		Intrinsic Viscosity		Oxidation	
g	g	dl/g	dl/g	g	g
100	100	1.0	1.0	100	100
200	200	1.5	1.5	200	200
300	300	2.0	2.0	300	300
400	400	2.5	2.5	400	400
500	500	3.0	3.0	500	500
600	600	3.5	3.5	600	600
700	700	4.0	4.0	700	700
800	800	4.5	4.5	800	800
900	900	5.0	5.0	900	900
1000	1000	5.5	5.5	1000	1000
1100	1100	6.0	6.0	1100	1100
1200	1200	6.5	6.5	1200	1200
1300	1300	7.0	7.0	1300	1300
1400	1400	7.5	7.5	1400	1400
1500	1500	8.0	8.0	1500	1500
1600	1600	8.5	8.5	1600	1600
1700	1700	9.0	9.0	1700	1700
1800	1800	9.5	9.5	1800	1800
1900	1900	10.0	10.0	1900	1900
2000	2000	10.5	10.5	2000	2000
2100	2100	11.0	11.0	2100	2100
2200	2200	11.5	11.5	2200	2200
2300	2300	12.0	12.0	2300	2300
2400	2400	12.5	12.5	2400	2400
2500	2500	13.0	13.0	2500	2500
2600	2600	13.5	13.5	2600	2600
2700	2700	14.0	14.0	2700	2700
2800	2800	14.5	14.5	2800	2800
2900	2900	15.0	15.0	2900	2900
3000	3000	15.5	15.5	3000	3000
3100	3100	16.0	16.0	3100	3100
3200	3200	16.5	16.5	3200	3200
3300	3300	17.0	17.0	3300	3300
3400	3400	17.5	17.5	3400	3400
3500	3500	18.0	18.0	3500	3500
3600	3600	18.5	18.5	3600	3600
3700	3700	19.0	19.0	3700	3700
3800	3800	19.5	19.5	3800	3800
3900	3900	20.0	20.0	3900	3900
4000	4000	20.5	20.5	4000	4000
4100	4100	21.0	21.0	4100	4100
4200	4200	21.5	21.5	4200	4200
4300	4300	22.0	22.0	4300	4300
4400	4400	22.5	22.5	4400	4400
4500	4500	23.0	23.0	4500	4500
4600	4600	23.5	23.5	4600	4600
4700	4700	24.0	24.0	4700	4700
4800	4800	24.5	24.5	4800	4800
4900	4900	25.0	25.0	4900	4900
5000	5000	25.5	25.5	5000	5000
5100	5100	26.0	26.0	5100	5100
5200	5200	26.5	26.5	5200	5200
5300	5300	27.0	27.0	5300	5300
5400	5400	27.5	27.5	5400	5400
5500	5500	28.0	28.0	5500	5500
5600	5600	28.5	28.5	5600	5600
5700	5700	29.0	29.0	5700	5700
5800	5800	29.5	29.5	5800	5800
5900	5900	30.0	30.0	5900	5900
6000	6000	30.5	30.5	6000	6000
6100	6100	31.0	31.0	6100	6100
6200	6200	31.5	31.5	6200	6200
6300	6300	32.0	32.0	6300	6300
6400	6400	32.5	32.5	6400	6400
6500	6500	33.0	33.0	6500	6500
6600	6600	33.5	33.5	6600	6600
6700	6700	34.0	34.0	6700	6700
6800	6800	34.5	34.5	6800	6800
6900	6900	35.0	35.0	6900	6900
7000	7000	35.5	35.5	7000	7000
7100	7100	36.0	36.0	7100	7100
7200	7200	36.5	36.5	7200	7200
7300	7300	37.0	37.0	7300	7300
7400	7400	37.5	37.5	7400	7400
7500	7500	38.0	38.0	7500	7500
7600	7600	38.5	38.5	7600	7600
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8100	8100	41.0	41.0	8100	8100
8200	8200	41.5	41.5	8200	8200
8300	8300	42.0	42.0	8300	8300
8400	8400	42.5	42.5	8400	8400
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8900	8900	45.0	45.0	8900	8900
9000	9000	45.5	45.5	9000	9000
9100	9100	46.0	46.0	9100	9100
9200	9200	46.5	46.5	9200	9200
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9700	9700	49.0	49.0	9700	9700
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10000	10000	50.5	50.5	10000	10000



**MECHANICAL ENGINEERING LABORATORY**  
ARMOUR INSTITUTE OF TECHNOLOGY

1

**Test of** Wastinghouse three cyl. Gas Engine  
**Type** Four cycle, throttling  
**Size** 8 x 10  
**Fuel Used** Artificial Gas

**Brake Circumference, ft.** 33.263  
**Dead Weight of Arm, lbs.** 16.4  
**On Scales, lbs.** 15.9  
**Total, lbs.** 32.3

Date	Particulars	Rs.	Paise	Total
1950	1950			
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2	2			
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87	87			
88	88			
89	89			
90	90			
91	91			
92	92			
93	93			
94	94			
95	95			
96	96			
97	97			
98	98			
99	99			
100	100			

# MECHANICAL ENGINEERING LABORATORY

## ARMOUR INSTITUTE OF TECHNOLOGY

1

Test of Balling Gun Inst. 2711 Gas Engine  
 Type Four Cycle, Portable  
 Size 3 1/2  
 Fuel Used Artificial Gas

Brake Circumference, ft 33.653  
 Dead Weight of Arm, lbs 13.4  
 On Scales, lbs 15.9  
 Total, lbs 29.3

**LOG OF TEST:** Barometer 29.62 Date December 28, 1914.

Time	Revolutions Per Minute	Per Minute Revolutions	Gas Meter Per Hour	Temp Per Hr	TEMPERATURE—DEGREES F					Exhaust	Gas Meter	Air Meter	In Water	Water	Scale	Reading	Total	Horse Power
					Inlet Water	Outlet Water	Exhaust Temp	Exhaust Temp	Exhaust Temp									
11/17	331	3765	38	76	64	57	5"											
26	339	3781	31.2	38	76	64												
27	336	3817	31.2	38.5	76.5	64	57											
31	332	3844	32.4	38	78.5	64	57											
37	332	3870	31.2	38.5	76.5	64.5	57											
Average	332	3855	31.5	38.2	76	64.1	57	5"										911# 20 min 91.7#
Corrected							333.9											
10/45	330	3558		37	76.5	55	50	4"										
50	330	3595	31.1	37	81	64												
55	330	3635	44.4	37	61	33												
11/00	330	3640	40.0	37	33	63												
35	330	3701	43.8	37	30	33	54.5											
Average	330	3638	39.9	37	31.1	63.6	53.5	1"										963# 2 min 91.7#
Corrected							330.9											
19/25	330	7671		37	66	67	54.5	2"										
31	326	749	57.6	37	37	69												
35	328	758	59.8	37	37.5	69												
40	328	7816	57.5	37	67	69												
45	329	7766	60.0	37	67	69												
Average	328	195	55.5	37	63.9	64.6	54.5	2"										1099# 20 min 91.7#
Corrected							330.1											

REMARKS

Observer



**MECHANICAL ENGINEERING LABORATORY**  
ARMOUR INSTITUTE OF TECHNOLOGY

2

Test of Testinghouse three cyl. Gas Engine

Type Four cycle throttling

Size 8 x 10

Fuel Used Artificial gas

Brake Circumference, ft. 33.263

Dead Weight of Arm, lbs. 16.4

On Scales, lbs. 15.9

Total, lbs. 32.3



# MECHANICAL ENGINEERING LABORATORY

## ARMOUR INSTITUTE OF TECHNOLOGY

2

Test of Gas Engine Fract. Circumference, ft. 37.250  
 Type four cycle torttling Dead Weight, l. Arm. lbs. 15.4  
 Size 8 x 12 On Scales, lbs. 15.9  
 Fuel Used Artificial Gas Total lbs. 55.2

LOG OF TEST: and speedometer. 25.0 Date December 28, 1914.

Time	Revolutions Coentr	Karlston's Per Minute	Revolutions Per Minute	Gas Meter	Therm. Per Inch	TEMPERATURE—DEGREES F				Exhaust Gas at Meter	Pressure In Meter	At Top In Water	Inlet Water	Gas Reading	Brake Net	Horse Power		
						Exhaust Water	Exhaust Gas at Meter	Water	Room									
9/30		325	7921		375	90.5	69	53	1"									
55		322	7930		708	37	94	69										
4 10/10		322	8047		834	37	93.5	69										
65		322	8097		600	37	95.25	69										
10		322	8156		728	37	94	69										
Average		322	8031		775	37.1	92.65	69	53	1"				836.5	15 min	44.7#		
Corrected																		
10/10		318	8221		37	94	59	51	7"									
20		314	8290		826	37	94	69										
25		315	8360		840	37	95	59										
30		317	8426		792	37	95	59										
Average		316	8381		825	37	94.5	59	54	7"				870	15 min	43.7#		
Corrected																		

REMARKS

Observer





# MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

*Test of "estirghouse three cyl. Gas Engine. Date December 28, 1914.*



# MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of 105.425033 torque cylinder Gas Engine. Date December 10, 1911.

Size 5 1/2" Type Test Cells Clearance 0.0017 in. Total 109.99 cubic inches

Rating 10 H.P. at 325 R.P.M. Clearance 0.0017 in. Total 109.99

Indicator Used Crosby Maximum Compression 35.2 lbs. per sq. in.

Scale Spring 507

## DATA FROM CARDS

No.	R. P. M.	AREA	LENGTH OF CARD	MEAN EFFECTIVE PRESSURE	I. H. P.	I. H. P.	MECHANICAL EFFICIENCY
-----	----------	------	----------------	-------------------------	----------	----------	-----------------------

Left

1		1.04	2.97				
2		.93	2.69				
3		1.08	2.94				
4		1.05	2.95				
5		1.00	2.77				
Average		1.00	2.96	57.55	5.81		

Center

1		.71	2.30				
2		.75	2.90				
3		.80	2.89				
4		.85	2.95				
5		.95	2.90				
Average		.828	2.90	52.24	4.69		

Right

1		.50	2.96				
2		.93	2.95				
3		.80	2.95				
4		.83	2.96				
5		.80	2.94				
Average		.856	2.95	53.2	4.59	9.95	64.07
					15.89		

piston area = 51.0 sq. in.

REMARKS



# MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

*Test of* Westinghouse, three cyl. Gas Engine. *Date* December 28, 1914.



# MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

**Test of** *astirlicuse, torce cyl. Gas Engine.*

**Date** December 11, 1911.

Size *5" x 3 1/2"*

Type *Four cycle*

Clearance

cubic inches

Rating *40 H.P.*

at *325*

R.P.M.

Clearance, *1.111.87*, piston displacement

Indicator Used, *Crosby*

Maximum Compression *52.4*

lbs per sq. in

Scale Spring *EC*

## DATA FROM CARDS

No	R P M	AREA	LENGTH OF CARD	MEAN EFFECTIVE PRESSURE	I H P	I H P	MECHANICAL EFFICIENCY
----	-------	------	----------------	-------------------------	-------	-------	-----------------------

### Left

1		1.75	3.00				
2		1.94	2.99				
3		1.75	2.98				
Average		1.813	2.99	48.48	10.14		

### Center

1		1.20	2.90				
2		1.63	2.91				
3		1.40	2.92				
4		1.24	2.90				
Average		1.393	2.91	36.30	8.01		

### Right

1		1.52	2.96				
2		1.74	2.95				
3		1.54	2.97				
Average		1.60	2.96	43.25	9.05		
					27.20	20.53	75.4

REMARKS

Observer





# MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

*Test of* Westinghouse three cyl. *Gas Engine.*

*Date.* December 28, 1914.



## MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of *elastic web surface* on *Gas Engine*. Date *Sept. 24, 1914.*  
 No. *575* Tip *1/8" x 3/16" x 1/4"* *1/4" dia.  $\frac{1}{4}$ "*  
 Part *5005* at *325* *N.F.M. covers* post-impact at *8 ft/1st*  
 Indicator *1702* Maximum *1/4* *2.44*  
 No. Spring *1-5*

## DATA FROM CARDS

No.	F.F.M.	AREA	LENGTH OF CARD	MEAN EFFECTIVE PRESSURE	I.H.P.	H.I.	M.ECHANICAL EFFICIENCY
-----	--------	------	-------------------	-------------------------------	--------	------	---------------------------

## Left

1	.73	.73	3.67				
2	.71	.71	3.21				
3	.71	.71	4.15				
4	.66	.66	4.2				
5	.72	.72	3.22				
Average	.73	.73	3.67	96.	15.47		

## Center

1	.73	.73	3.67				
2	.71	.71	3.21				
3	.68	.68	4.15				
4	.73	.73	3.22				
5	.71	.71	4.17				
Average	.72	.72	3.67	96.	15.80		

## Right

1	.71	.71	4.17				
2	.71	.71	4.15				
3	.71	.71	3.67				
4	.70	.70	4.17				
5	.68	.68	4.17				
Average	.71	.71	4.15	96.50	16.13	0.60	91.5



# MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

*Test of* "testinghouse three cyl. *Gas Engine.*

*Date* December 28, 1914.



# MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of 90° Bend of Torque on Gas Engine.

Date 22.05.2017

Sr. No. 20170101

Type Test 1-2-3-4

Duration 10 min

Rating Excellent

Sl. No. 325

Chairman

Signature

Indicator Used C.F. 10

Maximum Compressive

1.200

Signature

Scale Spring 1000

## DATA FROM DATA CARDS

Sr. No.	F.P.M.	AREA	LENGTH OF LINK	MEAN EFFECTIVE PRESSURE	I.H.P.	E.H.P.	MECHANICAL EFFICIENCY
---------	--------	------	----------------	-------------------------	--------	--------	-----------------------

Cast

1		1.05	5.4				
2		1.04	5.4				
3		.91	5.4				
4		.88	5.4				
5		1.14	5.4				
Average		1.004		76.5	1.119		

Cast

1		.6	1.00				
2		.88	1.00				
3		.94	1.00				
4		.90	1.00				
5		.84	1.00				
Average		.856		74.5	1.005		

Cast

1		1.14	1.96				
2		1.00	1.96				
3		1.00	1.96				
4		.90	1.96				
5		1.16	1.96				
Average		1.04		111.6	100.9		

REVISION





# MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

*Test of* Test Airpump three cyl. *Gas Engine.*

*Date* December 28, 1914.



# MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of Cast Iron Gas Engine

Gas Engine.

Date August 2, 1914

Size 1 1/2" x 1 1/2" Type Vertical

(for copies)

Rating 42 at 525

R.P.M. 1000 Max. 1200 piston displacement

Indicator Used 2 1/2" x 7"

Maximum Compression 21.6

lbs. per sq. in.

Scale Spring 450

## DATA FROM CARDS

No.	R.P.M.	AREA	LENGTH OF CARD	MEAN EFFECTIVE PRESSURE	I.H.P.	I.H.P.	MECHANICAL EFFICIENCY
<b>Left</b>							
1		1.21	3.01				
2		1.24	3.03				
3		1.19	3.02				
4		1.16	3.01				
Average		1.20	3.017	95.29	19.08		
<b>Center</b>							
1		.98	2.87				
2		.98	2.88				
3		.96	2.89				
4		.96	2.88				
Average		.97	2.88	80.64	16.15		
<b>Right</b>							
1		1.14	2.98				
2		1.12	2.99				
3		.81	3.00				
4		.78	2.98				
Average		.962	2.997	77.28	15.48	44.80	83.4
				50.71	44.80		

REMARKS



**MECHANICAL ENGINEERING LABORATORY**

ARMOUR INSTITUTE OF TECHNOLOGY

*Test of Westinghouse 3 cyl. 8 x 10 Gas Engine*      *Date* December 28, 1914.*Kind of Fuel* Artificial Gas



# MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

*Test of Test Engine* 3 cyl. 1.6 x 1.0—*Gas Engine* Date December 28, 1914.

## Kind of Fuel Artificial Gas

No. of R.C.S.	1	2	3	4
Duration of test,	hours	1/3	1/3	1/3
Gas consumed,	cu. ft.	111.2	141	276.5
Air consumed,	cu. ft.			
*Calorific value of gas, total,	B. T. U. per cu. ft.	672.5	672.5	672.5
Calorific value of gas, effective,	B. T. U. per cu. ft.	625	625	625
Jacket water supplied,	lbs.	911	998	1099
*Gas per hour,	cu. ft.	632.43	420.29	637.15
*Air per hour,	cu. ft.			
Jacket water per hour,	lbs.	2732	2954	3197
Gas at meter,	ins. mercury.	.56	.295	.15
Barometer,	ins. mercury.	29.60	29.60	29.60
Gas at engine,	ins. water.			
Jacket water { Inlet	deg. F.	35.2	37	37
{ Outlet,	deg. F.	72.8	81.1	80.9
Gas at meter,	deg. F.	64.1	63.6	66.6
Air in room,	deg. F.	57	56.55	52.5
Revolutions per minute,	rev.	332	320	328.2
Explosions per minute,		166	165	164.1
Pressure in lbs. per sq. in. above atmosphere				
(a) Maximum pressure,		74.3	145.6	166.4
(b) Pressure just before ignition,		34.8	54.4	62.4
(c) Pressure at end of expansion,		10.4	18.4	24.0
(d) Exhaust pressure,		1.5	2.8	1.2
Mean effective pressure,	lbs. per sq. in.			
Builders' rating,	H. P.	40	40	40
Actual indicated H. P.,	H. P.	15.39	27.20	37.05
Actual brake H. P.,	H. P.	9.95	20.53	30.35
Mechanical Efficiency	%	64.6	75.4	81.9
B. T. U. per I. H. P. per hr.,		13500	9660	10240
B. T. U. per B. H. P. per hr.,		20680	12795	12500
*Cu. ft. gas per I. H. P.,		21.7	15.46	16.40
*Cu. ft. gas per B. H. P.,		36.4	20.50	20.00
Heat equivalent of I. H. P., efficiency	per cent.	19.9	26.4	24.9
Heat rejected in jacket water	per cent.	52.8	52.3	43.4
Heat rejected in exhaust and lost through radiation and incomplete combustion,	per cent.	27.3	21.2	31.
Heat equivalent of B. H. P., efficiency	per cent.	12.2	19.9	50.2

\*All gas volumes reduced to 62° F. and 30 inches mercury

Observer





**MECHANICAL ENGINEERING LABORATORY**  
ARMOUR INSTITUTE OF TECHNOLOGY

*Test of Westinghouse 3 cyl. 8 x 10 Gas Engine* Date December 28, 1914.

*Kind of Fuel* Artificial Gas  
2nd sheet



# MECHANICAL ENGINEERING LABORATORY

## ARMOUR INSTITUTE OF TECHNOLOGY

*Test of "Bell" Engine 3 cyl. 2 x 10. Gas Engine Date December 16, 1917.*

*Kind of Fuel Artificial Gas  
Tri sheet*

No. of Run	4	5	6
Duration of test,	hours. 1/3	1/4	
Gas consumed,	cu. ft. 249.1	217.5	
Air consumed,	cu. ft.		
*Calorific value of gas, total,	B. T. U. per cu. ft. 672.5	572.5	
Calorific value of gas, effective,	B. T. U. per cu. ft. 625	525	
Jacket water supplied,	lbs. 836.5	15	877
*Gas per hour,	cu. ft. 729.17	647.63	
*Air per hour,	cu. ft.		
Jacket water per hour,	lbs. 3346	3508	
Gas at meter,	ins. mercury. .074	.055	
Barometer,	ins. mercury. 29.60	29.60	
Gas at engine,	ins. water.		
Jacket water { Inlet	deg. F. 37.1	37	
{ Outlet,	deg. F. 52.65	94.5	
Gas at meter,	deg. F. 69	69	
Air in room,	deg. F. 53	54	
Revolutions per minute,	rev. 321.5	316	
Expansions per minute,			
Pressure in lbs. per sq. in. above atmosphere	161.2	156	
(a) Maximum pressure,	273.6	266	
(b) Pressure just before ignition,	73.8	61.6	
(c) Pressure at end of expansion,	28.2	38.4	
(d) Exhaust pressure,	1.2	1.2	
Mean effective pressure,	lbs. per sq. in.		
Builders' rating,	H. P. 40	40	
Actual indicated H. P.,	H. P. 46.47	50.71	
Actual brake H. P.,	H. P. 39.55	44.80	
Mechanical Efficiency	% 85.4	89.4	
B. T. U. per I. H. P. per hr.,	9400	10440	
B. T. U. per B. H. P. per hr.,	11400	11820	
*Cu. ft. gas per I. H. P.,	15.06	16.7	
*Cu. ft. gas per B. H. P.,	18.25	18.6	
Heat equivalent of I. H. P., efficiency	27.1	24.4	
Heat rejected in jacket water	per cent. 40.7	36.1	
Heat rejected in exhaust and lost through radiation and in complete combustion,	per cent. 22.2	27.5	
Heat equivalent of B. H. P., efficiency	per cent. 22.85	21.55	

\* All gas volumes reduced to 62° F. and 30 inches mercury

Observer



**MECHANICAL ENGINEERING LABORATORY**  
ARMOUR INSTITUTE OF TECHNOLOGY

**DETERMINATION OF THE CALORIFIC VALUE OF GAS. BY JUNKER'S CALORIMETER.**

*Date* December 28, 1914.



# MECHANICAL ENGINEERING LABORATORY

## ARMOUR INSTITUTE OF TECHNOLOGY

### DETERMINATION OF THE CALORIFIC VALUE OF GAS, BY JUNKER'S CALORIMETER.

Date December 26, 1914.

Kind of gas Artificial gas

Source City mains

NO. OF RUN	1	2	3	4	5
Time starting run.	11-21	07-05			
Time ending run.	14-42	31-40			
Duration of run, minutes.	3-21	4-15			
Temperature of chimney, F.	51	51.4 51.0 50.7			
Temperature of air, F.	59	59.6			
Temperature of gas at meter, F.	52	57.8 57.9			
Temperature of entering jacket water, C.	2.7	3.6			
Temperature of issuing jacket water, C.	31.7	24.1			
Range of temperature, OF	22.2	20.9			
Pressure of atmosphere, inches, mercury.	29.6	29.6			
Pressure of gas at meter, inches, water.	4.0	3.70 3.80			
Pressure of gas at burner, inches water.					
Weight of discharge tank and water, lbs.	7.99	10.46			
Weight of discharge tank, empty, lbs.	1.42	1.36			
Weight of jacket water, lbs.	6.57	9.10			
Reading of meter, beginning.	0	0			
Reading of meter, end.	.5	.5			
Total gas consumed, cu. ft.	.5	.5			
Total gas consumed reduced to 30" Hg. and 62° F., cu. ft.	.506	.503			
Cu. ft. gas per hour.	9.16	7.10			
Lbs. steam condensed per cu. ft. gas.	11 c.c.	10.7 c.c.			
Calorific value of Gas B. T. U., total.	.0478	.0439	Average		
Calorific value of Gas B. T. U., effective.	.078	.607	.672.5		
1 Gram = 0.0022046 lbs.	630	620	585		

Remarks:

1 inch water = 0.0726 inches mercury.

Observer \_\_\_\_\_





Load 9.95 B.H.P.  
Cyl. left.  
Card no.1.  
Spring 80 lb.  
Length 2.97 in.  
Area 1.04 sq. in.



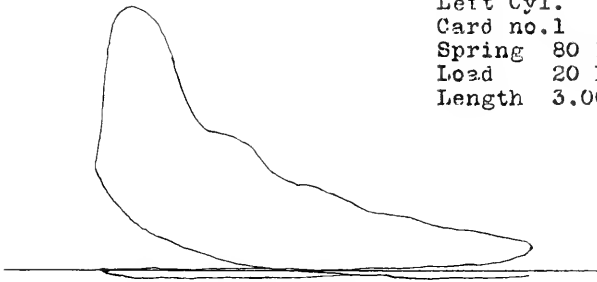
Load 995 B.H.P.  
Card Left Cyl.  
Length 2.98 in.  
Spring 20 lb.



Figure 11



Left Cyl.  
Card no.1  
Spring 80 lb.  
Load 20 B.H.P.  
Length 3.00 in.



Load 20 B.H.P.  
Spring 20 lb.

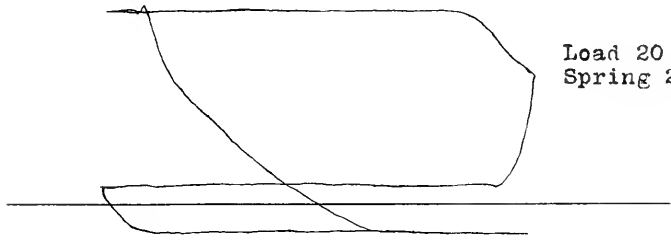


Figure 12.

1. 1997-1998  
2. 1998-1999  
3. 1999-2000  
4. 2000-2001  
5. 2001-2002

1997-1998

1997-1998

1997-1998

Cyl. left  
Card no.1  
Load 30 B.H.P.  
Spring 240  
A. - .73  
Length - 3.00 in.



Load 30 H.P.  
Spring 20 lb.

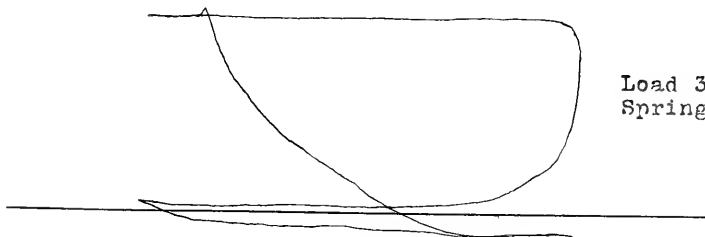
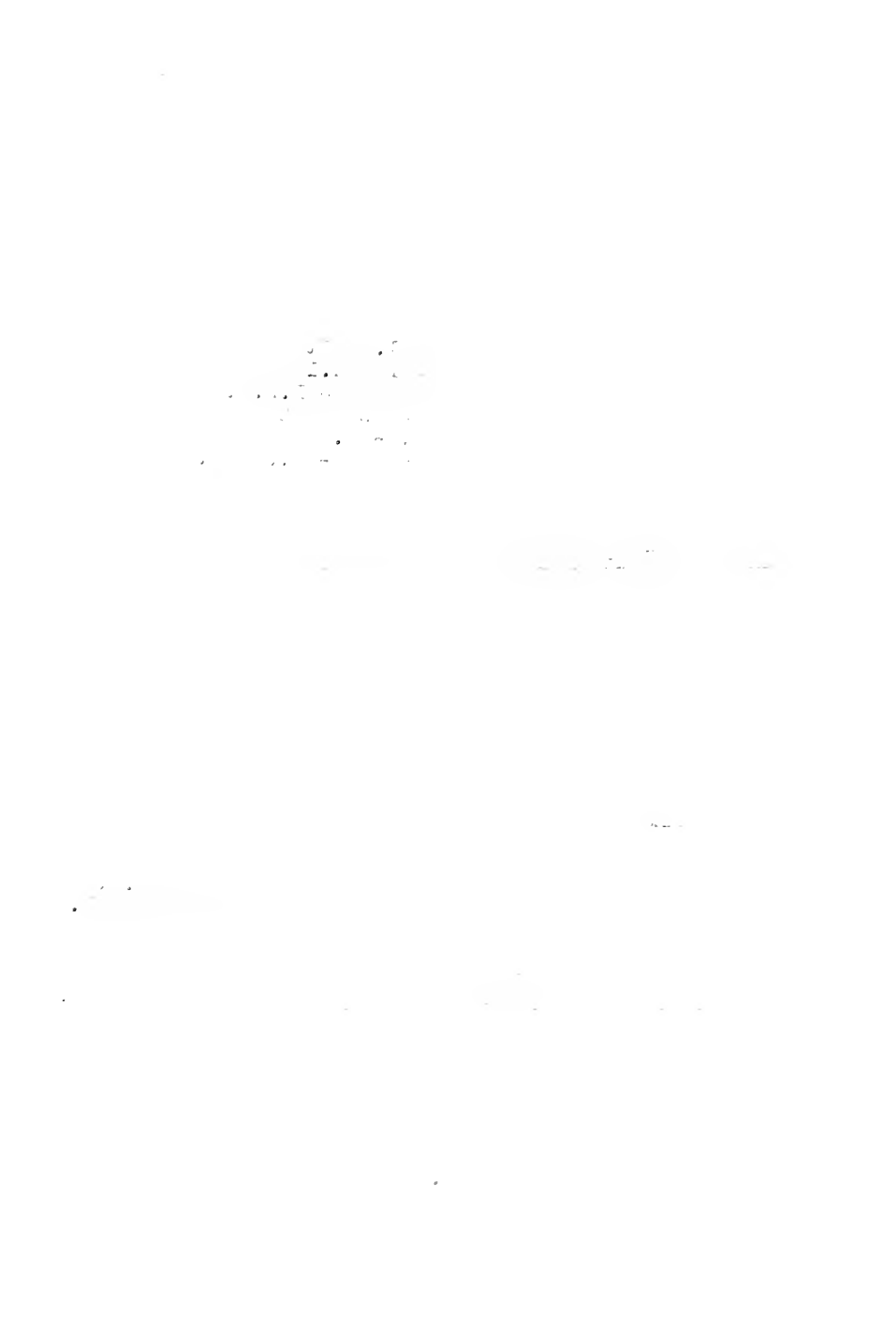
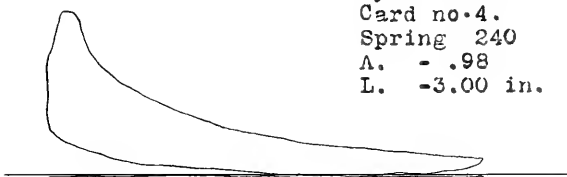


Figure 13.



Load 40 B.H.P.  
Cyl. left.  
Card no-4.  
Spring 240  
A. -.98  
L. -3.00 in.



Load 40 H.P.  
Spring 20 lb.

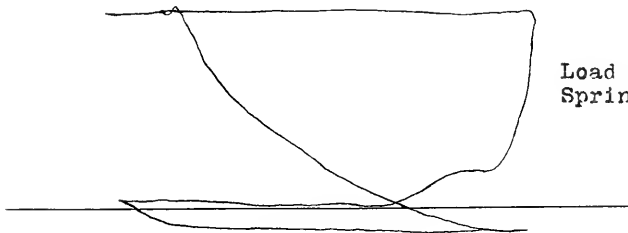


Figure 14.

1. The first part of the document is a letter from the author to the editor, dated 10/10/1964. The letter discusses the author's interest in the subject of the article and mentions that the author has been working on this topic for some time.

2. The second part of the document is a letter from the editor to the author, dated 10/15/1964. The editor expresses interest in the author's work and asks for more information about the author's background and previous work.

3. The third part of the document is a letter from the author to the editor, dated 10/20/1964. The author provides more information about their background and previous work, and expresses their hope that the editor will find the article of interest.

4. The fourth part of the document is a letter from the editor to the author, dated 10/25/1964. The editor thanks the author for their response and asks for a final revision of the article.

5. The fifth part of the document is a letter from the author to the editor, dated 10/30/1964. The author provides a final revision of the article and expresses their hope that the editor will find it acceptable for publication.

6. The sixth part of the document is a letter from the editor to the author, dated 11/5/1964. The editor thanks the author for their final revision and informs them that the article has been accepted for publication.

7. The seventh part of the document is a letter from the author to the editor, dated 11/10/1964. The author expresses their appreciation for the editor's interest and support, and wishes the editor well.

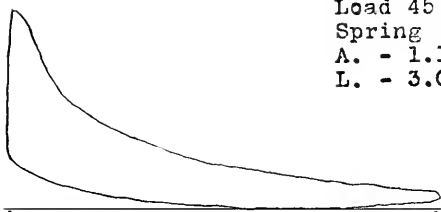
8. The eighth part of the document is a letter from the editor to the author, dated 11/15/1964. The editor thanks the author for their letter and wishes them well.

9. The ninth part of the document is a letter from the author to the editor, dated 11/20/1964. The author expresses their appreciation for the editor's interest and support, and wishes the editor well.

10. The tenth part of the document is a letter from the editor to the author, dated 11/25/1964. The editor thanks the author for their letter and wishes them well.



Cyl. left  
Card no.4  
Load 45 B.H.P.  
Spring 240 lb.  
A. - 1.16  
L. - 3.01 in.



Load 45 B.H.P.  
Spring 20 lb.

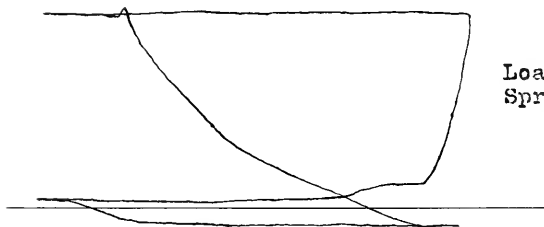


Figure 15.

11 E. 10th St.  
New York, N.Y.  
10003

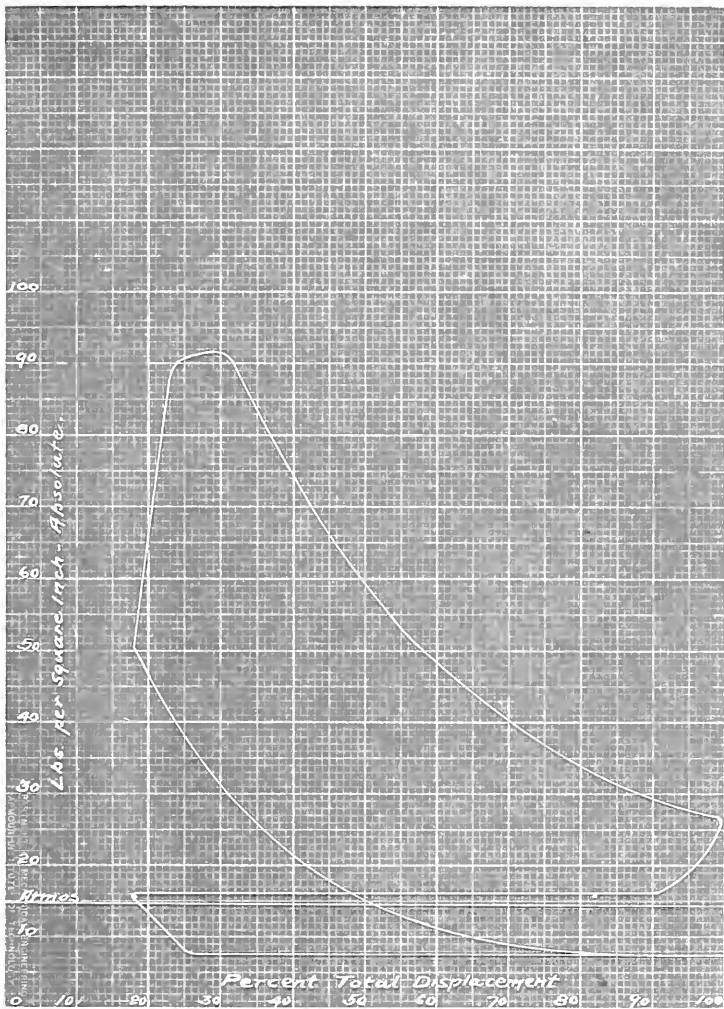


Figure 16



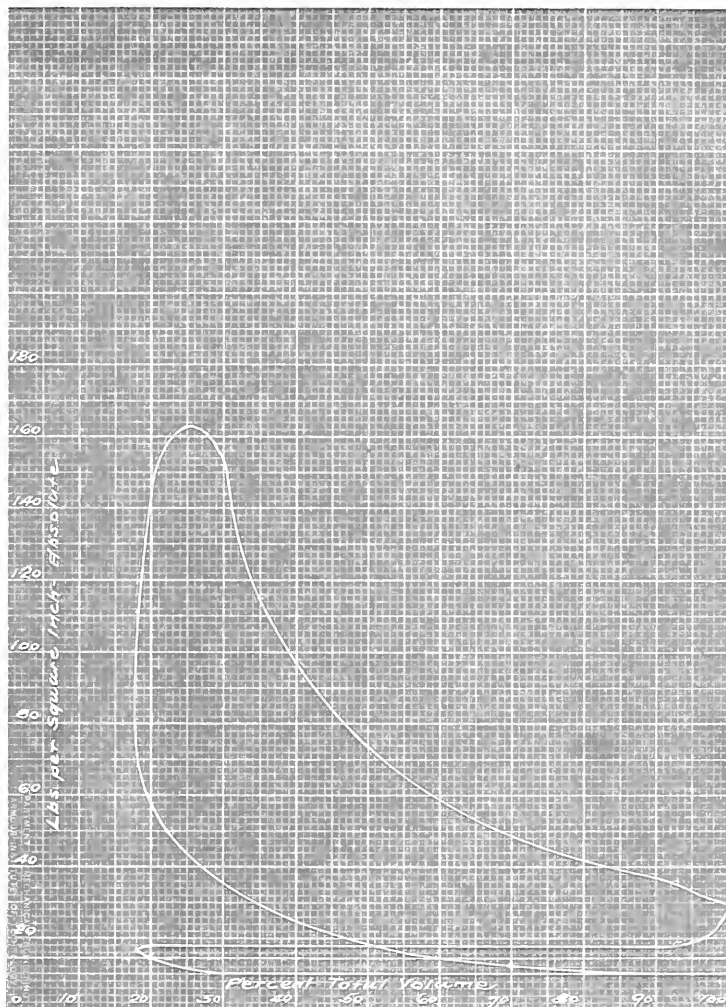


Figure 17



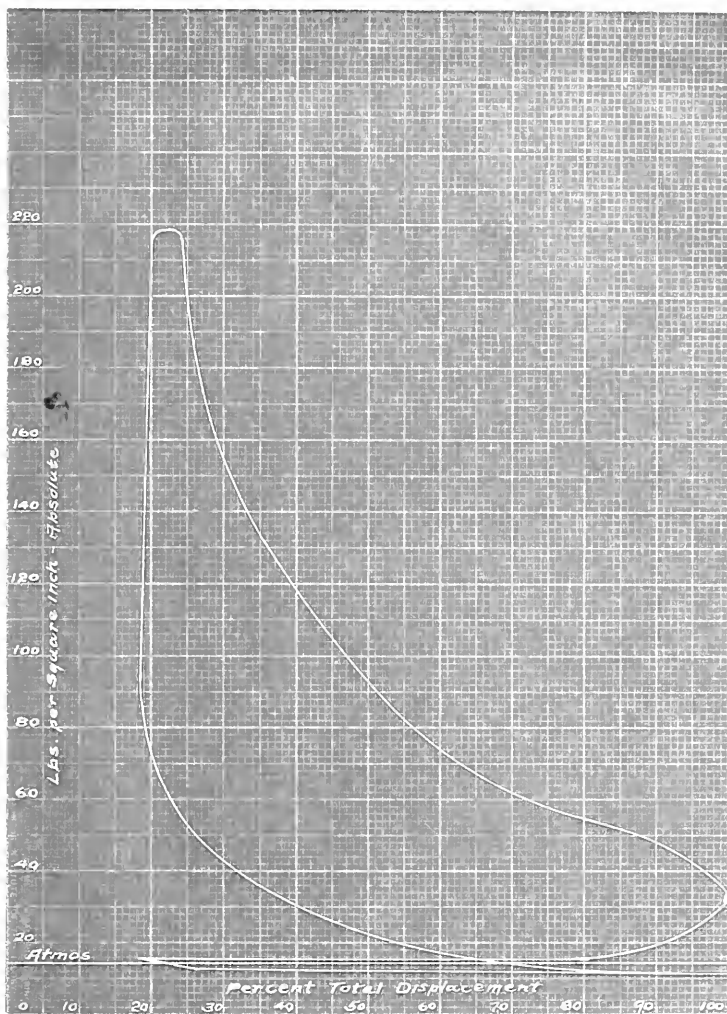


Figure 13





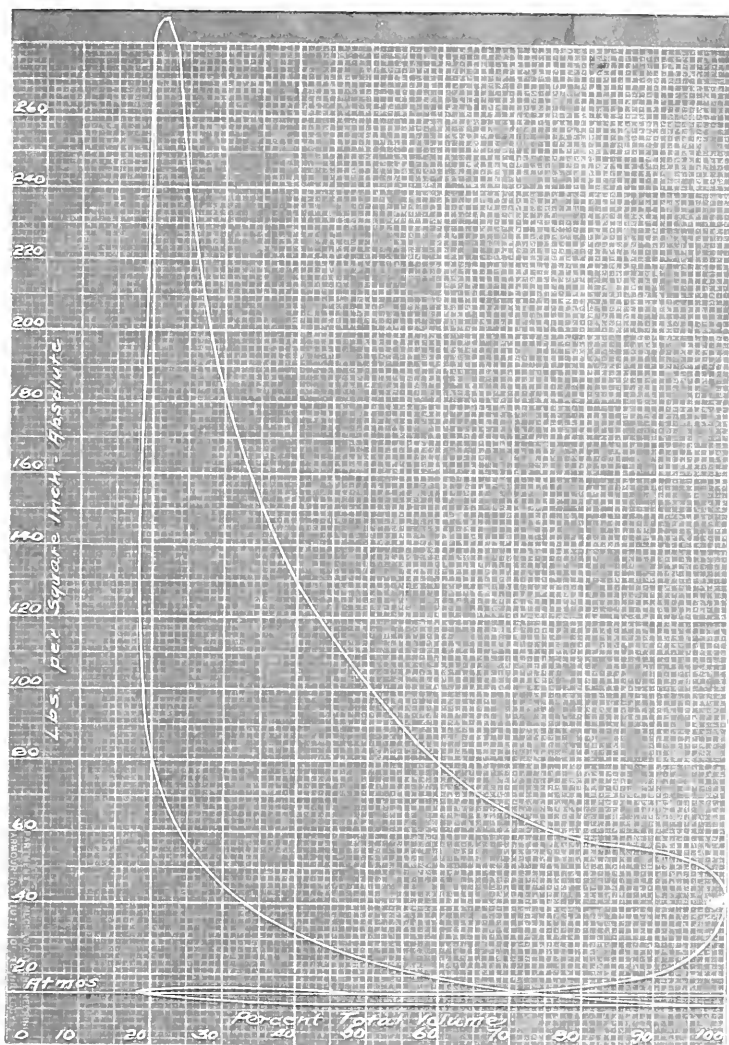


Figure 19



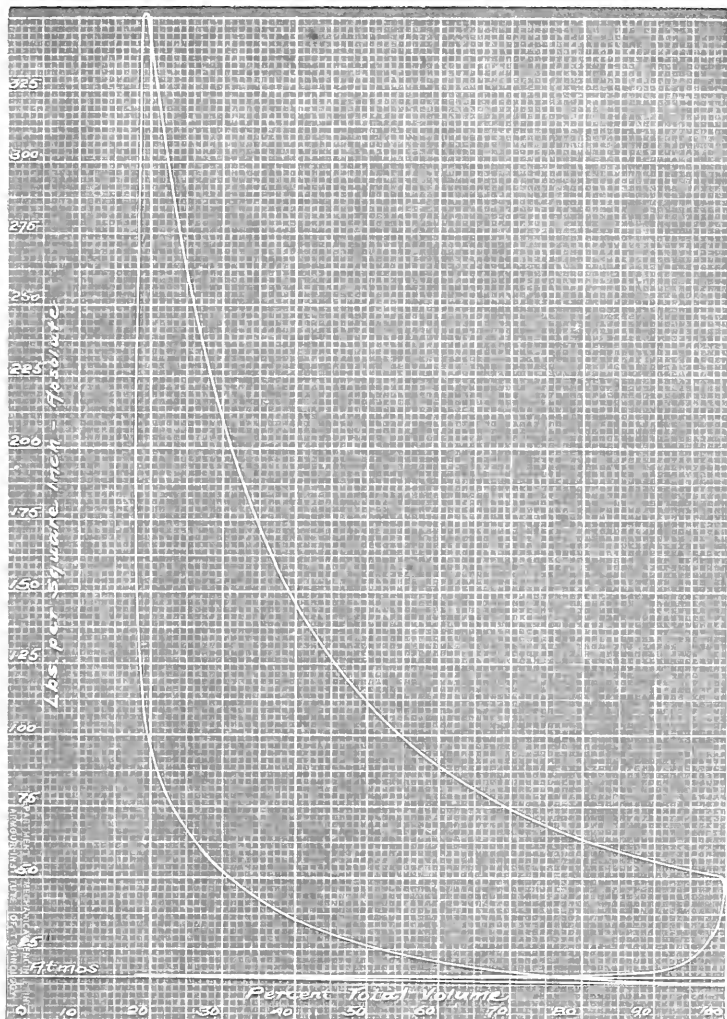


Figure 20



The fuel used was artificial gas and its calorific value was determined by means of a Junker calorimeter before and after the engine tests. The results of these determinations are given in log 10 and the average effective value used in the calculations.

In a test made by Professor Roesch, the gas meter was found to register 6% below the actual quantity passed and corrections were made for this discrepancy. Corrections were also made reducing the gas to standard conditions of temperature and pressure, 30" mercury and 62° F, both in the engine tests and calorimetric determinations. Air and gas were admitted to the mixing valve in about the ratio of six to one by volume.

#### Changes Determined Upon

As already stated, it was thought the possible maximum power output of the engine might be increased by altering the valve motion as controlled by the cams. The possibilities in this respect are limited to changes in (1) the total period during which the valve is open (2) the periods of opening and closing (3) length of dwell (4) amount of valve lift.

It is, of course, desirable to reduce the fluid friction as much as possible and this may be accomplished to some extent by making the valves open as quickly as possible and remain wide open during as great a part of the period between the beginning of opening and end of closing as possible. It is desirable however to have the action such that the valves work smoothly and quietly. To accomplish this a motion is required which proceeds gradually but is at the same time accomplished in the shortest possible time. A motion that proceeds at a constant rate of acceleration has been found in many cases satisfactorily to meet these requirements. The working parts must be so arranged that the motion is constantly accelerated during one half of the distance to be travelled and decelerated at the same rate during the other half. It was therefore decided to design the new cams to give a motion of this nature. The length of dwell is determined of necessity as a consequence of the decision as to the duration

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of the constantly accelerated motion as it is the total period of port opening less the sum of the opening and closing periods. The possible improvement by increasing the amount of valve lift is limited by the size of the passages on either side of the valves and by the clearances of the working parts of the engine. It was recognized that the maximum lift must be enough to give a maximum port opening at least equal to the area of the passages through which the gases must pass. The determination of what these lifts should be will be discussed in a later paragraph.

The principal object in changing the total period during which the valve is off its seat is to allow of as great a period of dwell as can be obtained. There are of course certain limits within which the events must fall and the shorter the periods of opening and closing can be made the greater is the portion of the total period which can be allotted to the period of dwell. An examination of the Figs. 11 to 16 shows in the upturned toe that exhaust opening is later than it should be. Exhaust closing should occur a little after the upper dead center has been passed to obtain full advantage of the inertia of the exhaust gases. Inlet opening should occur as near the beginning of the stroke as possible and closing should occur some considerable interval after the crank has passed the lower dead center.

The sequence of events decided upon, for the experimental purposes of this investigation, as a basis for the design of the cams was as follows:

Inlet opening	0°
" closing	40° late
Exhaust opening	55° early
" closing	10° late

Reckoning in degrees from the upper dead center as zero, this gives inlet opening at zero and closing at 220° of angular displacement of the crank. As the cam shaft makes only one half a revolution to one of the crank, the corresponding inlet cam travel is 110°. Of this amount 40° each were allowed for opening and closing and the remaining 30° for dwell.

In the same way the total exhaust valve motion occurs in a period corresponding to 245° of angular crank displacement, and this is equal to 122.5° of the cam shaft. In this case opening and closing are to occur during 45° each and the period of dwell

1. The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that proper record-keeping is essential for the integrity of the financial system and for the ability to detect and prevent fraud.

2. The second part of the document outlines the specific procedures for recording transactions. It details the steps involved in the accounting cycle, from identifying the transaction to posting it to the appropriate ledger account.

3. The third part of the document discusses the role of internal controls in ensuring the accuracy of financial records. It highlights the importance of segregation of duties, authorization, and independent verification.

4. The fourth part of the document addresses the challenges of maintaining accurate records in a complex and rapidly changing business environment. It suggests strategies for staying up-to-date on the latest accounting standards and technologies.

5. The fifth part of the document discusses the importance of regular audits in verifying the accuracy of financial records. It explains the different types of audits and the role of auditors in providing an independent opinion on the financial statements.

6. The sixth part of the document discusses the impact of technology on financial record-keeping. It highlights the benefits of using accounting software and the importance of ensuring the security and integrity of digital records.

7. The seventh part of the document discusses the importance of transparency and disclosure in financial reporting. It emphasizes the need for companies to provide clear and accurate information to investors and other stakeholders.

8. The eighth part of the document discusses the role of the accounting profession in maintaining the integrity of the financial system. It highlights the importance of professional standards and ethics for accountants.

9. The ninth part of the document discusses the importance of ongoing education and training for accountants. It highlights the need for accountants to stay up-to-date on the latest accounting standards and technologies.

10. The tenth part of the document discusses the importance of collaboration and communication between accountants and other professionals in the financial system. It emphasizes the need for a shared understanding of the importance of accurate financial records.

11. The eleventh part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that proper record-keeping is essential for the integrity of the financial system and for the ability to detect and prevent fraud.

12. The twelfth part of the document outlines the specific procedures for recording transactions. It details the steps involved in the accounting cycle, from identifying the transaction to posting it to the appropriate ledger account.

13. The thirteenth part of the document discusses the role of internal controls in ensuring the accuracy of financial records. It highlights the importance of segregation of duties, authorization, and independent verification.

14. The fourteenth part of the document discusses the challenges of maintaining accurate records in a complex and rapidly changing business environment. It suggests strategies for staying up-to-date on the latest accounting standards and technologies.



will be 32.5°.

The application of these figures to the design will be found in the next section.

### Design of New Cams

The periods of opening, dwell and closing having been decided upon, the design of the cams to produce these motions was largely a matter of kinematics. As it was thought desirable to increase the maximum valve lift if possible, some calculations were necessary to find what this might be made.

Considering first the inlet valves, an examination of them showed that there was sufficient clearance of all moving parts to allow for some considerable change in this respect. It was therefore necessary to find what maximum lift would give a port opening not less than the area of the passage around the valve stem. The minimum area about the valve stem, being an annular space, is the area within the cage less the sectional area of the stem. The internal diameter of the cage is 2 1-8" and the diameter of the stem is 7-16", see Fig. 2E. The area of the annular space is, therefore,

$$A_1 = \frac{\pi}{4} [(2\frac{1}{8})^2 - (\frac{7}{16})^2] = 3.396 \text{ sq. in.}$$

It remained to find a maximum port opening equal to this area. As the valves are conical in shape, making an angle of 45° with the axis of the stem, the port opening is given by the equation,

$$A_2 = \pi (e.707 dh + e.353 h^2) \quad (1)$$

where d = diameter of cage and h = valve lift. Equating  $A_1 = A_2 = 3.396$  sq. in.; substituting d = 2 1-8" as above and solving for h, a value is found of h = .63". As the clearances between the moving parts were enough to allow of this amount of lift, it was decided upon as the maximum lift to be effected by the new inlet cams.

The derivation of this equation is given in "The Gasline Automobile", by P. M. Heldt, on page 219, Vol. I and is as follows: Let d = the diameter of the bore of the valve seat and let h = the amount of valve lift in inches, as in Fig. 21. Also let x = the angle which the valve seat makes with a plane perpendicular to the axis of the valve stem. Now, if the valve and seat were flat, the

Dear Sir,

MEMORANDUM

1. The purpose of this memorandum is to advise you of the results of the investigation conducted by the Special Agent in Charge, [Name], on [Date].

2. It was determined that [Name] is a [Nationality] born [Date of Birth] at [Place of Birth]. He is currently residing at [Address].

3. The investigation revealed that [Name] has been active in [Organization/Activity] since [Date].

4. It is recommended that [Name] be placed on a list of persons of interest to the [Agency].

5. Very truly yours,  
[Signature]

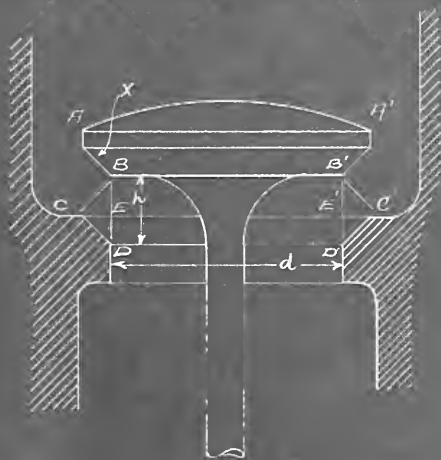


FIGURE 21.



passage when open would be in the form of a right circular cylinder but due to the conical shape of the valve it is actually the frustrum of a cone. The area of this truncated cone is therefore the area of port opening. Referring to Fig. 21 the line BC = B'C' is an element of the conical surface whose area is to be ascertained and is equal to  $h \cos X$ , also  $CE = BC \cos X = h \cos X \sin X$ . Therefore the diameter CC' is equal to  $d + 2h \cos X \sin X$ . The area of the conical surface is,  $\pi \frac{CC' + BB'}{2} \times BC$

$$= \pi(d + h \cos X \sin X) h \cos X$$

$$= \pi(dh \cos X + h^2 \cos^2 X \sin X)$$

In this case the angle X is equal to  $45^\circ$ . Substituting,  $\cos 45^\circ = \sin 45^\circ = .707$ , the equation becomes,

$$A_2 = \pi(0.707 dk + 0.353 k^2) \quad (1)$$

in which  $A_2$  is the area of port opening.

The method of determining the outline of a cylindrical cam to produce a motion of constant acceleration was taken from "The Gasoline Automobile", by E. M. Heldt, page 230, Vol. I. It is as follows:- Considering that the cam revolves at a constant angular velocity, if the vertical motion of a point in contact with the perimeter in a line through the axis of the cam is to proceed with a constant acceleration, then the displacement or lift,  $h$ , corresponding to the angular displacement of the cam through an angle  $A$  between any two positions will be proportional to the square of the time,  $t$ , required for the cam to revolve through this angle. This relation may be expressed by the equation,

$$h = Ct^2 \quad (2)$$

in which  $C$  is the constant of proportionality; or,  $A$  being directly proportional to  $t$ ,

$$h = C'A^2 \quad (3)$$

as the motion of the valve is to have a constant acceleration during one half of the period of opening and an equal but opposite acceleration or deceleration during the other half, the value of the constant,  $C'$ , is found by equating it to one half of the maximum lift divided by the square of the angle through which it is to turn, in order to produce this amount of lift. Thus the equation becomes,

$$C' = \frac{h}{2A^2} \quad (4)$$

In this instance  $h = .63''$  and  $A = 20^\circ$ , as the total period of opening covers the time required for the cam to turn through  $40^\circ$ . Sub-

STATE OF TEXAS,  
COUNTY OF \_\_\_\_\_

Know all men by these presents, that \_\_\_\_\_ of the County of \_\_\_\_\_ State of Texas, for and in consideration of the sum of \_\_\_\_\_ Dollars, to \_\_\_\_\_ in hand paid by \_\_\_\_\_ the receipt of which is hereby acknowledged, have granted, sold and conveyed, and by these presents do grant, sell and convey unto the said \_\_\_\_\_ of the County of \_\_\_\_\_ State of Texas, all that certain \_\_\_\_\_

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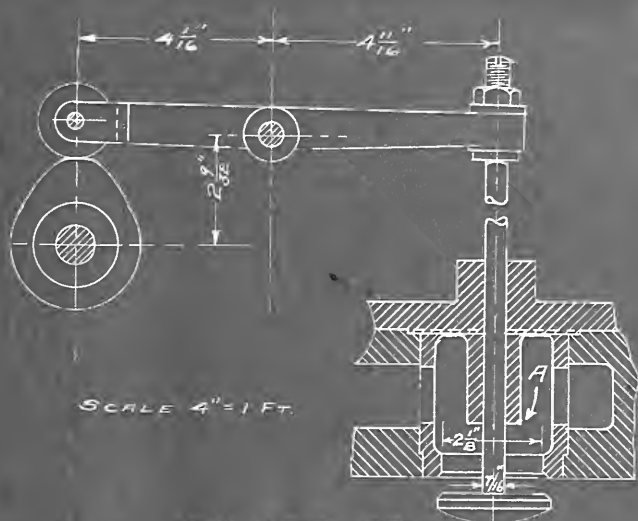
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SCALE 4" = 1 FT.

FIGURE 23.



of the roller pr. These points now represent the positions of the axis of the roller corresponding to the cam radii  $iO$  --  $nO$ . Arcs were next drawn about  $O$  as a center and having radii equal to  $Og$  --  $Oh$  and intersecting the cam radii at  $g$  ---  $h$ ". With these points as centers arcs were then drawn of radii equal to that of the roller and these arcs located the outline of the cam. The circle  $KK$  represents the cam radii corresponding to position  $C$  of the valve stem when the valve is closed and the circle,  $mln$ , or base circle, the actual outline of the cam in order to leave a small amount of clearance; in this case  $1-32$ ".

The same method was used in determining the outline of the exhaust cams. It was found however that no improvement could be effected here by means of increasing the maximum lift without more extensive alterations in the working parts of the engine than were thought warrantable on account of time limitations. This was due to the fact that although there is sufficient clearance above the valve to allow for greater lift, there is not enough clearance between the arm carrying the roller and the top of the crank case. What improvement was possible therefore in the exhaust valve motion was dependent on the periods of opening and closing and the length of dwell at maximum opening. The maximum lift was therefore taken the same as with the original-cams. This is half an inch, and by a similar set of calculations to those employed for the inlet valves, the amounts of lift corresponding to a number of cam positions were computed. The results are given in Table IV.

As the cam is to turn through an angle of  $45^\circ$  during period of opening,  $22\frac{1}{2}^\circ$  while the valve remains wide open, and  $45^\circ$  during closing, it remained to determine the cam outline by means of a kinematic drawing. This is shown in Fig. 24 and will be readily interpreted taken together with Fig. 25. The point  $O$  represents the center of the cam and the lines  $bh$  and  $b'g$  the top of the lever working about the pivot at  $a$ .  $cd$  is the line of motion of the valve stem resting on the top of the lever.  $mn$  is the base circle of the cam and is 4" in diameter.  $KK$  represents the clearance circle, an allowance of  $1-32$ " having been made for this purpose. The various cam positions are represented by the radial lines  $Og$ " to  $Oh$ ". The circle  $pr$  is the roller against which the cam operates. This roller moves along the arc  $St$ . The arc  $ii$  is as determined above  $32\frac{1}{2}^\circ$  and has a radius of 2.49", taken at  $2\frac{1}{2}^\circ$ . The various valve stem positions are laid off along  $cd$  as at  $e'$  ---  $f'$  and the intermediate points. This was done, for the sake of greater accuracy, by means of similar triangles, the line  $ef$  being drawn parallel to  $cd$  and at such a distance along  $bv$  that  $fv$  is ten times as great

The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry, no matter how small, should be recorded and properly classified. This ensures that the financial statements provide a true and fair view of the organization's financial position.

Next, the document covers the process of reconciling bank statements with the company's ledger. It highlights the need to identify and investigate any discrepancies between the two records. This step is crucial for detecting errors or potential fraud.

The following section addresses the preparation of financial statements. It outlines the steps involved in calculating the profit and loss account, the balance sheet, and the cash flow statement. It stresses the importance of using the correct accounting methods and consistently applying them throughout the period.

Finally, the document discusses the role of internal controls in ensuring the reliability of financial information. It suggests implementing a system of checks and balances to minimize the risk of errors and misstatements. Regular audits and reviews are also recommended to ensure ongoing compliance with accounting standards.

In conclusion, effective financial management is essential for the success of any organization. By following the principles and practices outlined in this document, you can ensure that your financial records are accurate, reliable, and compliant with all relevant regulations. This will enable you to make informed decisions and maintain the financial health of your organization.

as f'v. The valve lifts as given in Table IV were then multiplied by ten and these distances laid off along ef. The intersections of lines connecting these points to the point v, with the line cd therefore locate very accurately the positions of valve stem e'f', corresponding to the various angles. Lines through these points tangent to the circle wx and extended to some arc gh give at their intersections with gh a means of locating the various positions of the roller. This was done by describing the arcs gg' ----- hh' of equal radii to intersect the arc st at points g'----- h'. Then by describing arcs of radii equal to Og' ---- Oh' and intersecting the cam radii at g" ---- h", the positions of the center of the roller with respect to the cam are located. The intersections of arcs of radius equal to that of the roller with the cam radii give a series of points sufficient to mark the outline of the cam.

Table IV

Valve Lifts Corresponding to Cam Positions  
Exhaust Cams

Angle Degree	Lift Inches
0	0
5	0.0123
10	0.0485
15	0.1095
20	0.1940
22 $\frac{1}{2}$	0.2245
25	0.2960
30	0.3809
35	0.4415
40	0.4777
45	0.4900

For purposes of comparison the outlines of the new cams are shown in Figs. 8 and 10 together with those of the old in Figs. 7 and 9. The relation between port opening and crank position as contemplated in the design is represented graphically by the solid line in Fig. 26. This diagram affords a direct comparison of the valve motion as produced by the old cams with that for which the new cams were designed. The dotted line shows the valve action

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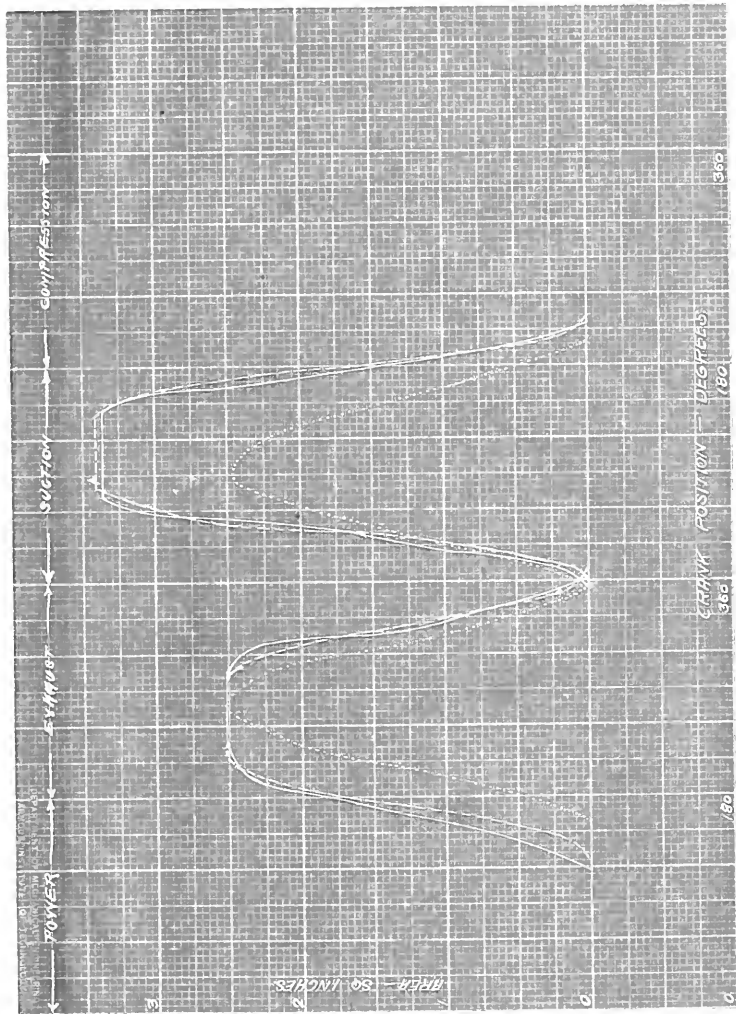


Figure 26



with the original cams. The solid line is plotted with values of port opening computed from the amount of valve lift in Tables III and IV and scheduled in Table V. The curve representing the old cam motion is plotted from Table II.

Table V

Valve Lift and Port Opening as per New Cam Design

Inlet valve			Exhaust valve		
Crank Position Degrees	Valve Lift Inches	Port Opening Sq. In.	Crank Position Degrees	Valve Lift Inches	Port Opening Sq. In.
0	0	0	125	0	0
10	0.020	0.093	135	0.012	0.056
20	0.079	0.378	145	0.048	0.225
30	0.177	0.870	155	0.109	0.513
40	0.315	1.595	165	0.194	0.831
50	0.453	2.541	170	0.245	1.192
60	0.551	2.936	175	0.296	1.454
70	0.610	3.293	185	0.381	1.904
80	0.630	3.414	195	0.442	2.236
110	0.630	3.414	205	0.478	2.437
140	0.630	3.414	215	0.490	2.508
150	0.610	3.293	280	0.490	2.508
160	0.551	2.936	290	0.478	2.437
170	0.453	2.541	300	0.442	2.236
180	0.315	1.595	310	0.381	1.904
190	0.177	0.870	320	0.296	1.454
200	0.079	0.378	330	0.245	1.192
210	0.020	0.093	335	0.194	0.831
220	0	0	340	0.109	0.513
			350	0.048	0.225
			360	0.012	0.056
			370	0	0





LOCK WASHERS

BOLTS  $\frac{3}{8}$  x  $\frac{3}{4}$

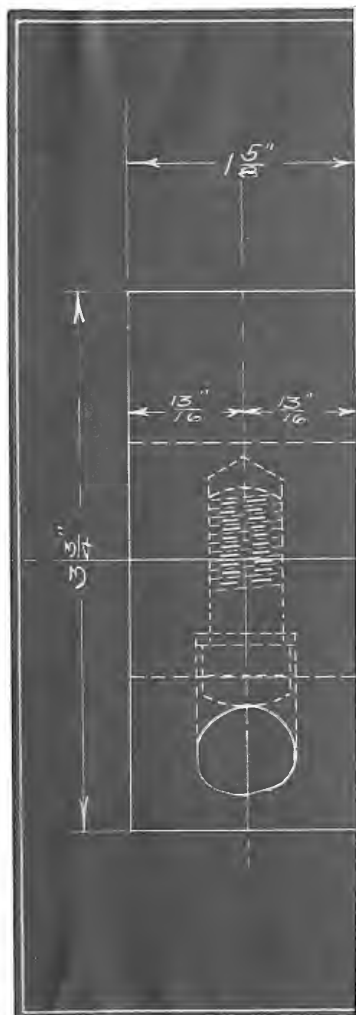


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### Installation and Adjustment

The keys of feathers on the cam shafts being set at angles of  $120^\circ$ , the new cams were fitted to the old keys so that the centers of their high points came at the same place relative to the other mechanism as the old ones. The adjustment is a matter of trial and was accomplished by turning the engine over and observing the positions of the cranks as marked on the fly wheel at the instants the events occurred. The occurrence of intake or exhaust valve events may be shifted forward or back with respect to the cranks by shifting the gears driving the cam shafts forward or back one or more teeth as required. This method has the defect that the amount of shift is restricted to a minimum corresponding to the pitch of the gear teeth. Further adjustment may be secured by changing the amount of clearance between cams and followers. An increase of clearance causes the interval between opening and closing to decrease and the opposite effect is produced by a decrease in clearance. After making a number of trials, shifting the gears and adjusting clearances, an adjustment was found which quite closely approximates the valve control contemplated in the design of the new cams. The sequence of events effected by this adjustment is given in Table VI

The actual port openings, as in the above adjustment corresponding to the various crank positions are given in Table VII and a graphical representation of this relation is superimposed, in broken line, in Fig. 26, on the corresponding curves for the old cams and the opening as contemplated in the design.

Table VI

Events	Dead Center	Cylinders		
		Left	Center	Right
Inlet opens	Upper	$6^\circ$ early	0	0
" closes	Lower	$35^\circ$ late	$40^\circ$ late	$43^\circ$ late
Ignition	Upper	$12^\circ$ early	$18^\circ$ early	$18^\circ$ early
Exhaust opens	Lower	$59^\circ$ early	$63^\circ$ early	$60^\circ$ early
" closes	Upper	$8^\circ$ late	$6^\circ$ late	$6^\circ$ late

STATE OF NEW YORK

IN SENATE  
 JANUARY 15, 1903

REPORT  
 OF THE  
 COMMISSIONERS OF THE LAND OFFICE  
 IN RESPONSE TO A RESOLUTION PASSED BY THE SENATE  
 ON MAY 28, 1902

ALBANY: JAMES BRONKHORST COMPANY, PRINTERS, 1903.

ALBANY: W. H. BURNETT, STATE BOOKSELLER, 1903.

STATE OF NEW YORK	LAND OFFICE	COMMISSIONERS
ALBANY	JAMES BRONKHORST COMPANY	PRINTERS
ALBANY	W. H. BURNETT	STATE BOOKSELLER

Table VII

Actual Valve Lift and Port Openings as Controlled by the New Cams

Left cylinder					
I n l e t			E x h a u s t		
Crank Posi- tion Degrees	Valve Lift Inches	Port Op- ening Sq. In.	Crank Posi- tion Degrees	Valve Lift Inches	Port Open- ing Sq. In.
351	0	0	117	0	0
10	0.05	0.239	135	0.07	0.326
25	0.19	0.937	150	0.15	0.712
40	0.32	1.625	165	0.26	1.266
55	0.54	2.874	180	0.36	1.794
70	0.62	3.357	195	0.46	2.345
85	0.62	3.257	210	0.48	2.456
100	0.62	3.257	225	0.49	2.513
115	0.62	3.257	240	0.49	2.513
130	0.62	3.357	255	0.49	2.513
145	0.57	3.051	270	0.49	2.513
160	0.50	2.627	285	0.49	2.513
175	0.35	1.727	300	0.47	2.399
190	0.15	0.733	315	0.31	1.527
205	0.05	0.239	330	0.19	0.910
216	0	0	345	0.10	0.469
			360	0.04	0.185
			362	0	0

The first part of the document discusses the importance of maintaining accurate records of all transactions. This includes not only sales and purchases but also the various expenses incurred in the course of business. It is essential to ensure that every receipt is properly filed and that the books are balanced regularly.

In addition, it is important to keep track of the inventory of goods on hand. This will help to identify any discrepancies between the recorded stock and the actual physical stock. Regular audits are necessary to ensure the accuracy of the inventory records.

Finally, the document emphasizes the need for transparency and honesty in all financial dealings. It is crucial to provide accurate and timely information to all stakeholders, including investors, creditors, and tax authorities.

Date	Description	Debit	Credit	Balance
1/1/20	Opening Balance			1000.00
1/5/20	Sales		500.00	1500.00
1/10/20	Purchases	200.00		1300.00
1/15/20	Expenses	100.00		1200.00
1/20/20	Receipts		300.00	1500.00
1/25/20	Payments	150.00		1350.00
1/30/20	Interest	50.00		1300.00
2/5/20	Dividends		200.00	1500.00
2/10/20	Depreciation	100.00		1400.00
2/15/20	Provision	50.00		1350.00
2/20/20	Transfer	200.00		1150.00
2/25/20	Interest		100.00	1250.00
2/30/20	Balance			1250.00



## Conclusion

It was the original intention to make a series of final tests, after the installation of the new cams, similar to the preliminary ones. Lack of time unfortunately has made this impossible. The engine was run however under various loads enough to show that its operation was satisfactory and a few indicator cards were taken. These cards are submitted herewith, Figs. 30 to 35. Fig. 36 is an enlargement of Fig. 30. This card was taken with a net brake load of 172 pounds which corresponds at normal speed to about 54 developed horse power. The engine appeared capable of operating at this load continuously, but it probably is close to the maximum output without further alteration. Compared to the 45 horse power developed in the last run of the preliminary test, which was about all the engine could carry continuously, a gain has been made of about 20% in this respect.

Referring again to Fig. 26, this diagram serves to show at a glance the improvement effected. The diagram records the facts only as taken from the left cylinder. The area under the curve is, in the case of the inlet valve, a measure of the weight of combustible per charge and as the driving force increases with the weight the cards should show a greater mean effective pressure. In the case of the exhaust valve the area under the curve is a measure of the capacity for exhausting burned gases and is in consequence an indication of reduced exhaust velocity and back pressure.

The result of the work is epitomized in Figs. 20 and 36. A comparison of these cards bears out the conclusions drawn from the consideration of the port opening diagram. The total area of the full load diagram is greatly increased due to increased charge of combustible and consequently greater m.e.p. Both compression and maximum pressures are increased and the toe is rounded off downward. This latter modification reduces unnecessary back pressure and crank pin stresses at the lower dead center. And in addition and conclusion, in proportion to the power developed, the negative work as represented by the lower loop is reduced.

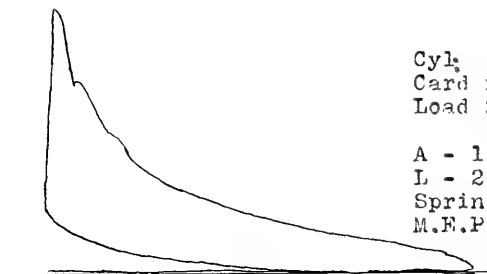
1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in the context of public administration and financial management.

2. The second part of the document outlines the various methods and tools used to collect, store, and analyze data. It highlights the need for robust information systems that can handle large volumes of data and provide timely insights into organizational performance and trends.

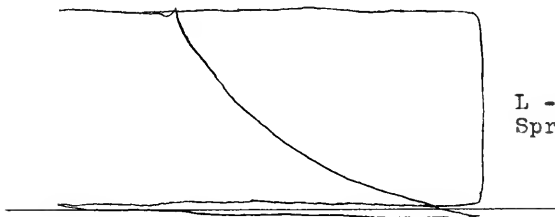
3. The third part of the document focuses on the role of data in decision-making and strategic planning. It argues that data-driven insights are crucial for identifying opportunities, assessing risks, and optimizing resource allocation. This section also discusses the importance of data security and privacy in protecting sensitive information.

4. The fourth part of the document addresses the challenges and opportunities associated with data management in the digital age. It notes that while technology offers powerful tools for data analysis, it also presents significant challenges, such as data integration, interoperability, and the need for skilled personnel to manage and interpret the data effectively.

5. The fifth part of the document provides a summary of the key findings and recommendations. It stresses the need for a holistic approach to data management, one that integrates data collection, storage, analysis, and security into a cohesive framework. The document concludes by emphasizing the ongoing nature of data management and the need for continuous improvement and innovation in the field.



Cyl; left  
Card no.1  
Load 202 lb. gr.,  
172 lb net.  
A - 1.34  
L - 2.95  
Spring 240 lb.  
M.F.P. 109 lb.



L - 2.995  
Spring 20 lb.

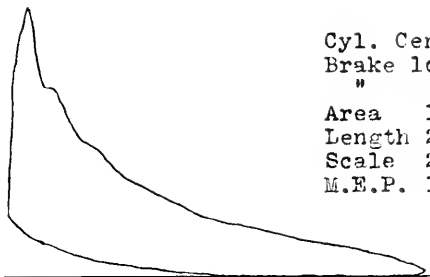
Figure 30

1918  
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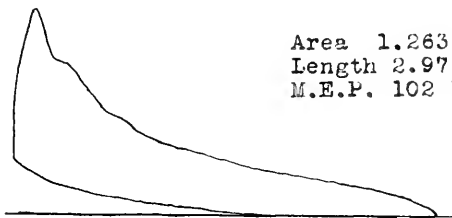
1918

1918



Cyl. Center  
Brake load 202 lb. gr.  
" " 170 lb. net.  
Area 1.44 sq. in.  
Length 2.93 in.  
Scale 240  
M.E.P. 118 lb.

Figure 31



Area 1.263 sq. in.  
Length 2.97 in.  
M.E.P. 102 lb.

Figure 32

2000  
2001  
2002



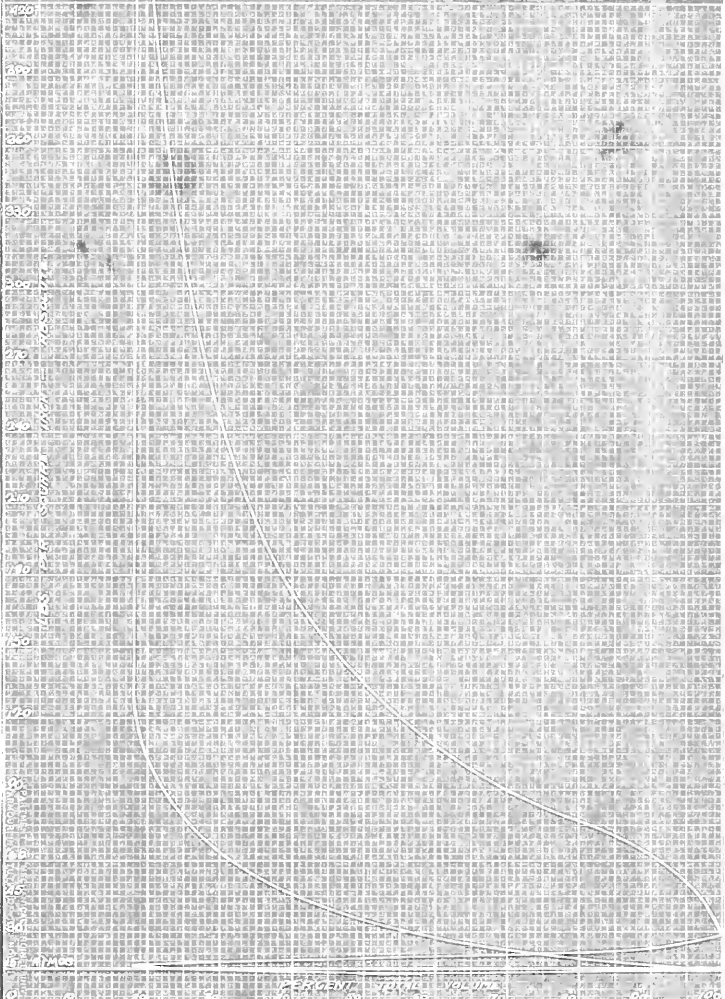


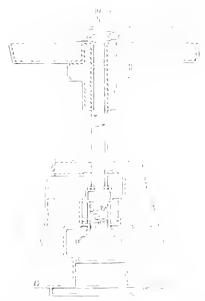
Figure 36

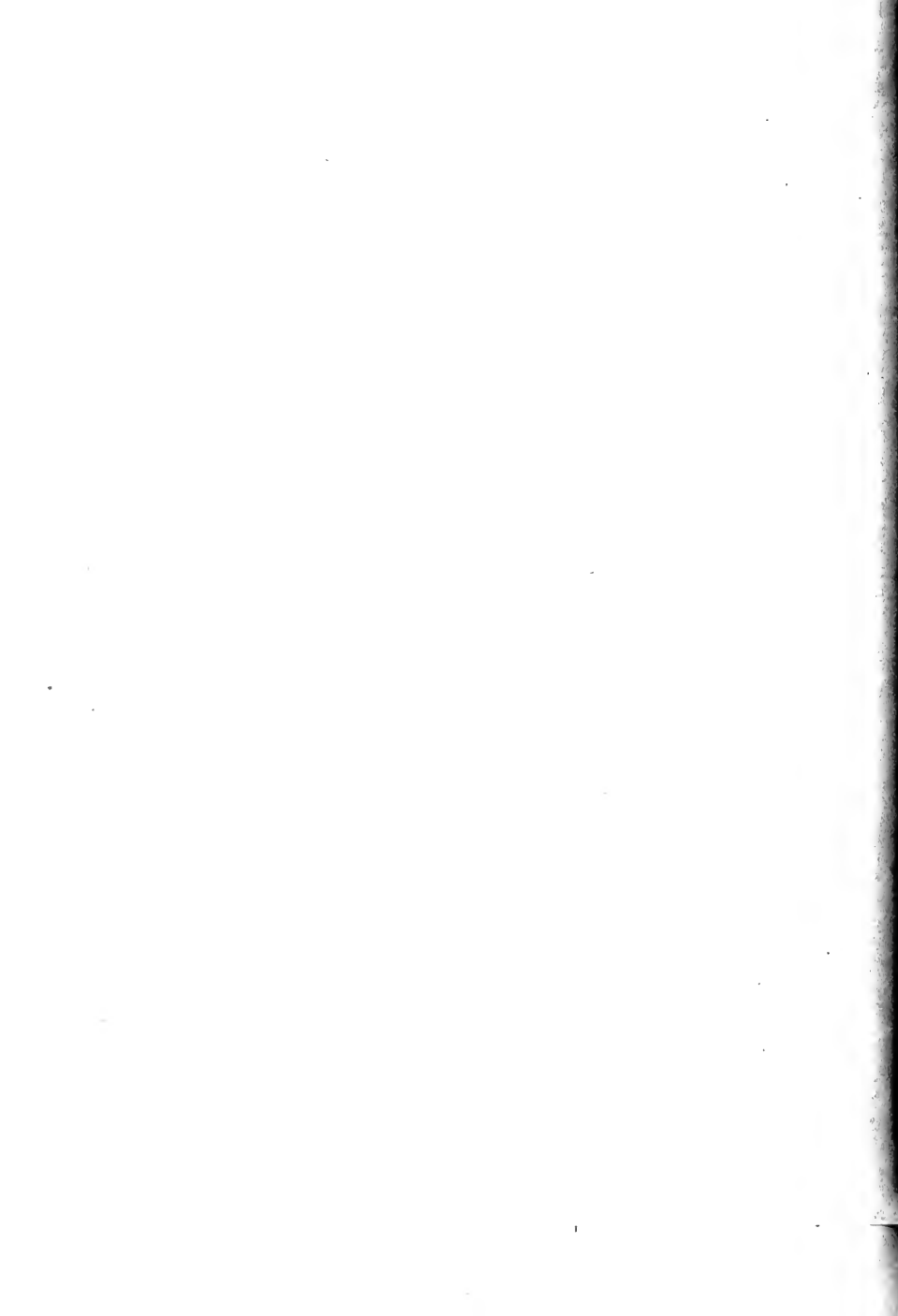


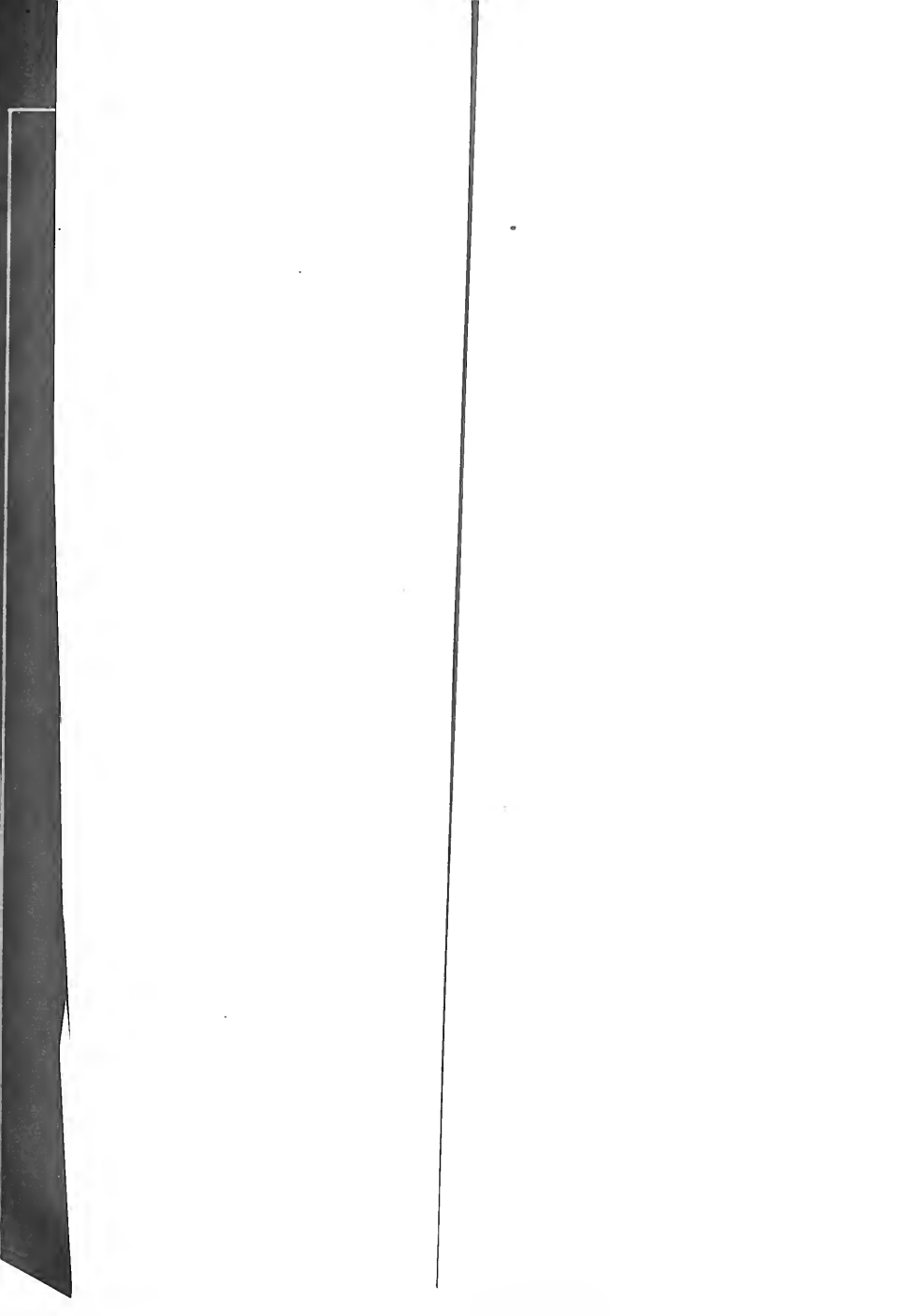


74











1900

1900

