EFFICIENCY TESTS OF A TWENTY HORSE-POWER AVERY TRACTION ENGINE NO. 2116.

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Efficiency Tests of a Twenty Horse-Power Avery Traction Engine.

Purpose: The purpose of the following is to set forth the mechanical efficiency of the Avery traction engine No. 2116, running as a stationary engine and as a traction engine; to determine the evaporative power of the boiler under a reasonable load while being fired with Lansing coal from the Kansas Penitentiary; and to determine the draft per ton of haul over dirt and macadamized roads with an ordinary four inch wagon.

The instruments used for the tests for mechanical efficiency were:

- Two Crosby indicators, each closely connected
- A Crosby disk revolution counter
- A Prony brake
- A platform scale and
- An indicator reducing motion

To make a reliable test of an engine requires a correct application of instruments and a skillful manipulation of the same. The error of every instrument should be determined before and after the test and necessary corrections made for the same. No instrument of doubtful reading should be used under any circumstances. Ease of manipulation adds much to the accuracy with which a reading may be made. All readings ought to be made simultaneously in order that they may harmonize.

The Indicators: Of the sources of error accompanying the use of indicators we found that two above all should be sought out. First, in setting up these instruments, directions should be followed explicitly, but after all we found no assurance of a perfect alignment of the piston in the cylinder. The small screw at the under side of the piston should be adjusted last, in order that the spring may be seated concentrically with the piston stem. Then to make sure of the adjustment a test should be made to prove that the upward run of the pencil point indicates the same pressures as for corresponding points on the downward run. The pencil motion with its records is next in importance. There should be no undue looseness in the joints. The pencil point should be sharp. It should touch the paper just enough to give a legible record. Any more than this will introduce errors due to paper friction amounting to 5% or even much more The greater accuracy therefore is given by very light though legible diagrams.

The Reducing Motion: The one used in these tests is shown in the accompanying drawing. The essential points are:

1st The bar to which the indicator cords are fastened should be parallel to the axis of the cylinder

2nd The points indicated by the letters A, B, & C and A, D, and E should be in straight lines, and B D should be parallel to C E. We found that if these conditions are not fulfilled the mechanism is worthless as far as accuracy is concerned. This motion was proportioned to give diagrams 3.45 inches long but in actual operation it gave diagrams varying in length from 3.39 to 3.5 inches, the average being about 3.46 inches.

To begin with our results gave a mechanical efficiency as great as 150%, a result altogether erroneous. Investigation proved; (1) some slight faults in lengths and a lack in precise adjustment of the parts of the reducing motion; (2) that we were making indicator diagrams altogether too heavy so that the friction between the pencil point and the paper produced distortion. The friction of the pencil point prevents it from rising so high or falling so low as it would under proper conditions, therefore reducing the area of the indicator diagrams and consequently the indicated horse power, thus making a high brake horse power as compared with the indicated horse power which would show a high efficiency; and (3) that the pencil motion was without fault as far as we could determine. Having made good these faults the results herewith, were obtained. (see curves and data sheets for same)

From the above it is plain that a manufacturing company may get any per cent efficiency desired from a machine by simply adjusting the instruments, and at the same time make it appear that the results were true and just. Furthermore the errors cannot be detected unless the tests are observed by the inspector.

The Prony Brake.

The essential points of the Prony brake are; a band to be placed around the pulley, and an arm at the end of which the force, exerted by the pulley in turning against the friction offered by the band, is measured.

However, if accurate results are wanted, several other points must be taken into consideration:

(1) Lubrication

(2) A constant supply of cooling water on the pulley.

(3) Adjustment of the band.

(4) The manner of measuring the pull, and

(5) The brake constant

If the cooling water is allowed to flow directly upon the face of the pulley, the use of oil as a lubricant is useless as it is washed off. But in this case the water itself makes a fair lubricant. The flow of water must be constant through each reading. Also, as the temperature of the pulley rises, a greater quantity of water is needed and should be increased accordingly between readings. In our own work with the brake as illustrated, much difficulty was experienced through irregularity of the flow of cooling water. A separate hose line was used for this purpose, the water being applied to the upper left quarter because the force of gravity tended to reduce the tangential flow of the water from the wheel.. The flow was farther confined by means of waste placed before each block. It was found also that the face of the pulley should not turn against the edge of the blocks, and that the blocks should be both grooved and beveled to facilitate the passage of water around the pulley. In addition to these precautions there should be some provision whereby the flow of water is not dependent upon a pipe line pressure. While making the tests there were, for many minutes at a time, no evidences of change in the coefficient of friction between the brake and the pulley. At another instant there was a great increase in the friction - so much so that within a few revolutions the engine became overloaded and stopped. This could be accounted for because of a variation in the amount of water on the pulley due to a change of pressure. This change of pressure could easily be caused by withdrawing water any where along the line, a thing not uncommon in water service.

If the brake could be supplied from a tank above, a more constant supply of water could be had and this difficulty overcome.

A better method of cooling, but inconvenient because of the splashing, is to flange the pulley on the inside edges of the rim and by means of a delivery pipe and take-off funnel, keep a constant supply of cold water on the rim. Then oil can be used on the brake with some success. A still better method would be to have a brake made of pipe through which water may be circulated for cooling. Oil can be applied directly on the face of the pulley with this form, also.

Brakes of small size may usually be adjusted by means of a bolt and hand wheel: but on larger sizes a nut and a wrench must be used. Every brake must be semi-automatic: that is, it must have enough elasticity to adjust itself to varying conditions. This is especially true with respect to wooden brakes or brakes with wooden blocks. In our own case, our greatest difficulty was to get a steady adjustment.

This we accomplished in a rather unsatisfactory manner by use of two springs of different strengths. A light spring intended to take the light loads and a heavy spring for the heavy loads, were used.

A load or force exerted by the beam is best measured by means of an ordinary scale which has been tested with standard weights. The beam should be parallel with a level line from the center of the pulley and the end of the beam must rest on knife edges.

The most accurate method of getting the brake constant is to hang the brake on a knife edge, placed directly over the center of the pulley. The brake should not touch the pulley. Then the constant can be weighed directly on the scale. Another method is to run the pulley with a light load on the brake in one direction and measure the load. Then reverse the direction of the pulley and again measure the load. The difference will be a fairly accurate brake constant. By means of counter weights the reading on the scale may be made equal to 0, when running with no load. Then there is no brake constant and the load is read directly. In our case we found the second method most practicable, but checked with the former; yet with this method, much discretion must be used, for values varying from 24 pounds to 75 pounds were obtained by trial with various loads.

The following conclusions are drawn from observation and data with respect to Mechanical efficiency.

(1) The efficiency increases with the load until the maximum capacity of the engine is reached, at which point the speed will commence to fall.

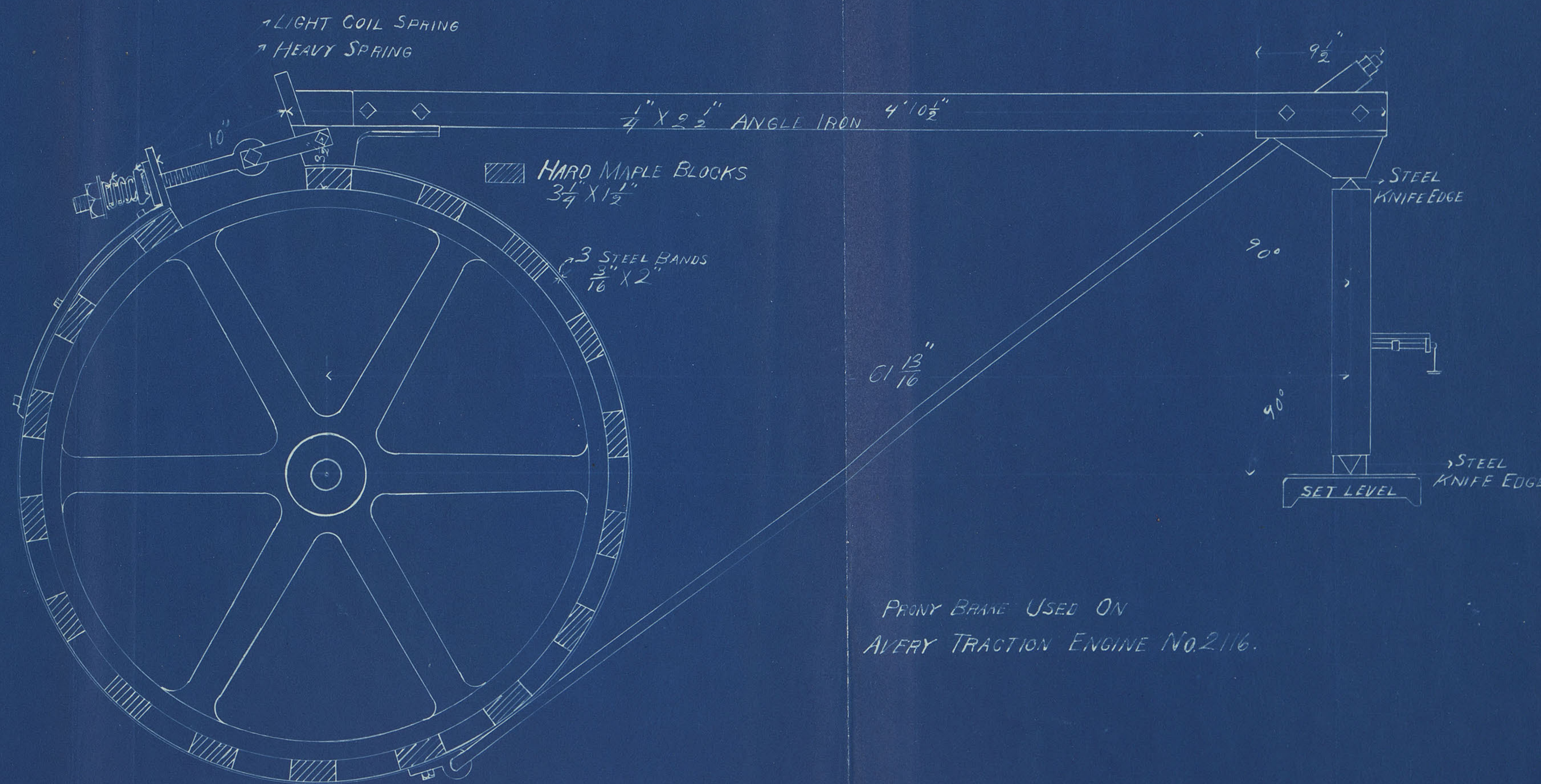
(2) The efficiency is greatly affected by the skill of the persons in charge. Unless all readings are made simultaneously large errors are liable to be introduced; this is particularly true with respect to indicators. The pressures in the cylinder should be recorded on the drums during the same stroke. The brake must be exactly balanced at the same instant.

(3) The R. P. M. is slightly variable because of the slightly varying loads produced by a brake, which are almost unavoidable. Hence the R. P. M. should be the average of several minutes during which time the load must be maintained constant.

(4) A throttling governor is extremely wasteful except under a very heavy load. The governor on the Avery frequently caused steam to become wire-drawn to such an extent that the pressure at admission was 60 pounds lower than the boiler pressure.

(5) Perfect lubrication of the valve is necessary: otherwise an undue amount of power is required to run the engine. Sticking of the valve when any loose motion exists may affect the events of the stroke.

(6) All of the mechanism should be as conveniently located as possible for the reason that the efficiency varies directly as the care taken to keep the engine up and when any part is so located that it cannot be adjusted or used without great bodily discomfort, it is apt to be neglected.



PRONY BRAKE USED ON
AVERY TRACTION ENGINE NO. 2116.

The Traction Tests.

This work was for the purpose of determining the draft required per ton of load to haul over dirt and Macadam roads and on different grades. These tests were made on May 29th and 30th. The surface of the dirt roads was, on the morning of May 29th, very sleek because of a rain early in the morning. By the afternoon the well graded dirt roads were in fairly good shape though a little soft. By the next day they were in excellent condition. The lower grades however were more or less sandy. The other were on heavy red clay except one stony hill. The Macadamized roads on the K. S. A. C. grounds were also used. These are smooth and even grades.

For this work, the engine was fitted up for extra water and coal supply, and with a platform on the left or cylinder side of the engine to facilitate the manipulation of the indicators. A wagon weighing 1900 lbs. was loaded with pig iron so that wagon and all weighed four tons. Coupling for guiding was made by means of a short tongue and for drawing a short doubletree chained from its middle to the front axle was used. One end of this was connected directly to the engine and the other through a 2000 # dynamometer. The following dynamometer readings are therefore to be multiplied by two. They were taken as rapidly as recording would permit in order that an average of the many would give more nearly the true pull. The single readings are and could not be otherwise than rough approximations because of the great and rapid fluctuations of the pointer, the small error of the dynamometer was considered within that due to reading and was therefore not considered.

The instruments used in this work were:

Two Crosby Indicators

A Crosby disc revolution counter

A Crosby lever revolution counter

An H. Heilchem scale type dynamometer.

These tests show an average traction efficiency of about 22.8%. No definite conclusions can be drawn from so limited a series of tests. Before this can be done a series of tests must be made which would include the following conditions.

(1) Roads; dusty, muddy, stony, soft, sandy, frozen

(2) Low wheeled wagons

(3) Broad tires, narrow tires.

No. 1.

Grade 0.25% fall May 30, 1905.

Kind and condition of grade

Ungraded, smooth , slightly sandy, dirt.

Circumference of wagon wheel	11.18
Revolutions of wagon wheel	72
Time in minutes	3.87
Distance in feet per minute	208
Average dynamometer readings	339 #
Average traction	678 #
Traction H. P.	4.27
Indicated H. P.	19.25
Starting load	1400 #

Observed dynamometer readings:

300	300	400	
400	500	300	
400	400	500	
300	300	400	
250	400	350	
300	400	300	
300	350	250	
300	300	200	
400	300	400	
350	300	400	
250	200	400	
		11800	Total
300	300		
		337	Average

No. 2.

Grade .253% fall May 29, 1905.

Kind and condition of grade

Smooth , ungraded, dirt.

Circumference of wagon wheel	11.18
Revolutions of wagon wheel	109
Time in minutes	5.75
Distance in feet per minute	211.9
Average dynamometer readings	432 #
Average traction	864 #
Traction H. P.	5.55
Indicated H. P.	17.83
Starting load	1100 #

Observed dynamometer readings:

350	500	400	300	
500	500	400	450	
500	500	350	400	
450	400	400	500	
400	350	350	250	
400	400	300	400	
400	500	300	300	
350	500	400	400	
300	400	n300	300	
500	300	300	300	
400	400	300	350	
600	400	400	300	
400	400	400	400	
500	400	300	350	
500	300	300	300	
500	400	300	200	
600	300	400	300	
500	300	300	32800	Total
	300	300	432	Average

No. 3.

Grade	.29%	fall	May 30, 1905.

Kind and condition of raods

Well graded dirt.

Circumference of wagon wheel	11.18
Revolutions of wagon wheel	40
Time in minutes	225
Distance in feet per minute	199.5
Average dynamometer readings	495 #
Average traction	990 #
Traction H. P.	5.98
Indicated H. P.	
Starting load	1600 #

Observed dynamometer readings:

500	450	
400	400	
450	500	
400	500	
400	600	
400	650	
400	600	
450	700	
500	600	
500	500	
	9900	Total
	495	Average

No. 4.

Grade	.34%	rise	May 30, 1905.

Kind and condition of grade

Well graded dirt

Circumference of wagon wheel	11.18
Revolutions of wagon wheel	
Time in minutes	
Distance in feet per minute	
Average dynamometer, readings	296 #
Average traction	
Traction H. P.	
Indicated H. P.	
Starting load	

Observed dynamometer readings:

500	600	500	100	400	
100	200	150	150	100	
400	300	400	500	500	
600	100	800	50	300	
200	400	300	300	150	
300	200	400	400	700	
100	300	400	100	500	
400	50	200	300	23 675	Total
100	500	500	400		
300	100	600	50	296	Average
150	400	200	300		
300	150	800	500		
100	300	600	300		
400	50	150	500		
200	300	400	300		
500	100	100	500		
100	400	100	300		
	100	900	400		
	400	50	25		
	100	400	500		

No. 5.

Grade .355% fall May 29, 1905.

Kind and condition of grade; well graded, a little soft, dirt

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		71
Time in minutes		3.75
Distance in feet per minute		211.7
Average dynamometer readings		344 #
Average traction		688 #
Traction H. P.		4.40
Indicated H. P.		19.58
Starting load		1200 #

Observed dynamometer readings in pounds:

300	400	300	300	
350	400	400	400	
400	450	400	300	
500	500	300	400	
500	300	300	350	
400	300	350	400	
400	300	300	300	
400	300	350	500	
400	300	300	300	
300	350	350	250	
300	300	400	300	
400	350	400	400	
400	300	350	250	
400	350	300	20250	Total
			344	Average

No. 6.

Grade	0.355%	rise	May 30, 1905.

Kind and condition of grade; ungraded, smooth, slightly sandy, dirt

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		69
Time in minutes		3.75
Distance in feet per minute		206
Average dynamometer readings		378.3 #
Average traction		756.6 #
Traction H. P.		4.73
Indicated H. P.		25.25
Starting load		

Observed dynamometer readings in pounds:

400	400
400	450
400	400
300	350
300	350
300	500
300	500
400	500
400	400
300	600
300	500
350	300
250	400
300	450
350	300

11350 Total

378-1/2 # Average

No. 7.

Grade	0.46%	rise	May 30, 1905.
Kind and conditions of grade;	smooth, Macadam		
Circumference of wagon wheel		(feet)	11.18
Revolutions of wagon wheel			31
Time in minutes			1.60
Distance in feet per minute			216.4
Average dynamometer readings			309.5 #
Average traction			619.0 #
Traction H. P.			4.07
Indicated H. P.			
Starting load			

Observed dynamometer readings in pounds:

300
250
350
300
400
300
300
250
350
250
300
400
300
250
300
350

4950 Total

No. 8.

Grade .462% fall May 29, 1905.

Kind and condition of grade

Smoothe, Macadam

Circumference of wagon wheel	11.18
Revolutions of wagon wheel	56
Time in minutes	2.66
Distance in feet per minute	214.3
Average dynamometer readings	175 #
Average traction	350 #
Traction H. P.	2.27
Indicated H. P.	13.56
Starting load	

Observed dynamometer readings:

200	150	
250	150	
150	200	
200	200	
200	200	
200	200	
150	200	
200	200	
200	200	
100	100	
200	200	
200	250	
	4200	Total
	175	Average

No. 9.

Grade .462% rise May 29, 1905.

Kind and condition of grade; smooth, Macadam

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		37
Time in minutes		1.92
Distance in feet per minute		216
Average dynamometer readings		305 #
Average traction		610 #
Traction H. P.		3.99
Indicated H. P.		17.69
Starting load		900 #

Observed dynamometer readings in pounds:

450	200	
300	200	
350	200	
300	250	
350	200	
300	200	
300	250	
300	350	
350	300	
350	350	
350	350	
300	350	
300	350	
300	9150	Total
300		
350	305	Average
350		

No. 10.

Grade 1.87% rise May 29, 1905.

Kind and condition of grade

Well graded, slightly soft

Circumference of wagon wheel	11.18
Revolutions of wagon wheel	101
Time in minutes	5.25
Distance in feet per minute	215.1
Average dynamometer readings	326.2 #
Average traction	652.4 #
Traction H. P.	4.254
Indicated H. P.	20.404
Starting load	1000. #

Observed dynamometer readings:

300	200	500	500
300	400	200	500
300	300	500	300
300	400	500	300
200	300	400	200
300	500	300	200
200	200	200	500
200	200	100	300
200	450	150	500
400	300	300	400
400	300	300	400
500	100	200	500
150	500	200	450
500	100	400	500
100	400		300
600	100		23500 Total
100	500		
500	400		326.2 Average
100			
450			
450			

No. 11.

Grade	1.87%	rise	May 29, 1905.

Kind and condition of grade

Smooth , well graded dirt

Circumference of wagon wheel	11.18
Revolutions of wagon wheel	93
Time in minutes	5
Distance in feet per minute	208
Average dynamometer readings	372 #
Average traction	744 #
Traction H. P.	4.69
Indicated H. P.	24.57
Starting load	

Observed dynamometer readings:

600	500	400	
300	300	300	
400	300	400	
300	400	300	
400	500	300	
350	500	500	
500	600	400	
300	400	500	
400	500	400	
400	500	500	
300	600	300	
300	500	400	
300	500	400	
400	600	500	
400	600	300	
400	400	300	
500	400	200	
500	350	300	
500	400	300	
400	400	300	
		400	
		21900	Total
		372	Average

No. 12.

Grade 1.87% fall May 29, 1905.

Kind and condition of grade; smooth, well graded dirt.

Circumference of wagon wheel (feet)	11.18
Revolutions of wagon wheel	119
Time in minutes	6.22
Distance in fett per minute	214
Average dynamometer readings	294 #
Average traction	588 #
Traction H. P.	3.81
Indicated H. P.	18.34
Starting load	1500 #

Observed dynamometer readings in pounds:

350	400	300	400	300
350	450	300	400	200
300	450	300	400	300
300	350	300	500	400
350	300	200	400	300
400	200	250	400	100
400	300	200	300	200
300	200	150	400	200
350	300	200	400	200
350	100	300	400	300
250	200	200	400	400
250	300	200	200	400
300	200	250	150	350
300	300	350	150	300
300	300	200	100	400
400	350	300	200	350
400	350	250	300	300
450	300	400	400	250
400	300	350	300	27650 Total

294 Aver.

No. 13.

Grade 1.87% rise May 30, 1905.

Kind and condition of grade; well graded dirt

Circumference of wagon wheel (feet) 11.18

Revolutions of wagon wheel 96

Time in minutes 5.5

Distance in feet per minute 195

Average dynamometer readings 454.5 #

Average traction 909 #

Traction H. P. 5.37

Indicated H. P.

Starting load

Observed dynamometer readings in pounds:

400	500
600	500
500	400
300	500
300	500
400	300
500	400
400	300
300	600
400	500
300	200
300	800
500	400
800	500
	12700 Total
	454.5 Average

No. 14.

Grade	1.87%	fall	May 30, 1905.

Kind and condition of grade; well graded dirt

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		63
Time in minutes		2.75
Distance in feet per minute		256
Average dynamometer readings		337.5 #
Average traction		675.0 #
Traction H. P.		5.23
Indicated H. P.		
Starting load		1000 #

Observed dynamometer readings in pounds:

300	350	
400	300	
450	350	
400	300	
1000	350	
200	300	
250	400	
400	300	
500	400	
400	350	
	6750	Total
	337.5	Average

No. 15.

Grade	1.87%	fall	May 30, 1905.

Kind and condition of grade; well graded dirt

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		35
Time in minutes		
Distance in feet per minute		
Average dynamometer readings		287 #
Average traction		574 #
Traction H. P.		
Indicated H. P.		
Starting load		800 #

Observed dynamometer readings in pounds:

300	
400	
300	
350	
250	
350	
250	
300	
300	
300	
250	
300	
200	
150	
350	
500	
4600	Total
287	Average

No. 16.

Grade	1.87%	rise	May 30, 1905.
Kind and condition of grade;	well graded	dirt	
Circumference of wagon wheel	(feet)		11.18
Revolutions of wagon wheel			48
Time in minutes			263
Distance in feet per minute			204
Average dynamometer readings			412.5 #
Average traction			825.0 #
Traction H. P.			5.10
Indicated H. P.			21.03
Starting load			1200 #

Observed dynamometer readings in pounds:

400	
350	
550	
500	
400	
450	
400	
450	
300	
400	
350	
350	
400	
400	
400	
500	
6600	Total

No. 17.

Grade	2.78%	rise	May 30, 1905.

Kind and condition of grade; slightly rough, Macadam

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		26
Time in minutes		1.5
Distance in feet per minute		193.8
Average dynamometer readings		486 #
Average traction		972 #
Traction H. P.		5.71
Indicated H. P.		28.21 (?)
Starting load		

Observed dynamometer readings in pounds:

600
200
650
300
450
700
300
900
300
200
600
350
700
350
700
400
600
450

8750 Total

486 Average

No. 18.

Grade 3.65% rise May 30, 1905.

Kind and condition of grades; well graded, a little rough, dirt.

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		83
Time in minutes		4.35
Distance in feet per minute		214
Average dynamometer readings		545
Average traction		1090 #
Traction H. P.		7.07
Indicated H. P.		29.53
Starting load		2000 #

Observed dynamometer readings in pounds:

550	500	400	400
600	600	700	200
400	500	700	400
550	500	600	500
600	400	500	600
400	400	600	500
500	400	550	600
600	500	600	200
500	600	700	200
400	700	600	100
500	800	600	700
450	800	900	700
700	400	700	400
700	500	1000	600
400	500	1000	400
600	500	900	600
500	500	800	700
400	500		1200
			500
			400
			38650 Total
			545 Average

No. 19.

Grade	4.5%	rise	May 30, 1905.

Kind and condition of grade; well graded, hard clay

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		28
Time in minutes		1.534
Distance in feet per minute		204.2
Average dynamometer readings		682.5 #
Average traction		1365.0 #
Traction H. P.		8.44
Indicated H. P.		31.17
Starting load		1400 #

Observed dynamometer readings in pounds:

700	700
600	500
700	600
600	700
700	700
600	700
700	600
800	700
700	700
650	600
600	700
750	700
800	700
600	700
700	800
800	21100 Total
	682.5 Average

No. 20.

Grade 4.5% rise May 30, 1905.

Kind and condition of grade; well graded, hard clay.

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		28
Time in minutes		1.53
Distance in feet per minute		204.6
Average dynamometer readings		580 #
Average traction		1160 #
Traction H. P.		7.19
Indicated H. P.		34.96
Starting load		

Observed dynamometer readings in pounds:

700	800
600	800
400	800
800	700
700	800
600	700
600	400
800	600
800	550
700	500
	600
	600 %
	12750 Total

No. 21.

Grade	3.51%	rise	May 30, 1905.

Kind and condition of grade; smooth Macadam

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		27
Time in minutes		1.42
Distance in feet per minute		189
Average dynamometer readings		477 #
Average traction		954 #
Traction H. P.		5.461
Indicated H. P.		
Starting load		

Observed dynamometer readings in pounds:

450	
700	
300	
400	
650	
300	
400	
600	
350	
700	
350	
600	
400	
6200	Total

No. 22.

Grade	5.75%	rise	May 29, 1905.

Kind and condition of grade; smooth, Macadam

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		36
Time in minutes		1.87
Distance in feet per minute		215.7
Average dynamometer readings		478 #
Average traction		956 #
Traction H. P.		6.25
Indicated H. P.		35.12
Starting load		1800 #

Observed dynamometer readings in pounds:

400	500	
400	500	
500	450	
500	400	
600	400	
600	500	
600	450	
500	450	
600	450	
600	450	
600	500	
600	400	
500	400	
550	500	
500	500	
550	500	
500	500	
500	500	
600	500	
	550	
	19650	Total
	478	Average

No. 23.

Grade	5.75%	rise	May 30, 1905.

Kind and condition of grades; smooth, Macadam

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		41
Time in minutes		2.12
Distance in feet per minute		216.2
Average dynamometer readings		510 #
Average traction		1020 #
Traction H. P.		6.68
Indicated H. P.		
Starting load		

Observed dynamometer readings in pounds:

300	600	
400	600	
500	600	
500	500	
600	550	
500	500	
500	450	
500	500	
400	500	
600	12 750	Total
700		
300	510	Average
600		
500		
550		
500		

No. 24.

Grade 6.144% rise May 30, 1905.

Kind and condition of grade; ungraded, stony, dirt

Circumference of wagon wheel	(feet)	11.18
Revolutions of wagon wheel		34
Time in minutes		1.83
Distance in feet per minute		208
Average dynamometer readings		613 #
Average traction		1226 #
Traction H. P.		7.723
Indicated H. P.		43.79
Starting load		

Observed dynamometer readings in pounds:

900	500
600	600
500	500
800	500
900	400
600	400
700	500
700	600
600	500
700	600
700	500
800	600
600	16500 Total
600	
600	

TRACTION TESTS ON AVERY ENGINE No. 2116.

WEIGHT OF LOAD; GROSS 8000.
NET 6000.

JUNE 19 AND 20 – '05.

STARTING PULL.	DURATON OF PULL MINUTES	DISTANCE. FEET PER MIN.	AV. READING DYNAMOMETER.	GRADE PER CENT.	TRACTION H.P.	I.H.P.	EFF. %	REMARKS.
1400 #s.	3.87	208	339	0.25 f	4.27	19.25	22.18	f = FALL IN GRADE
1100 ..	5.75	211.9	432	0.253 f	5.55	17.83	31.13	R = RISE .. ..
1600 ..	2.25	199.5	495	0.29 f	5.98	—		AVERAGE READING OF DYNAMOMETER = ONE HALF AVERAGE TRACTION PULL.
—	—	—	296	0.34 R	—	—		
1200 ..	3.75	211.7	344	0.355 f	4.40	19.58	22.47	
—	3.75	206	378.3	0.355 R	4.73	25.25	18.73	
—	1.60	216.4	309.5	0.46 R	4.07	—	1	
—	2.66	214.3	175	0.462 f	2.27	13.56	16.74	
900 ..	1.92	216.	305	0.462 R	3.99	17.69	22.57	
1000 ..	5.25	215.1	326.2	1.87 R	4.25	20.404	20.83	
—	5.00	208.	372.	1.87 R	4.69	24.57	19 08	
1500 ..	6.22	214.	294.	1.87 f	3.81	18.34	20.78	
—	5.50	195.	454.5	1.87 R	5.37	—		
1000 ..	2.75	256.	337.5	1.87	5.23	—		
800 ..	—	—	287.	1.87 f	—	—		
1200 ..	2.63	204	412.5	1.87 R	5.10	21.03	24.25	
—	1.50	193.8	486	2.78 R	5.71	28.2	20.25	
2000 ..	4.35	214.	545	3.65 R	7.07	29.53	23.94	
1400 ..	1.53	204.2	682.5	4.50 R	8.44	33.17	25.45	
—	1.53	204.6	580.	4.50 R	7.19	34.96	20.57	
—	1.42	189.	477.	3.51 R	5.46	—		
1800 ..	1.87	215.7	478.	5.75 R	6.25	35.12	17.80	
—	2.12	216.2	510.	5.75 R	6.68	—		
—	1.83	208.	613.	6.14 R	7.72	43.79	17.63	

The Evaporative Test of the Boiler.

The purpose of this test as set forth was to determine the evaporation power of the boiler when fired with Lansing coal from the Kansas Penitentiary. This coal has a calorific power of 11,329 B. T. U. and 0.55% of water as determined under the direction of the chemical department of K. S. A. C. (See thesis by S. S. Fay, 1905.)

The instruments used in this work were those used in the tests for mechanical efficiency of the engine together with

- Standard thermometers
- A Barrus calorimeter
- Scales for weighing fuel and water
- A Crosby lever revolution counter

A running start was made. The test when conditions of water and fire were as nearly those at the start as could be attained.

The quality of the steam was determined by means of a Barrus throttling calorimeter, connected as per instructions (See Trans. of A. S. M. E., Vol. Xl. page 795 and C. H. Benjamin's Mechanical Laboratory Practice, page 48)

Normal readings of lower thermometer	285.4
Average reading lower thermometer	248.75
Degrees of cooling	36.65

$$X = \frac{\text{Degrees cooling}}{\text{Coefficient}} = \frac{36.65}{20.815} = 1.761 = \%\ \text{moisture}$$

$$100 - 1.761 = 98.239\%\ \text{of steam}$$

$$X = .9824$$

The equivalent of water apparently evaporated from and at

212° F is

$$e = \frac{w(r + q - q_2)}{965.8} = 6731.8$$

The equivalent of water actually evaporated from and at 212° F is

$$e = \frac{w(rx + q - q_2)}{r_{212° F}} =$$

w = weight of feed water = 5625 #

r = heat of vaporization at average boiler pressure = 870.55

q = heat of liquid " " " 316.80

q_2 = " feed water 31.62

$r_{212° F}$ = heat of evaporation at 212° F 965.8

x = quality of steam .9824

$$e = \frac{5625 (870.55 \times .9824 + 316.80 - 31.62)}{965.8}$$

= 6654

Equivalent water evaporated per hour from and at 210° F. = 737.4

Conclusions drawn from observation and data with respect to the evaporation power of the Avery Boiler.

(1) The grate area is insufficient for the size of the engine unless a superior quality of coal is used as fuel.

(2) The boiler is apt to foam and prime when the engine is working hard.

(3) The boiler must be kept free from sediment by washing when cold; blowing out does no good except immediately around the bloww-off opening.

(4) The steam pipe could be straight and better guarded against priming.

DATA AND RESULTS OF EVAPORATIVE TESTS.

Arranged in accordance with the short form advised by the boiler test committee of the American Society of Mechanical Engineers.

Grate surface	4.06	SQ. FT.
Water heating surface	104.	
Ratio of grate to water heating surface	1. TO	26.6
Kind of fuel: Kansas Penitentiary Coal		
TOTAL QUANTITIES.		
1. Date of trial	June 1,	1905.
2. Duration of trial in hours	9	
3. Weight of coal fired	1087.5	
4. Per cent of water in coal	.55	
5. Total weight of coal consumed, in pounds	940.	
6. Total ash and refuse	173.5	
7. Percentage ash and refuse in coal	15.95	
8. Total weight of water fed to boiler	5625.	
9. Condition of steam	.9840	
10. Equivalent water apparently evaporated from and at 212° F.	6731.8	
11. Equivalent water actually evaporated from and at 212° (corrected for moisture in steam)	6654.	
HOURLY QUANTITIES.		
12. Pounds coal consumed per hour	104.44	
13. Coal per hour per square foot of grate surface	25.73	
14. Pounds feed water per hour	625.	
15. Equivalent water evaporated per hour from and at 212° F. (corrected for moisture in steam)	737.4	
16. Equivalent water evaporated per square foot of heating surface per hour	7.19	
AVERAGE BOILER PRESSURES, TEMPERATURES, ETC.		
17. Average boiler pressure, pounds per square inch, gage	112.4	
18. Average boiler pressure, pounds per square inch, absolute	126.6	
19. Average temperature of feed water, Fahrenheit	63.5	
20. Average temperature of boiler room, Fahrenheit	79.8	
21. Average temperature of outside air, Fahrenheit	80.96	
22. Barometer	14.2	
HORSE-POWER.		
23. Horse-power developed	21.39	
24. Builders' rated horse-power		
25. Percentage of builders' rated horse-power		
ECONOMIC RESULTS.		
26. Water apparently evaporated per pound of coal under actual conditions	5.17	
27. Equivalent water actually evaporated from and at 212° F., per pound of coal fired	6.107	
28. Equivalent evaporation from and at 212° F., per pound of dry coal		
29. Equivalent evaporation from and at 212° F., per pound of combustible	7.06	

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

LOG OF BOILER TRIAL.

TEST MADE AT K. S. A. C.

ON AVERY TRACTION ENGINE

DATE JUNE 1, 1905.

OBSERVERS:

Time.	Pressures.		Temperatures, ~~F.~~ °C.				Weights.									Remarks.
							Coal.			Cinders.			Water.			
	Barometer.	Steam Gage. LBS.	External Air. °C	Boiler Room. °C	Feed Water. °C	Flue Gases.	Gross.	Tare.	Net.	Gross.	Tare.	Net.	Gross.	Tare.	Net.	
8-20 A.M.		106.5			20.		196.	83.	113.				505.	71.5	433.5	Shut down on account of Brake, at 8-56
8-30		112.5			17.								481.	62.5	418.5	Started at 8-59
8-40	28.865" =	115.			17.		197.	78.	119.				482.5	103.	379.5	
8-50	14.20 LBS.	110.5			17.		202.	79.	123.				483.	93.	390.	Shut down at 9-29 on account of Brake.
9-00		120.		22.0	17.								493.5	105.	388.5	Started at 9-30.
9-10		113.	22.0	22.5			221.	79.	142.							
9-20		113.	22.5	22.0												
9-31		117.		22.5												Shut down at 10-34.
9-40		115.		23.0												Started at 10-38½
9-50		120.		23.0						97.	77.	20.				Men changed at 11. AM.
10-00		112.5	23.5	23.0	18.								480.	88.	392.0	
10-10		113.		24.												Barometer taken at 8-45 AM.
10-20		113.		24.												
10-30		113.		24.5						97.	77.	20.				
10-40		120.		25.			210.	97.	113.							Barometer taken at 10-50 A.M.
10-50	28.88" =	115.		25.												
11-00	14.20 LBS.	113.		25.5												Boiler Pressure dro at 12-55 P.M.
11-10		120.		26.												
11-20		113.		26.												
11-30		113.		26.									506.	105.	401.	
11-40		118.5		26.	17.											Men changed at 2. P.M
11-50		118.5		26.												
12-00 M.		114.	25.8	26.									396.	83.	313.	
12-10 P.M.		117.		26.	18.											
12-20		118.5		26.												
12-30		115.		26.			180.	77.	103.	93.	77.	16.				
12-40		111.		26.												
12-50		94.	27.0	26.									517.	105.	412.	
1-00		84.		26.5	17.7		200.	83.5	116.5	105.5	77	28.5				
1-10		115.5		27.									399.	84.	315.	
1-20		117.		27.2	17.2											
1-30		120.	28.2	27.2			200.	79.	121.							
1-40		120.	28.3	27.3						92.5	77.	15.5	515.	97.	418.	Barometer taken at 2. P.M.
1-50		119.5		27.5	17.8											
2-00	28.85" =	113.	28.5	27.5												
2-10	14.2 LBS.	115.5		27.8									491.	85.	406.	
2-20		116.	28.5	28.2	17.											
2-30		119.		29.			208.5	77.	131.5	105.5	77.	28.5				
2-40		116.	28.5	29.												
2-50		115.		28.5												
Total,		4694.5														
Average,																

☛ CARRIED TO PLATE No. 2.

No. 2.

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

TEST MADE AT K. S. A. C.

ON AVERY TRACTION ENGINE

DATE JUNE 1 1905

LOG OF BOILER TRIAL.

OBSERVERS:

Time.	Pressures. Barometer.	Pressures. Steam Gage. LBS.	Temperatures, °F °C External Air. °C	Boiler Room. °C	Feed Water. °C	Flue Gases.	Weights. Coal. Gross.	Coal. Tare.	Coal. Net.	Cinders. Gross.	Cinders. Tare.	Cinders. Net.	Water. Gross.	Water. Tare.	Water. Net.	Remarks.
3-00 P.M.		122		28.	17.2					96.	77.	19.	514.	102	412	
3-10		118.5		28												
3-20		116.	28.5	28.8												
3-30		118.5		28.5												
3-40		117.		29.												
3-50		115.		29.												BAROMETER TAKEN
4-00	28.95" =	115.		28.5												AT 4 P.M.
4-10	14.25 LBS.	113.		29.												
4-20		115.	30.	29.			213.5									
4-30		118.5		29.												
4-40		110.		29.						ROCK & SLATE						
4-50		111.		29.						103	77	26		23.	39.2	
5-00		111.	29.8	28.5												
5-10		110.		28.						112	77	35		105	154	
5-20		105.5	30.	29.												
									125 — COAL WEIGHED BACK							
TOTAL SHEET #1		4694.5	262.8	924.7	210.7											
" " #2		1809.5	118.3	430.3	17.2											
TOTAL FOR TEST		6504.0	381.1	1355.0	227.9											
Total,	56.85	6504.0	381.1	1355.0	227.9		2028	815.5	1212.5	686.5		147.5	6982	1357	5625	
Average.	14.21	118.2	27.2	26.57	17.5											

TOTAL COAL = 2028
ROCK & SLATE = 26
GROSS TOTAL = 2054

TOTAL COAL = 1212.5
COAL WEIGHED BACK = 125.
NET TOTAL = 1087.5

NET CINDER = 147.5
ROCK & SLATE = 26.
TOTAL CINDERS = 173.5

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

LOG OF ENGINE TRIAL.

TEST MADE AT K. S. A. C.

ON AVERY TRACTION ENGINE

DATE MAY 8, 1905.

CONSTANTS OF ENGINE.

Diameter of cylinder.... 8.75 in.
Diameter of piston rod.. 1.375 in.
Length of stroke........ .834 ft.
CUT OFF 36.6%

Area of piston H. E...... 60.132 sq. in.
Area of piston C. E...... 58.647 sq. in.
Engine constant for H. E., .000152
Engine constant for C. E., .0001482

OBSERVERS:

No. Card.		Time.	R. P. M.	M. E. P.		I. H. P.			Brake Load (Dynamo).		B. H. P.	Remarks.	
				H. E.	C. E.	H. E.	C. E.	Total.	Volts.	Amperes.		EFF.	
1			258	6.53	7.9	2.56	3.02	5.58			3.44	61.6%	
2	a.		256	10.22	10.15	3.98	3.85	7.84			5.94	75.8%	
	b.		256	9.8	10.15	3.92	3.96						
3	a.							11.23			8.67	77.2%	NO CARDS
	b.		263	14.33	14.1	5.73	5.50						
4	a.		257	17.91	18.69	7.42	7.12	14.41			11.04	76.6%	
	b.		257	18.12	18.91	7.08	7.20						
5	a.		253	21.08	22.96	8.11	8.61	16.56			13.37	80.7%	
	b.		253	21.71	21.47	8.35	8.05						
6	a.		260	26.34	27.66	10.41	10.66	20.405			16.31	79.8%	
	b.		260	24.76	25.84	9.78	9.96						
7	a.		264	29.93	31.30	12.01	12.24	24.035			19.17	79.7%	
	b.		264	29.18	30.87	11.72	12.09						
8	a.		267	33.30	34.50	13.51	13.65	26.97			22.02	81.7%	
	b.		267	33.30	33.54	13.51	13.27						
9	a.		265	34.98	36.31	14.09	14.26	28.755			24.47	85.1%	
	b.		265	35.95	37.38	14.48	14.68						
		Maximum,											
		Minimum,											
		Total,											
		Average,											

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

LOG OF ENGINE TRIAL.

TEST MADE AT K. S. A. C.

ON AVERY TRACTION ENGINE.

DATE MAY 15, 1905.

CONSTANTS OF ENGINE.

Diameter of cylinder.... 8.75 in.
Diameter of piston rod.. 1.375 in.
Length of stroke .... .834 ft.
CUT OFF 59.7 %

Area of piston H. E...... 60.132 sq. in.
Area of piston C. E...... 58.647 sq. in.
Engine constant for H. E., .000152
Engine constant for C. E., .0001482

OBSERVERS:

No. Card.	Time.	R. P. M.	M. E. P.		I. H. P.			Brake Load (Dynamo).		B. H. P.	Remarks.	
			H. E.	C. E.	H. E.	C. E.	Total.	Volts.	Amperes.		EFF. %	
1 a		249	4.53	5.13	1.714	1.89	3.52			.86	24.4	
b		249	3.79	5.45	1.43	2.01						
2 a		248	8.43	7.37	3.18	2.71	5.51			3.31	60.00	
b		"	6.95	6.84	2.62	2.51						
3 a		"	12.65	13.34	4.77	4.90	9.27			5.76	62.1	
b		"	11.07	12.82	4.17	4.71						
4 a		247	13.49	14.31	5.06	5.24	10.69			8.18	76.5	
b		"	14.86	15.06	5.58	5.51						
5 a		"	18.34	18.37	6.88	6.72	13.54			10.62	78.4	
b		"	18.23	18.05	6.84	6.65						
6 a		"	23.50	23.50	8.82	8.62	17.24			13.32	77.2	Second Notch
b		"	22.55	23.4	8.47	8.57						
7 a		"	25.18	25.63	9.45	9.38	18.83			15.50	82.25	
b		"	25.08	25.74	9.42	9.42						
8 a		248	28.76	29.59	10.84	10.88	21.50			18.01	83.67	
b		"	28.87	28.31	10.88	10.41						
9 a		250	30.87	31.00	11.73	11.48	23.76			20.63	86.82	
b		"	32.56	32.26	12.37	11.95						
10 a		254	36.77	36.32	14.20	13.67	27.87			23.47	84.25	
b		"	36.78	36.32	14.20	13.67						
11 a		255	39.73	39.1	15.01	14.78	30.48			26.08	85.48	
b		"	40.37	40.04	15.65	15.52						
12 a		256	38.36	41.66	14.93	15.80	31.67			28.71	90.64	
b		"	40.68	44.22	15.83	16.78						
	Maximum,											
	Minimum,											
	Total,											
	Average,											

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

LOG OF ENGINE TRIAL.

TEST MADE AT K. S. A. C.

ON AVERY TRACTION ENGINE

DATE MAY 15, 1905

CONSTANTS OF ENGINE.

Diameter of cylinder.... 8.75 in.
Diameter of piston rod.. 1.375 in.
Length of stroke .... .834 ft.
CUT OFF 67.4%

Area of piston H. E...... 60.132 sq. in.
Area of piston C. E...... 58.647 sq. in.
Engine constant for H. E., .0001.52
Engine constant for C. E., .0001482

OBSERVERS:

No. Card.		Time.	R. P. M.	M. E. P.		I. H. P.			Brake Load (Dynamo).		B. H. P.	Remarks.
				H. E.	C. E.	H. E.	C. E.	Total.	Volts.	Amperes.		EFF. %
1	a		251	5.69	7.16	2.17	2.16	5.04			2.85	56.6
	b		"	6.95	8.33	2.65	3.10					
2	a		252	10.54	12.28	4.04	4.59	8.45			5.35	63.3
	b		"	10.64	11.21	4.08	4.19					
3	a		246	14.01	15.06	5.23	5.49	11.01			7.66	69.6
	b		"	15.39	15.27	5.75	5.56					
4	a		247	17.07	16.45	6.41	6.02	12.57			10.13	80.5
	b		"	16.97	17.30	6.37	6.34					
5	a		254	24.87	23.50	9.60	8.85	17.53			12.93	73.8
	b		"	22.13	21.47	8.54	8.08					
6	a		251	24.03	23.92	9.17	8.89	19.02			15.25	80.2
	b		"	27.77	26.27	10.21	9.77					
7	a		248	30.88	30.33	11.64	11.15	22.15			17.50	79.0
	b		"	29.19	28.62	11.00	10.52					
8	a		253	33.41	33.32	12.85	12.49	24.45			20.37	83.3
	b		"	31.30	30.76	12.04	11.53					
9	a		250	35.51	23.96	13.49	12.58	26.95			22.60	83.9
	b		"	37.72	36.42	14.33	13.50					
10	a		247	38.57	38.66	14.48	14.16	29.10			24.77	85.1
	b		"	40.15	39.62	15.07	14.50					
		Maximum,										
		Minimum,										
		Total,										
		Average,										

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

MADE AT K. S. A. C.
ON AVERY TRACTION ENGINE
DATE JUNE 1, 1905
BAROMETER 28.88 IN 14.20 LBS.

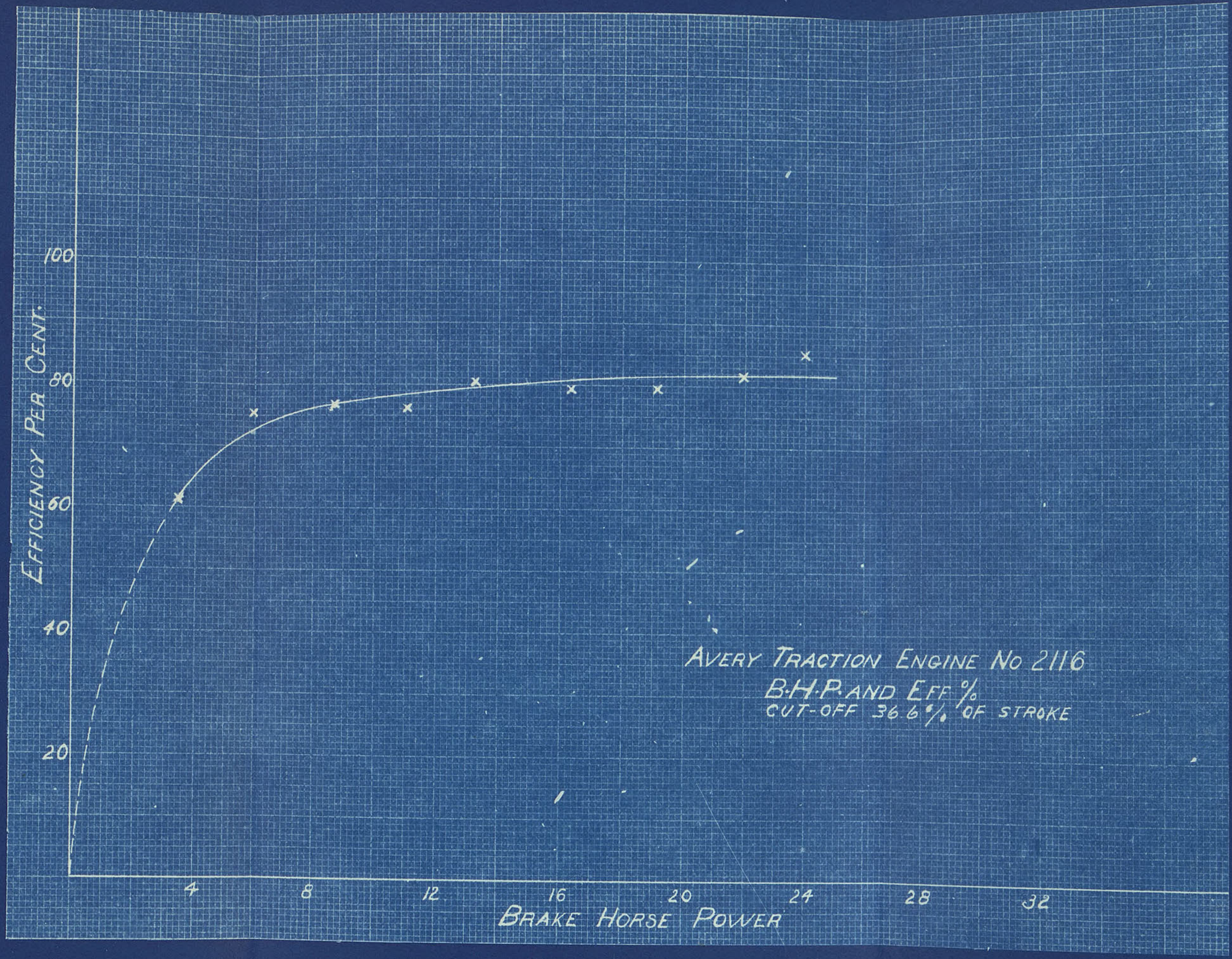
PRIMING LOG.

BARRUS THROTTLING CALORIMETER.

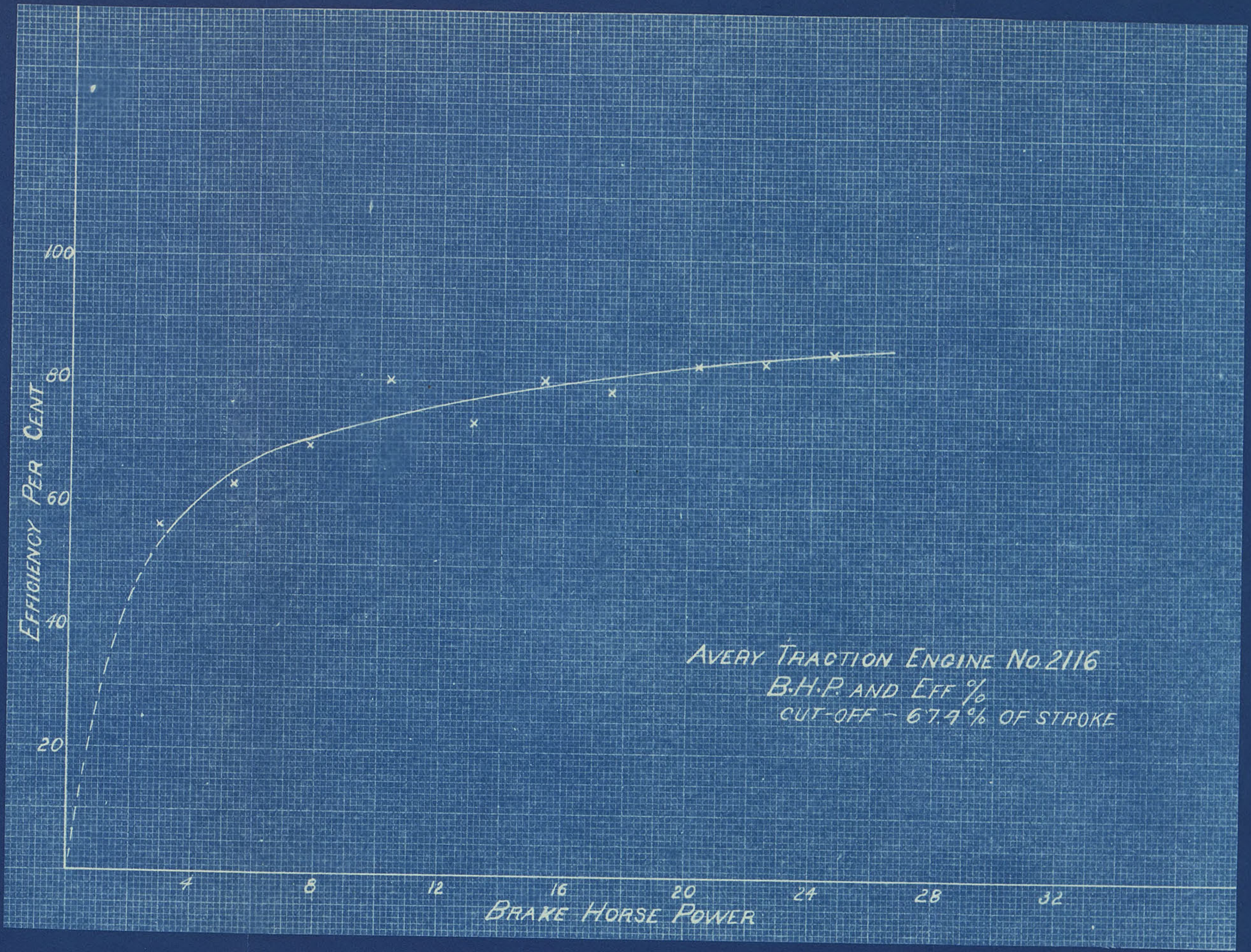
OBSERVERS:

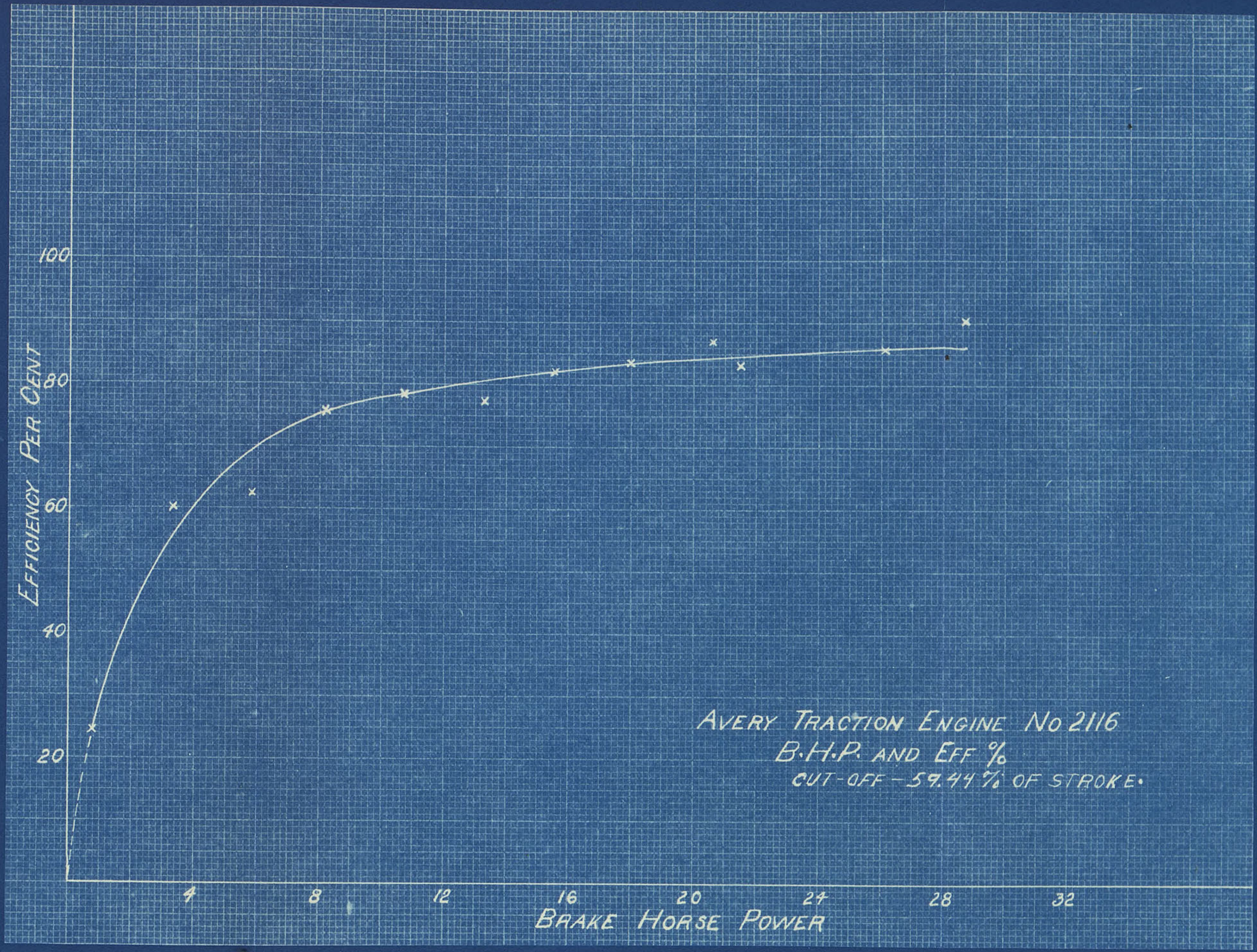
No.	Time.	Pressure in Steam Pipe.		Heat of Liquid. q	Heat of Vaporization. r	Calorimeter Pressure.		Total Heat. λ_1	Temperature Calorimeter.		~~Degree of Superheat.~~ $t_2 - t_1$ FINAL TEMP FAHRENHEIT	Quality of Steam. x	Remarks.
	P.M	Gage.	Abs. p			Gage.	Abs. p		Corresponding to Pressure p_1 t_1 INITIAL °C	By Thermometer. t_2			
	3-30	118.5							338		248		
	3-40	117.0							342		248		
	3-50	115.0							338		250		
	4-00	115.0							339		249		
	4-10	113.0							339		250		
	4-20	115.0							340		248		
	4-30	118.5							340		248		
	4-40	110.0							339		248		
	4-50	111.0							338		248		
	5-00	111.0							340		248		
	5-10	111.0							338		250		
	5-20	105.5							337		250		
	TOTAL	1359.5						TOTAL	4068		2985		
	AVERAGE	113.3						AVERAGE	339		248.75		

123456

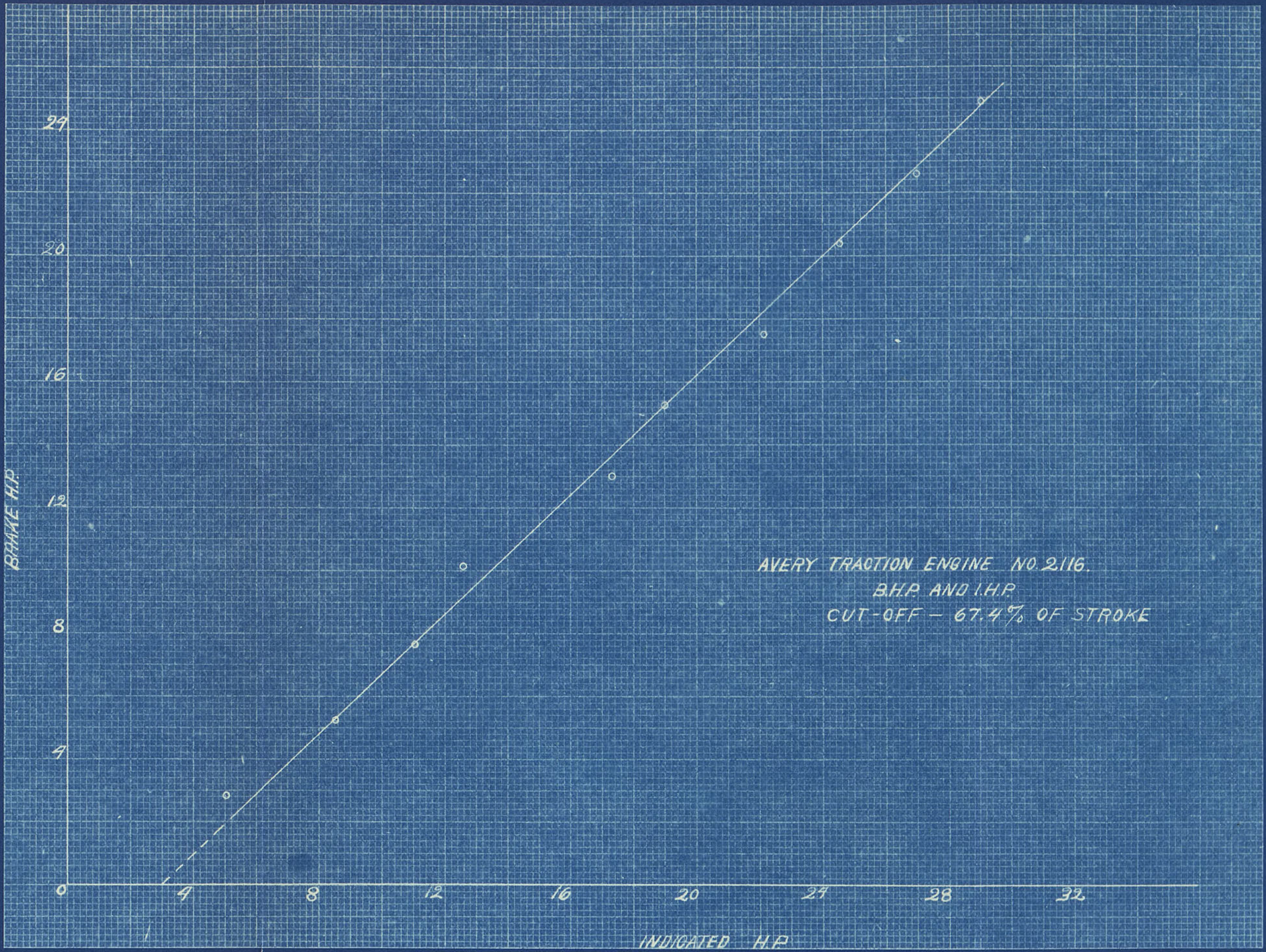


EFFICIENCY PER CENT.
100
80
60
40
20
4
8
12
16
20
24
28
32
BRAKE HORSE POWER
AVERY TRACTION ENGINE No 2116
B.H.P. AND EFF %
CUT-OFF 36.6 % OF STROKE

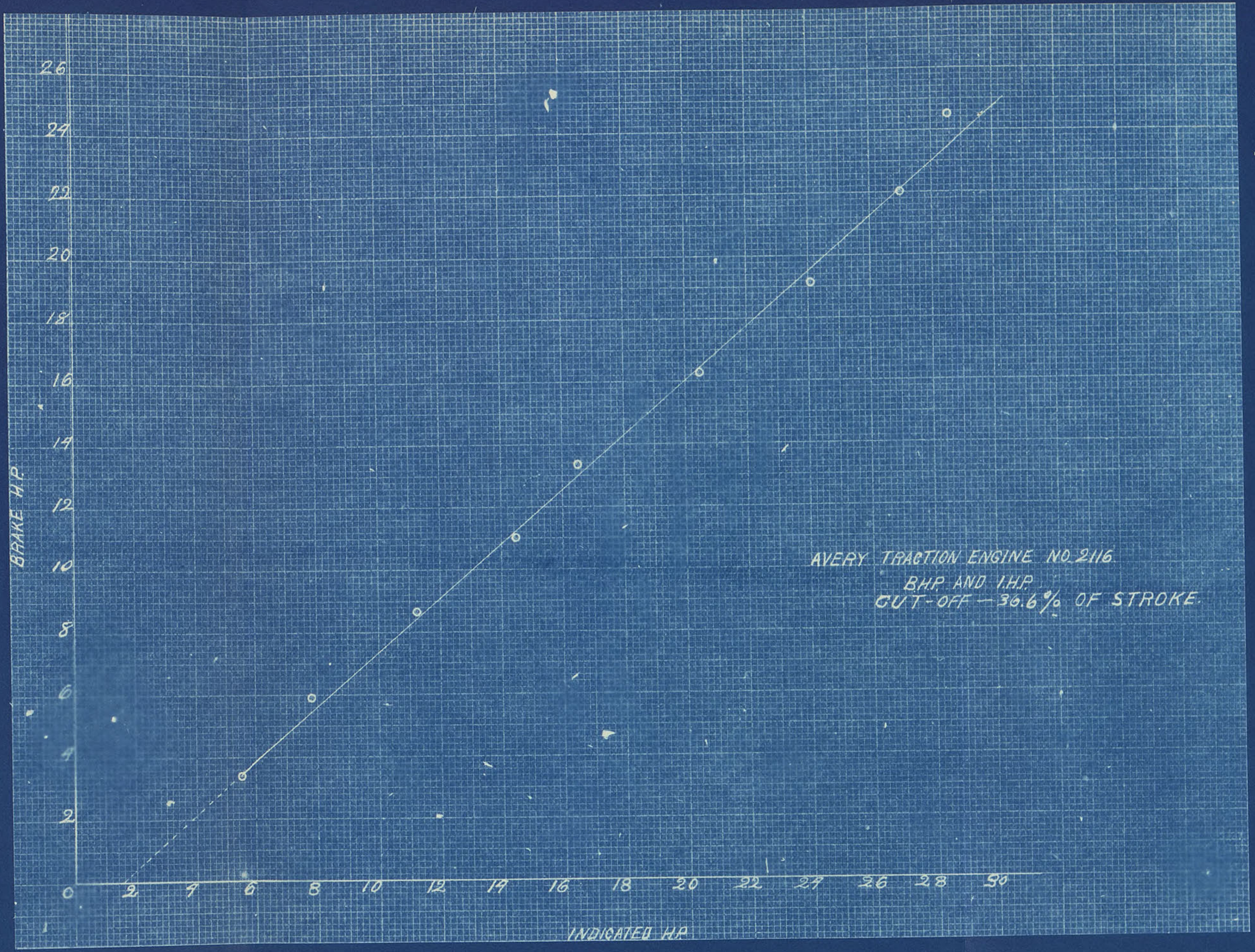

AVERY TRACTION ENGINE NO. 2116
B.H.P. AND EFF %
CUT-OFF - 67.9% OF STROKE
EFFICIENCY PER CENT
100
80
60
40
20
4
8
12
16
20
24
28
32
BRAKE HORSE POWER



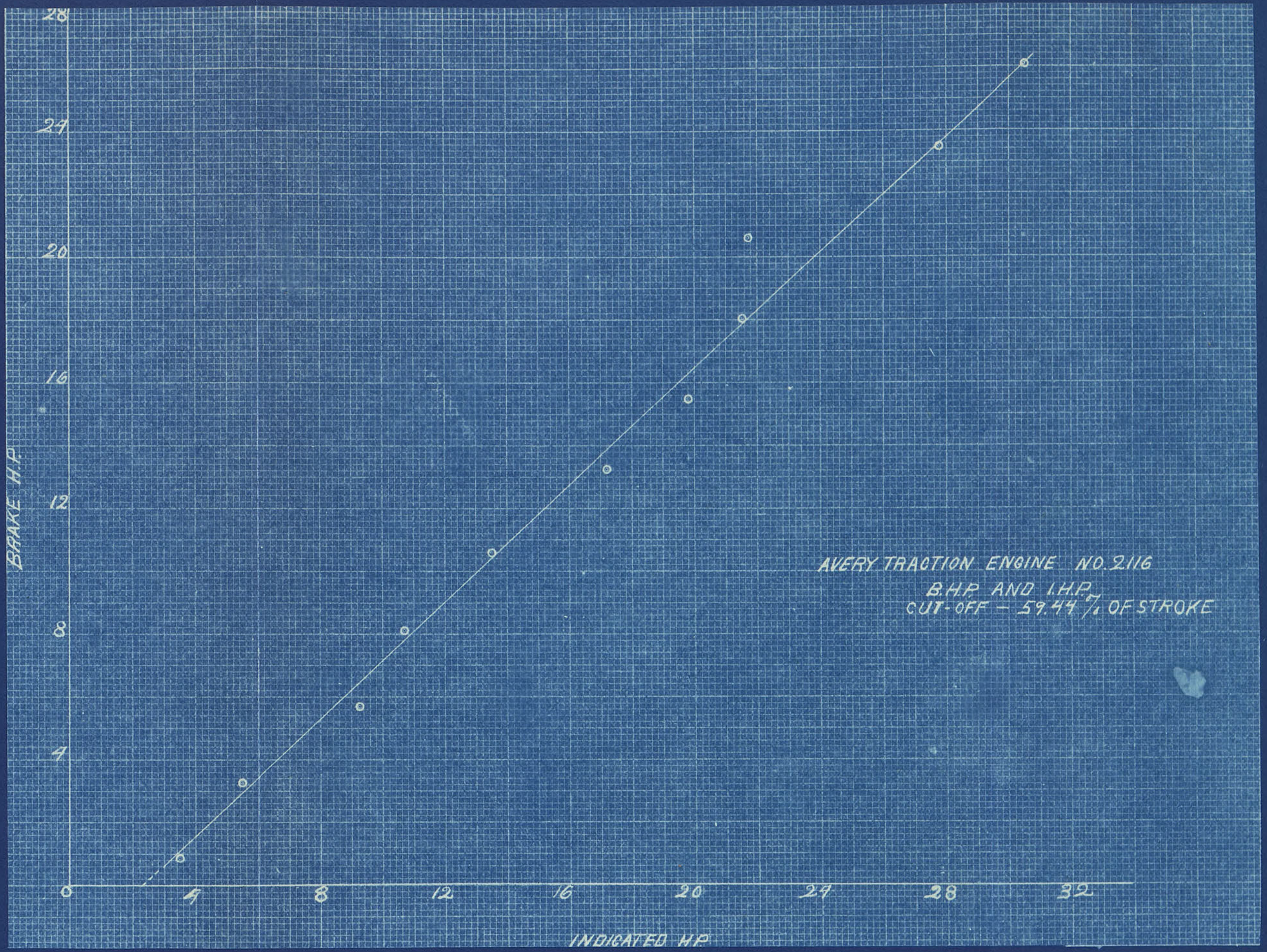
AVERY TRACTION ENGINE NO 2116
B.H.P. AND EFF %
CUT-OFF - 59.44 % OF STROKE.
EFFICIENCY PER CENT
100
80
60
40
20
4
8
12
16
20
24
28
32
BRAKE HORSE POWER

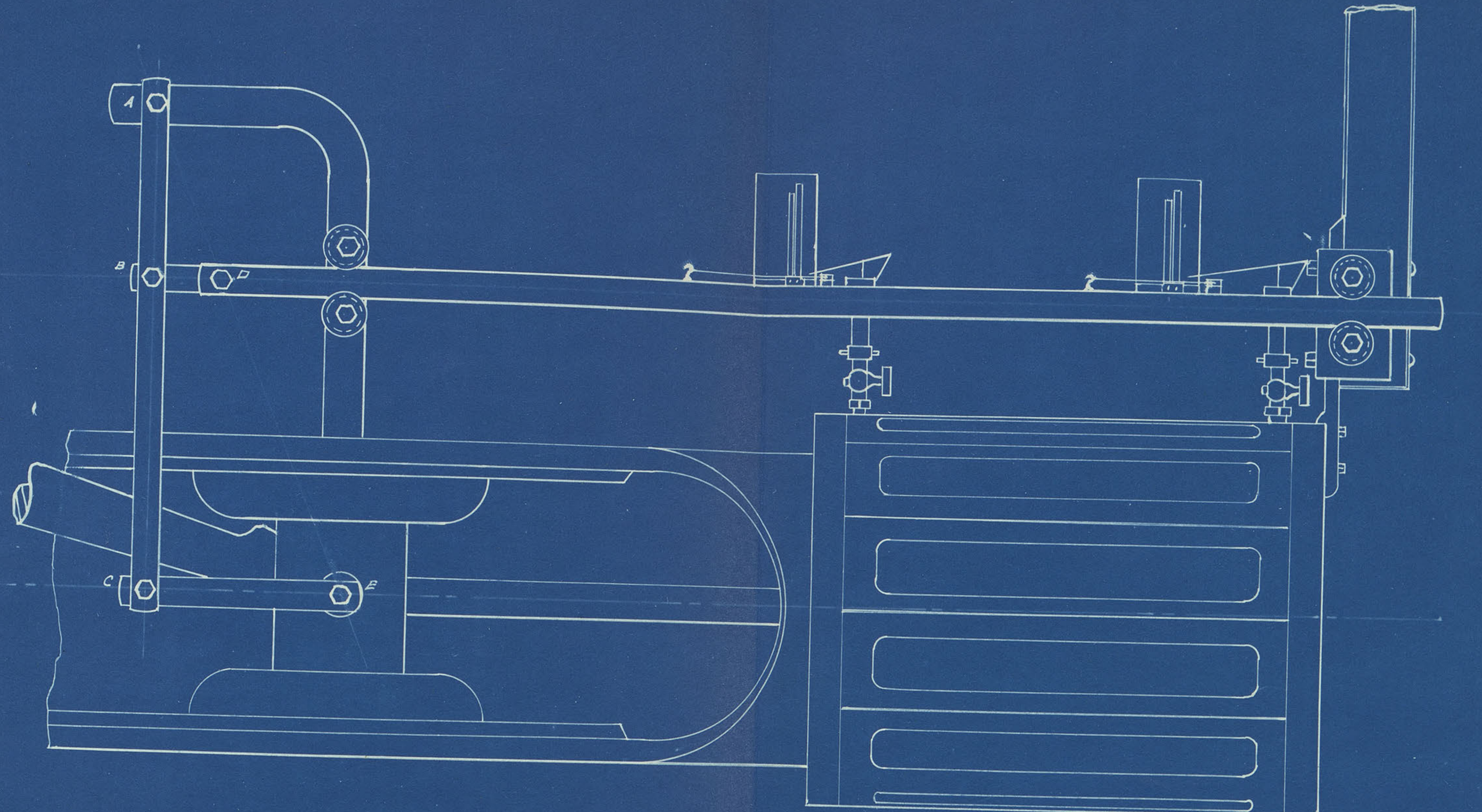


AVERY TRACTION ENGINE NO. 2116.
B.H.P. AND I.H.P.
CUT-OFF — 67.4% OF STROKE
BRAKE H.P.
INDICATED H.P.
0
4
8
12
16
20
24
28
32



AVERY TRACTION ENGINE NO. 2116
B.H.P. AND I.H.P.
CUT-OFF — 36.6% OF STROKE
BRAKE H.P.
INDICATED H.P.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30


AVERY TRACTION ENGINE NO. 2116
B.H.P. AND I.H.P.
CUT-OFF - 59.44 % OF STROKE
BRAKE H.P.
INDICATED H.P.
0
4
8
12
16
20
24
28
32



REDUCING MOTION
FOR
AVERY TRACTION ENGINE
№ 2116.

SCALE: $\frac{1}{4}'' = 1''$

The Valve Gear.

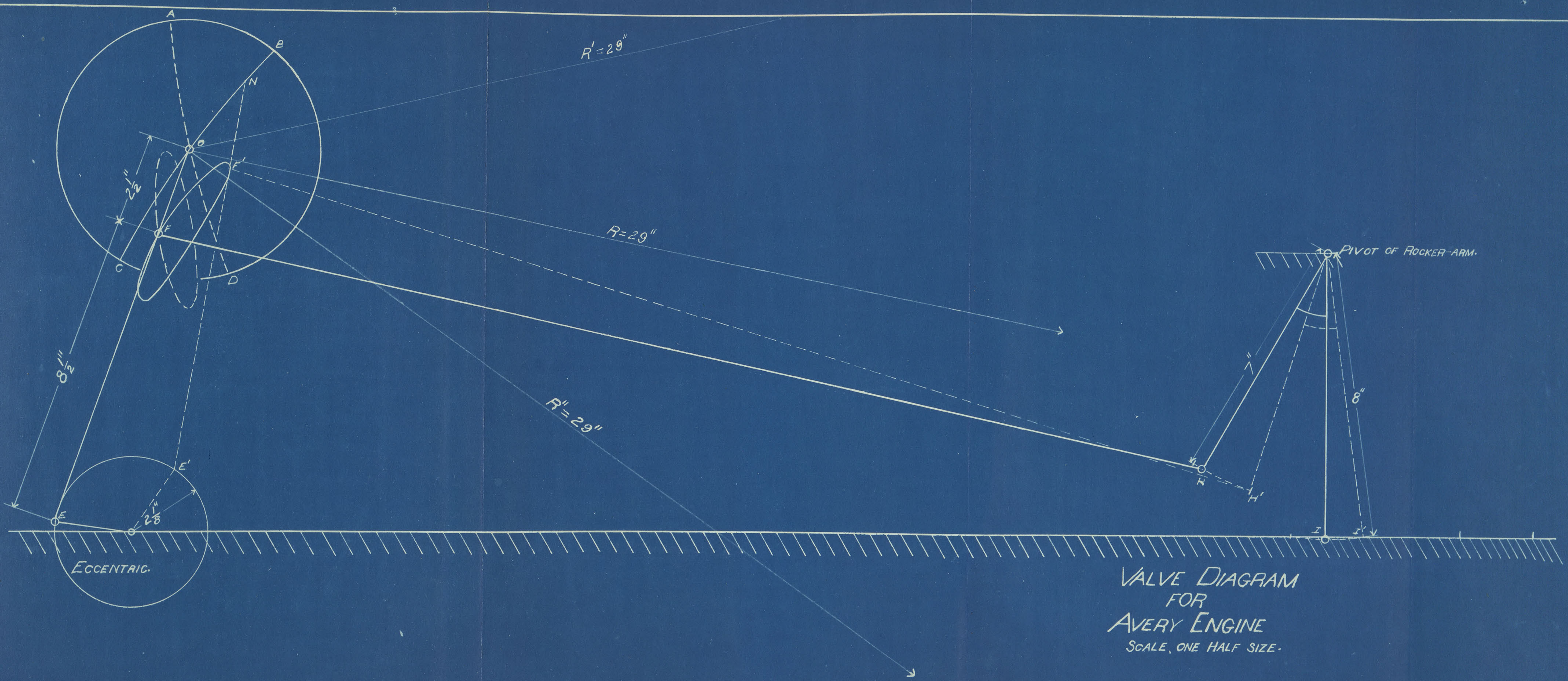
The proper working of the valve is the most important part of the steam engine. The admission, cut off and release of the steam, all depend upon this mechanism, and for an engine to attain the highest efficiency possible it is necessary that these various events take place at the proper time and also that the various parts move with as little friction as possible.

The valve gear on the Avery No. 2116 is a modification of the Hackworth and the Spangler gears. It is provided with a sliding block which travels in the arc B C (see diagram) the locus of its center point. This arc has a radius of 29 inches. The block is driven by a short eccentric represented by the line O E to which the valve connecting rod is attached at F, 2-1/2 inches below center of the block.

The locus of the point F is an ellipse. The travel of the valve for forward motion of the engine is represented by the ellipse F F'. Thus the travel of the valve and consequently the events of the stroke depend largely upon the inclination of the ellipse. The engine is reversed by tilting the block arc from B C to A D, the new position being represented by the dotted ellipse. The valve rod is connected with the valve stem through the rocker arm H I. The gear is strong and may be readily adjusted to any desired length of cut off. The notches are so placed in the quadrant that the range of cuttoff is between 36.6% and 67.4% of the stroke.

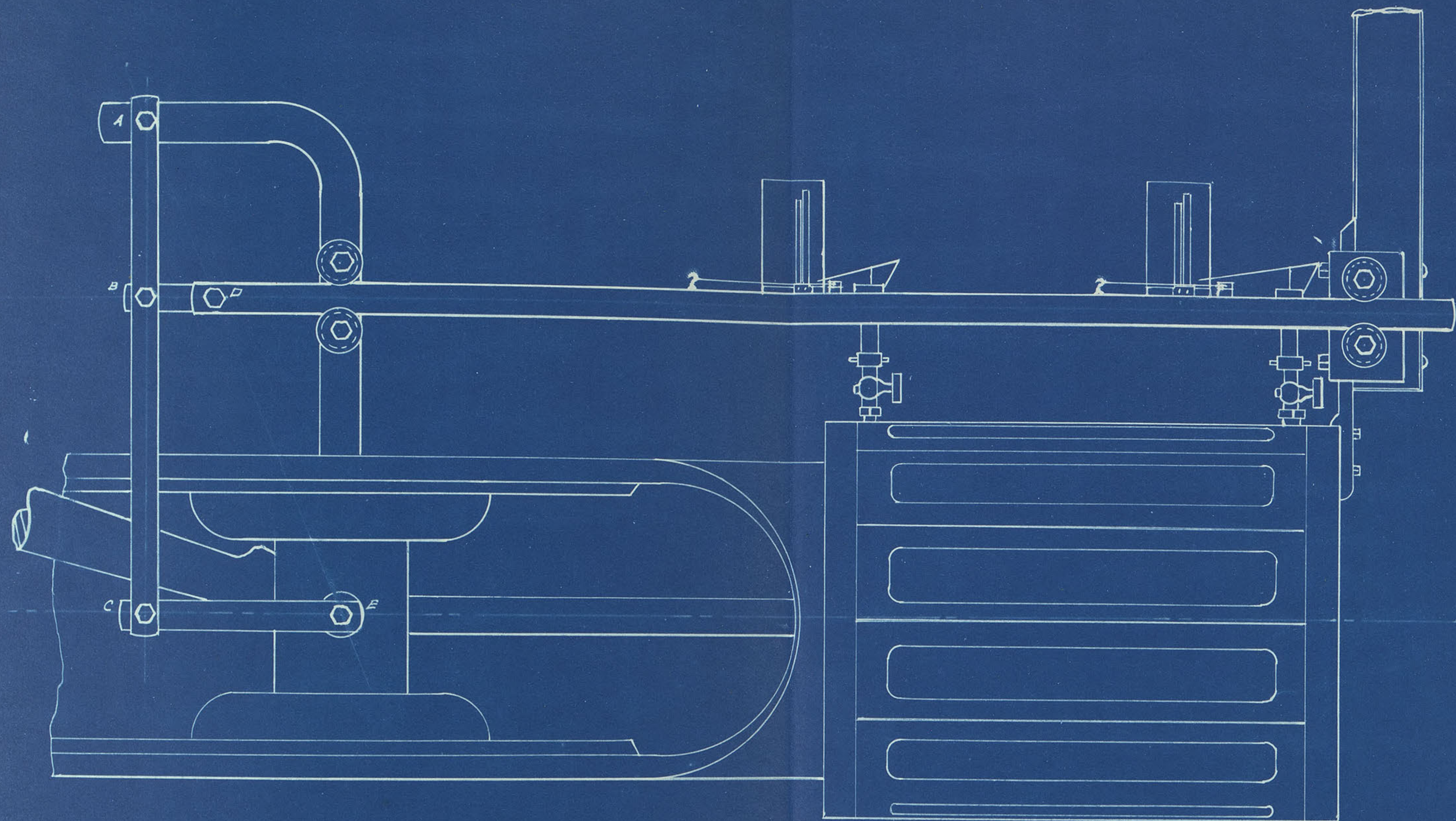
The general appearance of the indicator diagrams shows a low initial pressure and a severe throttling effect, due to the throttling governor. Special pains were taken to set the valve at equal lead forward and reverse. This proved practically nothing as shown by the diagrams which declare a late admission for both head and crank ends. Release on all the cards is shown a little early and compression a little late for the speed used. The point of cut off seems a little indistinct, though with the throttling of the steam there could be no marked point.

No positive conclusions can be drawn from the accompanying valve motion diagram since the measurements were taken from the assembled engine and are therefore rough.



VALVE DIAGRAM
FOR
AVERY ENGINE

SCALE, ONE HALF SIZE.



REDUCING MOTION
FOR
AVERY TRACTION ENGINE
Nº 2116.
SCALE: ¼" = 1"