EFFICIENCY TESTS OF AN AIR COMPRESSING PLANT.

by

WILLIAM TURNBULL

&

WENDELL P. TERRELL.

EFFICIENCY TESTS OF AN AIR COMPRESSING PLANT.

The air compressor plant tested is a part of the equipment of the Mechanical Engineering Laboratory at the Kansas State Agricultural College. It consists of a vertical steam engine, an air compressor, an air receiver, and a Westinghouse steam engine used as an air motor. The arrangement of the plant is shown in the accompanying scheme.

The vertical steam engine is supposed to develop about ten horse power when running at two hundred fifty recolutions per minute. The diameter of its piston is six inches, and its stroke is eight inches. The diameter of the piston rod is one and one-eighth inches.

The engine receives steam from a two and one-half inch pipe, which is connected to the steam main. The steam before reaching the engine passes through a steam separator.

The condition of the steam was about .995. The engine exhausted into the air.

The air compressor is of the Ingersoll-Sergeant make. The diameter of its piston is eight inches, and its stroke is eight inches. The diameter of its piston rod is one and three-eighths inches. The compressor is driven by the steam engine with a two ply leather belt.

The Westinghouse steam engine which was used as an air motor consists of two vertical, single acting cylinders. The diameter of the pistons are five inches, and their stroke six inches. The cranks are one hundred and eighty degrees apart.

The air from the air compressor is delivered into a two and one half inch pipe, which leads to the receiver, whose capacity is eighteen and eighty-five hundredths cubic feet. From the compressor to the receiver the pipe is fifteen feet long. From the receiver to the motor the air passes through twenty-eight feet of two and one-half inch pipe and thirty-three feet of two inch pipe. Making in all fifteen feet of pipe from the compressor to receiver, and about sixty-one feet from the receiver to the motor.

The purpose of the test was to find the efficiency of the plant, and that of the compressor and engine. In order to obtain these efficiencies it was necessary to find the indicated horse power of the engine and compressor and the brake horse power of the air motor. The other readings or observations taken were: the number of revolutions of the engine, compressor, and motor; the temperature of the entering and leaving cooling water; the temperature of the air at admission and also after being discharged into the delivery pipe; the weight of the cooling water; the gauge pressure of the steam and of the air in the receiver; and the scale readings of the spring balance on the rope brake.

The indicated horse power of the engine is the sum of the horse power found from the cards for the head and the crank end of the cylinder. These horse powers were found by the following formula:

For the head end:--

$$1\ HP = \frac{R.\ P.\ M. \times M.\ E.\ P. \times \text{Area of piston sq. in} \times \text{length of stroke in ft.}}{33000}$$

For the crank end:-

$$1\ HP = \frac{R.P.M. \times M.E.P. \times \text{Area of piston sq. in} \times \text{length of stroke in ft.} - \text{Area of piston rod in sq. in.}}{33000}$$

The indicated horse power of the compressor was worked up in the same way. A rope brake was used to find the brake horse power of the motor. One end of the brake was attached to a spring balance which was suspended from a beam by a rope. The brake passed around the pulley once and weights were hung on the other end. The brake was so placed that the pulley in revolving would tend to lift the weights. The bearing surface of the pulley was cooled by the exhaust from the motor. The brake horse power was obtained in the following way:

Let W.= Work of the revolving wheel.

W =Weight on the brake.

W2= Scale reading of the spring balance with a load on.

W3= Scale reading when the motor is running empty.

P = Unbalanced force.

V = Velocity of wheel in feet per minute.

R = Radius of the wheel plus the radius of the rope, in feet.

N = Number of revolutions per minute.

Then,

$$W. = P. V.$$

But,

$$P. = W - (W2 - W3).$$

And, $V. = 2. \pi . R. N.$

Therefore:-

$$W. = \frac{(W - (W2-W3))\ 2.\ \pi\ R.\ N.}{33000}$$

And the air brake horse power equals;

$$B.\ HP. = \frac{(W - (W2-W3) -) 2.\ \Pi.\ R.\ N.}{33000}$$

The horse power lost in the cooling water was:

$$HP. = \frac{778.\ C.\ W.\ (T2 - T.)}{33000}$$

In which T. is the initial temperature of the cooling water; T2 its final temperature; C. the specific heat of water; which is one; and W. the number of pounds of cooling water. The temperatures were taken with centigrade thermometers but were reduced to Fahreinheit before they were used in the above formula.

The horse power lost on account of the rise in temperature of the air during compression could be obtained in the same way if the value of the specific heat of air was definitely known.

The efficiency of the plant is the ratio of the brake horse power of the motor to the indicated horse power of the engine. The efficiency of the air compressor and engine, is the ratio of the indicated horse power of the compressor to that of the engine.

Four tests were made on the plant. The cards and readings were taken every five minutes. From this data the horse powers were computed and the efficiencies obtained. During the test the air supply to the motor was throttled, in order to keep the pressure in the receiver as near constant as possible. In spite of this regulation it often varied ten pounds during the test. The principal cause of this was the inability to keep a constant steam pressure.

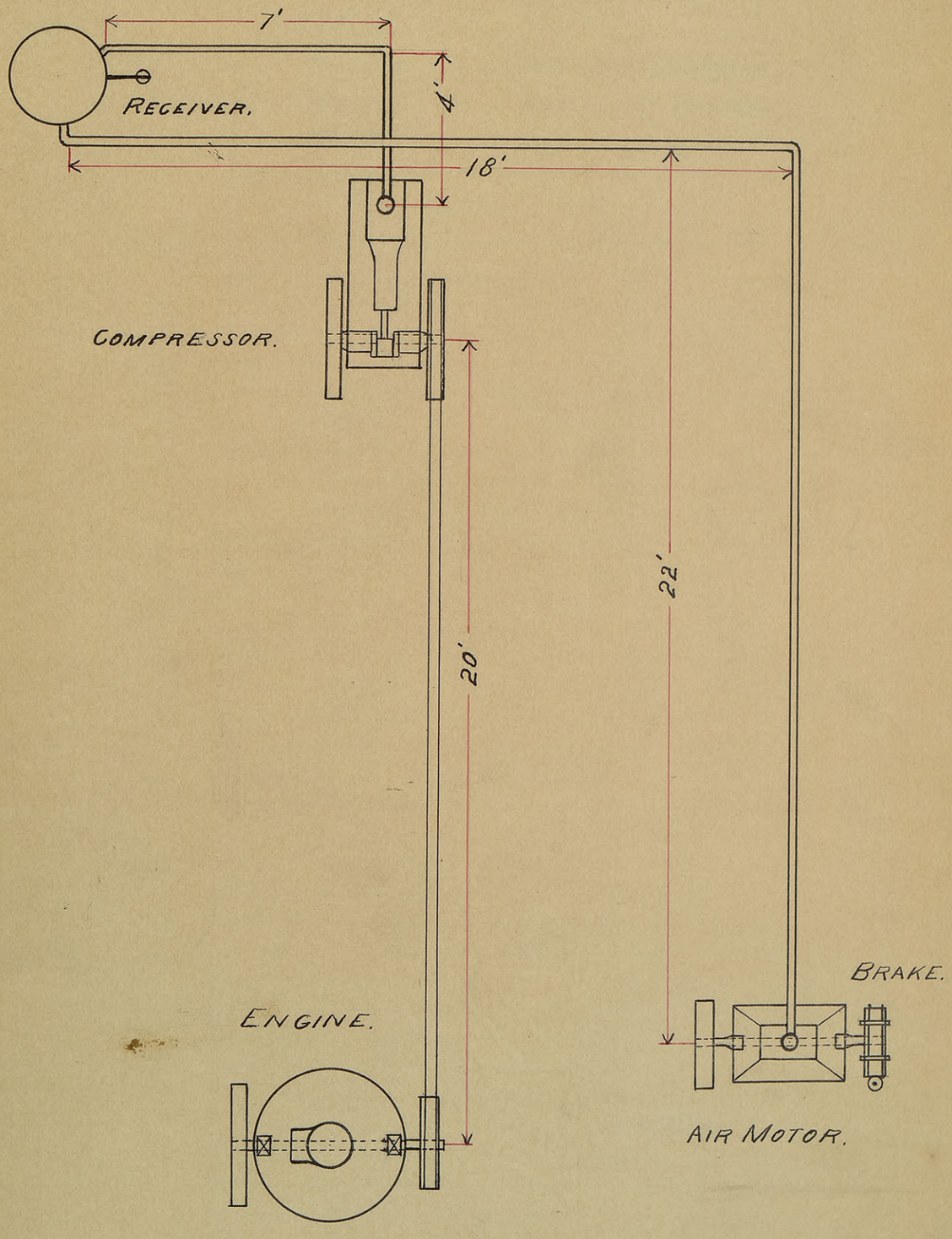
The low efficiency of the plant may in a measure be expected. The engine was of an old type and the mechanical losses were great. It had been discarded as useless sometime before but had been overhauled and practically rebuilt by the department. The belt would slip when-

ever the pressure in the receiver would go above fifty pounds gauge.

The losses in cooling the walls of the cylinder, and that lost by the rise in temperature of the air during compression amounts to considerable. There was a great loss of power in the air motor. This was partly due to the small ports, which should be larger for air than for steam in an engine that will develop the same horse power. The average horse power of the engine was six and ninety-nine hundredths, and the compressor four and sixty-two hundredths. The average brake horse power of the motor was seven hundred fifty nine thousandths. The average efficiency of the compressor and engine combined, as shown by the ratio of their indicated horse powers was sixty-five and two tenths per cent.

An average of each test has been made, and also a final average of the four.

PLAN OF THE PLANT.



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

LOG OF ROPE BRAKE.

CONSTANTS OF BRAKE.

OBSERVERS:

Test made at KANSAS STATE AGRICULTURAL COLLEGE.
On AIR MOTOR.
Date APRIL 18. 1904.

Radius of pulley..... 8.95 in.
Weight of brake..... 6. lbs.
Weight on brake..... 56. lbs
Brake constant..... .0001499

WILLIAM TURNBULL.
WENDELL P. TERRELL.

Number of Reading.	R. P. M.	Balance Reading.	B. H. P.	Remarks.
1.	115.	13.	.845	
2.	110.	14.	.792	
3.	115.	14.	.828	
4.	100.	17.	.675	
5.	70.	24.	.399	
6.	85.	23.	.497	
7.	100.	20.	.629	
8.	110.	19.	.709	
9.	80.	20.	.504	
10.	95.	19.	.612	
11.	100.	18.	.660	
12.	110.	17.	.742	
MAXIMUM.	115.	24.	.845	
MINIMUM.	70.	13.	.399	
TOTAL.	1190.	218.	7.892.	
AVERAGE	99.	18.	.658	

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

LOG OF ENGINE TRIAL.

TEST MADE AT KANSAS STATE AGRICULTURAL COLLEGE.
ON STEAM ENGINE.
DATE APRIL. 18. 1904.

CONSTANTS OF ENGINE.

Diameter of cylinder.... 6. in. Area of piston H. E. 28.27 sq. in.
Diameter of piston rod.. 1 5/8 in. Area of piston C. E. ..27.28 sq. in.
Length of stroke ..... 2/3 ft. Engine constant for H. E., .0005712
Engine constant for C. E., .0005501

OBSERVERS:

WILLIAM TURNBULL.
WENDELL P. TERRELL

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.	GAUGE ~~Volts.~~ PRESSURE.	Amperes.		
1.	3:00	205.	34.97	33.37	4.09	3.76	7.85	65.			
2.	3:05	205.	34.28	33.37	4.01	3.76	7.77	60.			
3.	3:10	205.	34.74	33.82	4.06	3.81	7.87	60.			
4.	3:15	165.	31.31	30.62	2.95	2.78	5.73	55.			
5.	3:20	140.	29.71	28.57	2.37	2.20	4.57	50.			
6.	3:25	155.	30.17	28.57	2.67	2.44	5.11	50.			
7.	3:30	180.	32.23	30.62	3.32	3.04	6.36	55.			
8.	3:35	180.	33.37	32.00	3.43	3.17	6.60	60.			
9.	3:40	150.	30.62	29.03	2.69	2.40	5.09	50.			
10.	3:45	165.	33.14	31.54	3.12	2.86	5.98	50.			
11.	3:50	165.	32.00	31.77	3.01	2.88	5.89	55.			
12.	3:55	185.	33.60	33.60	3.55	3.42	6.97	60.			
Maximum,		205.	34.97	33.82	4.09	3.81	7.85	65.			
Minimum,		140.	30.17	28.57	2.37	2.20	4.57	50.			
Total,		2100.	390.14	376.88	39.27	36.52	75.79	670.			
Average,		175.	32.51	31.40	3.27	3.04	6.31	56.			

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

LOG OF COMPRESSOR TRIAL.

TEST MADE AT KANSAS STATE AGRICULTURAL COLLEGE.
ON AIR COMPRESSOR.
DATE APRIL. 18. 1904.

CONSTANTS OF ENGINE.

Diam. of cylinder... 8. in. Area of piston H. E 50.26 sq. in
Diam. of piston rod, 1 3/8 in. Area of piston C. E 48.78 sq. in
Length of stroke .... 2/3 ft. Comp. constant for H. E .001016
Air per revolution .458 cu. ft. Comp. constant for C. E .000989

OBSERVERS:
WILLIAM TURNBULL.
WENDELL P. TERRELL

No. of card.	Time.	R. P. M.	Area.		M. E. P.		I. H. P.			Temperature of Air. C.			Temperature Cooling Water. C.			H. P. Dissipated in heat. 5 MIN.	Remarks.	
			H. E.	C. E.	H. E.	C. E.	H. E.	C. E.	Total.	Initial.	Final.	Rise.	Initial.	Final.	Rise.		WATER LBS.	PRESSURE IN RECEIVER
1.	3:00	125.	1.87	1.50	22.58	19.20	2.87	2.37	5.24	23.	91.5	68.5	13.	30.0	17.0	4.68	6.5	46.
2.	3:05	125.	1.88	1.50	22.70	19.20	2.88	2.37	5.25	23.	96.5	73.5	14.	31.5	17.5	5.94	8.0	47.
3.	3:10	125.	1.86	1.49	22.46	19.07	2.85	2.35	5.20	23.	100.0	77.0	14.	30.0	16.0	4.41	6.5	47.
4.	3:15	100.	1.76	1.41	21.25	18.05	2.16	1.78	3.94	23.	98.5	75.5	14.	25.0	11.0	4.20	9.0	42.
5.	3:20	85.	1.67	1.23	20.17	15.75	1.74	1.32	3.06	23.	92.0	69.0	14.	28.0	14.0	8.61	14.5	38.
6.	3:25	95.	1.67	1.27	20.17	16.26	1.95	1.52	3.47	23.	88.0	65.0	14.	29.0	15.0	10.16	16.0	38.
7.	3:30	110.	1.77	1.32	21.37	16.90	2.39	1.83	4.22	23.	90.0	67.0	14.	30.0	16.0	7.12	10.5	44.
8.	3:35	110.	1.77	1.40	21.37	17.92	2.39	1.95	4.34	23.	93.0	70.0	14.	32.0	18.0	9.54	12.5	44.
9.	3:40	90.	1.61	1.24	19.43	15.87	1.78	1.41	3.19	23.	92.0	69.0	14.	37.0	23.0	5.36	5.5	39.
10.	3:45	105.	1.75	1.36	21.13	17.41	2.25	1.80	4.05	23.	92.0	69.0	14.	35.0	21.0	8.01	9.0	43.
11.	3:50	110.	1.75	1.37	21.13	17.54	2.36	1.90	4.26	23.	94.0	71.0	14.	36.0	22.0	8.02	9.0	43.
12.	3:55	120.	1.80	1.48	21.74	18.94	2.65	2.24	4.89	23.	96.0	73.0	14.	37.0	23.0	5.85	6.0	45.
	Maximum,	125.	1.88.	1.50.	22.70	19.20	2.88	2.37	5.25	23.	100.	77.0	14.0	37.0	23.0	10.16	16.0	47.
	Minimum,	85.	1.61.	1.23	19.43	15.87	1.78	1.41	3.19	23.	88.	65.0	13.0	25.0	11.0	4.20	5.5	38.
	Total,	1300.	21.75	16.57	255.50	212.11	28.27	22.84	51.11	276.	1123.5	847.5	167.0	380.5	213.5	81.90	113.0	516.
	Average,	109.	1.81	1.38	21.39	17.67	2.35	1.90	4.26	23.	93.6	70.6	13.9	31.7	17.8	6.82	9.4	43.

Run No. 1 April 18.

Efficiency of Plant.

	Engine	Motor	Difference	Efficiency
1	7.85	.845	7.005	10.8
2	7.77	.792	6.978	10.2
3	7.87	.828	7.062	10.6
4	5.73	.675	5.055	11.8
5	4.57	.399	4.171	8.7
6	5.11	.497	4.613	9.7
7	6.36	.629	5.731	9.9
8	6.60	.709	5.891	10.7
9	5.09	.504	4.586	9.9
10	5.98	.612	5.368	10.2
11	5.89	.660	5.230	11.2
12	6.97	.742	6.228	10.6
Total	75.79	7.892	64.918	124.3
Average	6.31	.658	5.409	10.36

Run No. 1 April 18.

Ratio of Indicated Horse Powers.

	Engine	Compressor	Difference	Ratio
1	7.85	5.24	2.61	66.7
2	7.77	5.25	2.52	67.6
3	7.87	5.20	2.67	66.1
4	5.73	3.94	1.79	68.8
5	4.57	3.06	1.51	66.9
6	5.11	3.47	1.64	67.9
7	6.36	4.22	2.14	66.3
8	6.60	4.34	2.26	65.8
9	5.09	3.19	1.90	62.7
10	5.98	4.05	1.93	67.7
11	5.89	4.26	1.63	72.3
12	6.97	4.89	2.08	70.1
Total	75.79	51.11	24.68	808.9
Average	6.31	4.26	2.05	67.4

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

LOG OF ROPE BRAKE.

CONSTANTS OF BRAKE.

Test made at KANSAS STATE AGRICULTURAL COLLEGE.

On AIR MOTOR.

Date MAY. 2. 1904.

Radius of pulley..... 8.95 in.

Weight of brake..... 6. lbs.

Weight on brake..... 56. lbs

Brake constant..... .0001499

OBSERVERS:

WILLIAM TURNBULL

WENDELL P. TERRELL

Number of Reading.	R. P. M.	Balance Reading.	B. H. P.	Remarks.
1.	130.	14.	.935	
2.	120.	15.	.845	
3.	122.	15.	.860	
4.	120.	16.	.827	
5.	115.	17.	.776	
6.	118.	16.	.814	
7.	118.	16.	.814	
8.	118.	17.	.815	
9.	118.	16.	.814	
10.	115.	18.	.779	
11.	135.	14.	.971	
12.	130.	15.	.916	
MAXIMUM.	135.	18.	.971	
MINIMUM.	115.	14.	.776	
TOTAL.	1459.	189.	10.166	
AVERAGE	121.	15.	.847	

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

LOG OF COMPRESSOR TRIAL.

TEST MADE AT KANSAS STATE AGRICULTURAL COLLEGE.
ON AIR COMPRESSOR.
DATE MAY. 2. 1904.

CONSTANTS OF ENGINE.

Diam. of cylinder... 8 in. Area of piston H. E. 50.26 sq. in
Diam. of piston rod, 1 3/8 in. Area of piston C. E. 48.78 sq. in
Length of stroke .... 2 ft. Comp. constant for H. E. .001016
Air per revolution .458 cu. ft. Comp. constant for C. E. .000989

OBSERVERS:

WILLIAM TURNBULL.
WENDELL P. TERRELL

No. of card.	Time.	R. P. M.	Area.		M. E. P.		I. H. P.			Temperature of Air. C.			Temperature Cooling Water. C.			H. P. Dissipated in heat. 5 MIN.	Remarks.	
			H. E.	C. E.	H. E.	C. E.	H. E.	C. E.	Total.	Initial.	Final.	Rise.	Initial.	Final.	Rise.		WATER LBS.	PRESSURE IN RECEIVER
1.	2:30	125.	1.28	1.80	16.38	21.74	2.08	2.68	4.76	29.0	81.5	52.5	15.	28.	13.	4.13	7.5	44.
2.	2:35	115.	1.27	1.61	16.26	19.44	1.90	2.21	4.11	29.0	83.0	54.0	17.	28.	11.	2.80	6.0	41.
3.	2:40	115.	1.25	1.65	16.00	19.92	1.87	2.26	4.13	28.5	86.0	58.5	18.	29.	11.	4.20	9.0	41.
4.	2:45	120.	1.26	1.69	16.13	20.41	1.97	2.42	4.39	28.5	88.5	60.0	19.	30.	11.	3.96	8.5	42.
5.	2:50	120.	1.29	1.77	16.51	21.37	2.01	2.53	4.54	28.5	90.0	61.5	19.	31.	12.	4.32	8.5	45.
6.	2:55	120.	1.35	1.81	17.28	21.86	2.11	2.59	4.70	28.0	93.5	65.5	19.	32.	13.	3.86	7.0	45.
7.	3:00	118.	1.26	1.78	16.13	21.49	1.93	2.50	4.43	28.0	95.5	67.5	19.	33.	14.	4.15	7.0	46.
8.	3:05	122.	1.31	1.78	16.77	21.49	2.08	2.59	4.67	28.0	97.0	69.0	19.	34.	15.	5.09	8.0	46
9.	3:10	128.	1.32	1.80	16.89	21.74	2.20	2.75	4.95	28.0	99.0	71.0	19.	34.	15.	3.18	5.0	46.
10.	3:15	120.	1.39	1.80	17.79	21.74	2.17	2.58	4.75	28.0	101.0	73.0	19.	35.	16.	6.78	10.0	45
11.	3:20	120.	1.30	1.78	16.64	21.49	2.03	2.55	4.58	28.0	101.5	73.5	19.	35.	16.	5.77	8.5	43.
12.	3:25	120.	1.33	1.80	17.02	21.74	2.08	2.58	4.66	28.5	101.5	73.0	19.	36.	17.	2.89	4.0	43.
Maximum,		125.	1.39	1.80	17.79	21.86	2.20	2.75	4.95	29.0	101.5	73.5	19.0	36.0	17.0	6.78	10.0	46.
Minimum,		115.	1.25	1.61	16.00	19.44	1.87	2.21	4.11	28.0	81.5	52.5	15.0	28.0	11.0	2.80	4.0	41.
Total,		1443.	15.61	20.98	199.80	254.41	24.42	29.84	54.67	340.0	1118.0	779.0	221.	385.0	164.0	51.13	89.0	527.
Average,		120.	1.30	1.75	16.65	21.20	2.03	2.49	4.55	28.3	93.1	64.9	18.3	32.0	13.7	4.26	7.4	44.

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

LOG OF ENGINE TRIAL.

TEST MADE AT KANSAS STATE AGRICULTURAL COLLEGE.
ON STEAM ENGINE.
DATE MAY. 2. 1904.

CONSTANTS OF ENGINE.

Diameter of cylinder.... 6. in. Area of piston H. E.. 28.27 sq. in.
Diameter of piston rod.. 1⅛ in. Area of piston C. E.. 27.28 sq. in.
Length of stroke..... 3/8 ft. Engine constant for H. E., .0005712
Engine constant for C. E., .0005501

OBSERVERS:
WILLIAM TURNBULL.
WENDELL P. TERRELL

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.~~ GAUGE PRESSURE.	Amperes.		
1.	2:30	205.	33.60	32.68	3.93	3.63	7.61	60.			
2.	2:35	180.	34.28	32.91	3.52	3.25	6.77	60.			
3.	2:40	182.	34.51	32.45	3.59	3.25	6.84	60.			
4.	2:45	182.	34.28	32.23	3.57	3.23	6.80	60.			
5.	2:50	180.	35.89	33.60	3.69	3.33	7.02	65.			
6.	2:55	200.	34.05	32.45	3.89	3.57	7.46	62.			
7.	3:00	182.	33.60	32.00	3.49	3.20	6.69	60.			
8.	3:05	200.	34.28	32.23	3.92	3.68	7.60	60.			
9.	3:10	200.	34.05	32.91	3.89	3.62	7.51	62.			
10.	3:15	198.	34.51	33.37	3.90	3.64	7.54	60.			
11.	3:20	200.	33.37	32.23	3.81	3.55	7.36	55.			
12.	3:25	200.	33.37	32.23	3.81	3.55	7.36	55.			
	Maximum,	205.	35.89	33.60	3.93	3.68	7.61	65.			
	Minimum,	180.	33.37	32.00	3.49	3.23	6.69	55.			
	Total,	2309.	409.99	391.29	45.01	41.55	86.56	719.			
	Average,	192.	34.16	32.60	3.75	3.46	7.21	59.			

Run No. 2 May 2.

Efficiency of Plant.

No.	Engine	Motor	HP lost	Efficiency
1	7.61	.935	6.675	12.3
2	6.77	.845	5.925	12.4
3	6.84	.860	5.980	12.5
4	6.80	.827	5.973	12.2
5	7.02	.776	6.244	11.1
6	7.46	.814	6.646	10.9
7	6.69	.814	5.876	11.7
8	7.60	.815	6.785	10.7
9	7.51	.814	6.696	10.8
10	7.54	.779	6.761	10.3
11	7.36	.971	6.389	13.2
12	7.36	.916	6.444	12.4
Total	86.56	10.166	76.394	140.5
Average	7.21	.847	6.366	11.7

Run No. 2 May 2.

Ratio of Indicated Horse Powers.

No.	Engine	Compressor	HP. Lost	Ratio
1	7.61	4.76	2.85	62.5
2	6.77	4.11	2.66	61.6
3	6.84	4.13	2.71	60.4
4	6.80	4.39	2.41	64.5
5	7.02	4.54	2.48	64.7
6	7.46	4.70	2.76	63.0
7	6.69	4.43	2.26	60.2
8	7.60	4.67	2.93	61.4
9	7.51	4.95	2.56	65.8
10	7.54	4.75	2.79	63.0
11	7.36	4.58	2.78	62.2
12	7.36	4.66	2.70	63.3
Total	86.56	54.67	31.89	759.9
Average	7.21	4.55	2.65	63.3

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

LOG OF ROPE BRAKE.

Test made at KANSAS STATE AGRICULTURAL COLLEGE

On AIR MOTOR

Date MAY 10, 1904

CONSTANTS OF BRAKE.

Radius of pulley..... 8.95 in.

Weight of brake..... 6 lbs.

Weight on brake..... 50 lbs

Brake constant..... 0.0001499

OBSERVERS:

WENDELL P. TERRELL

WILLIAM TURNBULL.

Number of Reading.	R. P. M.	Balance Reading.	B. H. P.	Remarks.
1	105.5	15.0	.644	
2	111.0	16.0	.661	
3	83.0	18.0	.470	
4	63.0	19.5	.343	
5	76.5	19.5	.416	
6	160.0	16.0	.954	
7	86.0	18.5	.480	
8	89.0	19.0	.494	
9	90.0	19.5	.502	
10	102.0	18.0	.578	
11	107.0	17.0	.622	
12	116.0	16.0	.691	
MAXIMUM	160	19.5	.954	
MINIMUM	63	15.0	.343	
TOTAL	1189.	212.0	6.855	
AVERAGE	99.	17.6	.571	

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

TEST MADE AT KANSAS STATE AGRICULTURAL COLLEGE
ON AIR COMPRESSOR
DATE MAY 10, 1904

LOG OF COMPRESSOR TRIAL.

CONSTANTS OF ENGINE.

Diam. of cylinder... 8 in. — Area of piston H. E. 50.26 sq. in
Diam. of piston rod, 1 3/8 in. — Area of piston C. E. 48.78 sq. in
Length of stroke .... 2/3 ft. — Comp. constant for H. E. 0.001016
Air per revolution . 4.58 cu. ft. — Comp. constant for C. E. 0.000989

OBSERVERS:

WENDELL P. TERRELL
WILLIAM TURNBULL.

No. of card.	Time.	R. P. M.	Area.		M. E. P.		I. H. P.			Temperature of Air. C.			Temperature Cooling Water. C.			H. P. Dissipated in heat.	Remarks.	
			H. E.	C. E.	H. E.	C. E.	H. E.	C. E.	Total.	Initial.	Final.	Rise.	Initial.	Final.	Rise.	5 MIN	WATER (COOLING LBS	PRESSURE IN RECEIVER
1	1:45	115	1.27	1.41	15.40	17.52	1.80	1.98	3.78	21.5	67.0	45.5	15.0	21.0	6.0	4.58	18	40
2	1:50	100	1.04	1.22	12.56	15.00	1.28	1.48	2.76	21.5	71.0	49.5	16.0	24.0	8.0	5.77	17	38
3	1:55	90	.86	1.05	10.32	12.84	.94	1.14	2.08	24.0	69.0	45.0	16.0	25.0	9.0	6.11	16	30
4	2:00	80	.80	1.04	9.64	12.84	.78	1.02	1.80	24.5	67.0	42.5	17.0	26.0	9.0	5.34	14	27
5	2:05	95	.90	1.06	10.84	12.80	1.04	1.20	2.24	25.0	65.0	40.0	17.0	27.0	10.0	6.35	15	30
6	2:10	140	1.27	1.37	15.20	16.56	2.16	2.29	4.45	25.5	72.0	46.5	17.0	28.0	11.0	6.06	13	33
7	2:15	95	1.29	1.43	15.28	17.24	1.47	1.61	3.08	25.5	82.0	56.5	17.5	32.0	14.5	6.15	10	40
8	2:20	100	1.38	1.46	16.88	17.60	1.71	1.65	3.36	25.5	84.5	59.0	18.0	32.5	14.5	5.54	9	40
9	2:25	100	1.30	1.41	15.70	17.20	1.59	1.69	3.28	25.5	84.5	60.0	18.5	34.0	15.5	5.26	8	40
10	2:30	115	1.42	1.58	17.16	19.70	1.99	2.24	4.23	25.0	87.5	62.5	19.0	37.0	18.0	6.87	9	43
11	2:35	118	1.46	1.63	17.63	19.85	2.11	2.31	4.42	25.0	91.5	66.5	19.5	44.0	24.5	7.27	7	45
12	2:40	128	1.52	1.67	18.43	20.19	2.39	2.54	4.93	27.0	96.0	69.0	20.5	46.5	26.0	7.72	7	47
Maximum,		140	1.52	1.67	18.43	20.19	2.39	2.54	4.93	27	96	69	20.5	46.5	26	7.72	18	47
Minimum,		80	.80	1.04	9.64	12.80	.78	1.02	1.80	21.5	65	40	15	21	6	4.58	143	27
Total,		1276	14.51	16.33	175.04	199.30	19.26	21.15	40.43	295.5	937	642.5	211	377	166	73.02	143.0	453
Average,		106	1.21	1.36	14.58	16.61	1.60	1.76	3.37	24.	78.1	53.5	17.6	31.4	13.8	6.08	19.9	37.7

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

LOG OF ENGINE TRIAL.

TEST MADE AT KANSAS STATE AGRICULTURAL COLLEGE
ON STEAM ENGINE
DATE MAY 10, 1904

CONSTANTS OF ENGINE.

Diameter of cylinder.... 8 in. Area of piston H. E. 28.27 sq. in.
Diameter of piston rod.. 1 1/8 in. Area of piston C. E. 27.28 sq. in.
Length of stroke..... 2/3 ft. Engine constant for H. E., 0.0005712
Engine constant for C. E., 0.0005501

OBSERVERS:
WENDELL P. TERRELL
WILLIAM TURNBULL.

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.	PRESSURE ~~Volts.~~ GAUGE	Amperes.		
1	1:45	170	33.78	32.2	3.28	3.01	6.29	67.5			
2	1:50	140	31.22	29.85	2.50	2.25	4.75	63.0			
3	1:55	130	27.47	26.55	2.03	1.89	3.92	55.0			
4	2:00	120	25.72	24.44	1.76	1.61	3.38	53.0			
5	2:05	140	28.36	26.60	2.27	2.06	4.33	56.0			
6	2:10	215	33.90	31.65	4.16	3.74	7.90	70.0			
7	2:15	140	34.53	33.86	2.75	2.61	5.36	67.0			
8	2:20	160	35.18	34.20	3.22	3.01	6.23	70.0			
9	2:25	140	34.84	34.97	2.78	2.75	5.53	67.0			
10	2:30	175	36.20	34.60	3.62	3.33	6.95	72.0			
11	2:35	175	36.10	34.05	3.61	3.20	6.81	74.0			
12	2:40	200	37.00	36.15	4.29	3.98	8.27	75.0			
	Maximum,	215.0	37.	36.15	4.29	3.98	8.27	75.0			
	Minimum,	120.0	25.72	24.44	1.76	1.61	3.38	53.0			
	Total,	1905.0	394.3	379.12	36.27	33.44	69.72	789.5			
	Average,	158.7	32.87	31.59	3.02	2.79	5.81	65.8			

Run No. 3 May 10.

Efficiency of Plant.

No.	Engine	Motor	HP Lost	Efficiency
1	6.29	.644	5.646	10.2
2	4.75	.661	4.089	13.9
3	3.92	.470	3.450	11.8
4	3.38	.343	3.037	10.1
5	4.33	.416	3.914	9.6
6	7.90	.954	6.946	12.0
7	5.36	.480	4.880	8.9
8	6.23	.494	5.736	7.9
9	5.53	.502	5.028	9.0
10	6.95	.578	6.372	8.3
11	6.81	.622	6.188	9.1
12	8.27	.691	7.579	8.3
Total	69.72	6.855	63.665	119.1
Average	5.81	.571	5.200	9.9

Run No. 3 May 10.

Ratio of Indicated Horse Powers.

No.	Engine	Compressor	HP Lost	Ratio
1	6.29	3.78	2.51	60.0
2	4.75	2.76	1.99	58.1
3	3.92	2.08	1.84	53.3
4	3.38	1.80	1.58	53.2
5	4.33	2.24	2.09	51.7
6	7.90	4.45	3.45	56.3
7	5.36	3.08	2.28	57.4
8	6.23	3.36	2.87	53.9
9	5.53	3.28	2.25	59.3
10	6.95	4.23	2.72	60.8
11	6.81	4.42	2.39	64.9
12	8.27	4.93	3.34	59.6
Total	69.72	40.43	29.31	688.5
Average	5.81	3.37	2.44	57.37

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

LOG OF ROPE BRAKE.

CONSTANTS OF BRAKE.

OBSERVERS:

Test made at KANSAS STATE AGRICULTURAL COLLEGE.

On AIR MOTOR.

Date MAY 16. 1904.

Radius of pulley..... 8.95 in.

Weight of brake..... 6. lbs.

Weight on brake..... 50. lbs

Brake constant..... .0001499

WILLIAM TURNBULL.

WENDELL P. TERRELL

Number of Reading.	R. P. M.	Balance Reading.	B. H. P.	Remarks.
1.	160.	17.	.936	
2.	170.	17.	.994	
3.	240.	14.	1.510	
4.	210.	18.	1.196	
5.	210.	17.	1.228	
6.	180.	20.	.972	
7.	130.	20.	.702	
8.	100.	21.	.525	
9.	145.	19.	.804	
10.	150.	19.	.832	
11.	160.	18.	.912	
12.	160.	17.	.936	
MAXIMUM.	240.	21.	1.510	
MINIMUM	100.	14.	.525	
TOTAL.	2015.	237.	11.547	
AVERAGE	168.	19.	.962	

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

TEST MADE AT KANSAS STATE AGRICULTURAL COLLEGE.
ON AIR COMPRESSOR.
DATE MAY. 16. 1904.

LOG OF COMPRESSOR TRIAL.

CONSTANTS OF ENGINE.

Diam. of cylinder... 8 in. Area of piston H. E. 50.26 sq. in
Diam. of piston rod, 1 3/8 in. Area of piston C. E. 48.78 sq. in
Length of stroke .... 2/3 ft. Comp. constant for H. E. .001016
Air per revolution . 4.58 cu. ft. Comp. constant for C. E. .000989

OBSERVERS:

WILLIAM TURNBULL.
WENDELL P. TERRELL

No. of card.	Time.	R. P. M.	Area.		M. E. P.		I. H. P.			Temperature of Air. C.			Temperature Cooling Water. C.			H. P. Dissipated in heat. 5 MIN.	Remarks.	
			H. E.	C. E.	H. E.	C. E.	H. E.	C. E.	Total.	Initial.	Final.	Rise.	Initial.	Final.	Rise.		WATER LBS.	PRESSURE IN RECEIVER
1.	2:45	140.	1.30	1.73	16.64	20.89	2.37	2.88	5.25	24.	97.	73.	20.	43.	23.	4.87	5.	38.
2.	2:50	160.	1.37	1.63	17.54	19.68	2.85	3.11	5.96	24.	100.	76.	16.	38.	22.	8.40	9.	41.
3.	2:55	180.	1.67	1.68	21.37	20.29	3.91	3.60	7.51	24.	108.	84.	17.	33.	16.	7.46	11.	42.
4.	3:00	170.	1.48	1.91	18.94	23.06	3.27	3.87	7.14	24.	112.	88.	19.	39.	20.	7.63	9.	40.
5.	3:05	185.	1.61	1.76	20.61	21.25	3.87	3.88	7.75	24.	114.	90.	20.	42.	22.	6.53	7.	43.
6.	3:10	150.	1.55	1.93	19.84	23.30	3.02	3.45	6.47	24.	115.	91.	20.	45.	25.	10.60	10.	45.
7.	3:15	135.	1.52	1.80	19.46	21.73	2.67	2.90	5.57	24.	112.	88.	21.	48.	27.	10.30	9.	44.
8.	3:20	115.	1.41	1.79	17.85	21.61	2.09	2.45	4.54	24.	108.	84.	20.	47.	27.	10.30	9.	38.
9.	3:25	140.	1.66	1.78	21.25	21.49	3.02	2.97	5.99	24.	106.	82.	18.	44.	26.	7.72	7.	44.
10.	3:30	150.	1.67	1.85	21.37	22.34	3.26	3.31	6.57	24.	109.	85.	19.	47.	28.	9.50	8.	48.
11.	3:35	150.	1.72	1.89	22.01	22.82	3.35	3.38	6.73	26.	111.	85.	17.	40.	23.	12.68	13.	48
12.	3:40	140.	1.64	1.85	20.99	22.34	2.99	3.09	6.08	26.	112.	86.	18.	44.	26.	13.23	12.	46.
Maximum,		185.	1.72	1.93	22.01	23.30	3.91	3.88	7.75	26.0	115.	91.	21.	48.	28.0	13.23	13.	48.
Minimum,		115.	1.30	1.63	16.64	19.68	2.09	2.45	4.54	24.0	97.	73.	16.	33.	16.0	4.87	5.	38.
Total,		1815.	18.60	21.60	237.87	260.80	36.50	38.89	75.56	292.0	1304.	1012.	225.	510.	285.0	109.22	110.	517.
Average,		151.	1.55	1.80	19.82	21.73	3.04	3.24	6.29	24.3	109.	84.	19.	42.	23.7	9.10	9.	44.

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

LOG OF ENGINE TRIAL.

TEST MADE AT KANSAS STATE AGRICULTURAL COLLEGE.
ON STEAM ENGINE.
DATE MAY. 16. 1904.

CONSTANTS OF ENGINE.

Diameter of cylinder.... 6. in. Area of piston H. E. 28.27 sq. in.
Diameter of piston rod.. 1⅛ in. Area of piston C. E. 27.28 sq. in.
Length of stroke ..... 2/3 ft. Engine constant for H. E., .0005712
Engine constant for C. E., .0005501

OBSERVERS:

WILLIAM TURNBULL.
WENDELL P. TERRELL.

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.	GAUGE ~~Volts.~~ PRESSURE.	Amperes.		
1.	2:45	220.	32.21	30.53	4.05	3.69	8.74	67.			
2.	2:50	240.	30.74	28.63	4.21	3.78	7.99	74.			
3.	2:55	290.	33.67	31.58	5.58	5.04	10.62	70.			
4.	3:00	260.	33.26	30.53	4.94	4.37	9.31	80.			
5.	3:05	280.	37.26	33.89	5.96	5.22	11.18	82.			
6.	3:10	240.	31.58	28.84	4.33	3.81	8.14	82.			
7.	3:15	250.	30.74	28.63	4.36	3.91	8.27	62.			
8.	3:20	180.	29.47	27.99	3.03	2.77	5.80	60.			
9.	3:25	220.	33.67	29.26	4.23	3.54	7.77	65.			
10.	3:30	230.	36.21	31.78	4.76	4.02	8.78	76.			
11.	3:35	240.	34.74	31.58	4.75	4.17	8.92	74.			
12.	3:40	210.	34.94	31.16	4.19	3.60	7.79	70.			
Maximum,		290.	37.26	33.89	5.96	5.22	11.18	82.			
Minimum,		180.	29.47	27.99	3.03	2.77	5.80	60.			
Total,		2860.	398.49	364.40	54.59	47.92	104.31	862.			
Average,		238.	33.21	30.37	4.55	3.99	8.64	72.			

Run No. 4 May 16.

Efficiency of Plant.

No.	Engine	Motor	HP. Lost	Efficiency
1	8.14	.936	7.204	10.1
2	7.99	.994	6.995	12.4
3	10.62	1.510	9.110	14.2
4	9.31	1.196	8.114	12.8
5	11.18	1.228	9.952	11.0
6	8.14	.972	7.168	11.9
7	8.27	.702	7.563	8.5
8	6.80	.525	6.275	7.7
9	7.77	.804	6.966	10.4
10	8.78	.832	7.948	9.5
11	8.92	.912	8.008	10.2
12	7.79	.936	6.854	12.0
Total	104.31	11.547	92.163	130.7
Average	8.64	.962	7.680	10.9

Run No. 4 May 16.

Ratio of Indicated Horse Powers.

No.	Engine	Compressor	Difference	Ratio
1	8.14	5.25	2.09	64.4
2	7.99	5.96	2.03	74.5
3	10.62	7.51	3.11	70.7
4	9.31	7.14	2.17	76.0
5	11.18	7.75	3.43	69.3
6	8.14	6.47	1.67	79.6
7	8.27	5.57	2.70	67.3
8	6.80	4.54	2.26	66.7
9	7.77	5.99	1.78	77.0
10	8.78	6.57	2.21	74.8
11	8.92	6.73	2.19	75.4
12	7.79	6.08	1.71n	78.1
Total	104.31	75.56	27.35	873.8
Average	8.64	6.29	2.29	72.8

Four Tests.

Average Efficiency of Plant.

No.	Engine	Motor	HP. Lost	Efficiency
1	6.31	.650	5.409	10.36
2	7.21	.847	6.366	11.70
3	5.81	.571	5.200	9.90
4	8.64	.962	7.680	10.90
Total	27.97	3.038	24.655	42.86
Average	6.99	.759	6.143	10.71

Average Ratio of Indicated Horse Powers.

No.	Engine	Compressor	HP. Lost	Ratio
1	6.31	4.26	2.05	67.4
2	7.21	4.55	2.65	63.3
3	5.81	3.37	2.44	57.4
4	8.64	6.29	2.29	72.8
Total	27.97	18.47	9.43	260.9
Average	6.99	4.62	2.36	65.2