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LC,*

RESULTS OF MEASUREMENTS OF THE WATER CONSUMPTION OF AN UNJACKETED 1600 HORSE POWER COMPOUND HARRIS-CORLISS ENGINE.

BY J. E. DENTON, D. S. JACOBUS AND R. H. RICE.

(Members of the Society).

The engine under notice furnishes the motive power for the Bristol Manufacturing Company's fifty thousand Spindle Cotton Mill at New Bedford, Mass. It is of the cross-compound type, and of the following dimensions:—

Diameter high-pressure cylinder	30.025 inches.
Diameter low-pressure cylinder	55.915 inches.
Stroke of both cylinders	72.00 inches.
Average clearance each end high-pressure cylinder, per cent. piston displacement	2.6 per cent.
Average clearance each end low-pressure cylinder, per cent. piston displacement	3.6 per cent.

Each cylinder has separate eccentrics for the admission and exhaust valves, respectively. The cylinders are unjacketed on both the head an barrels.

The receiver between the cylinders is a cylinder 29 inches diameter and 13 feet long, having an annular space about its barrel which was intended to be used as a live-steam jacket. This jacket is not generally used. In the experiments here described no live steam was admitted to it, and it was connected with the interior of the receiver; all drip pipes for draining the jacket, and the interior of the receiver, being tightly closed.

The feed water was measured by a carefully calibrated meter placed between the feed pumps and the boilers.

All of the steam generated by the boilers passed through the engine, except a small portion amounting to 165 lbs. per hour, which represented the combined leakage from the blow-off cocks

* Presented at the Montreal meeting (June, 1894) of the American Society of Mechanical Engineers, and forming part of Vol. XV, of the *Transactions.*

and water-glass drips, 93 lbs, per hour, which was the average amount used by a Barrus calorimeter, and a portion amounting to 230 lbs. per hour, which was drawn from a dead end in the live-steam pipe leading to the low pressure cylinder.

The first quantity was determined by collecting and weighing the leakage during a certain time. The second quantity was determined by calibrating the orifice of the calorimeter. The latter quantity was determined by the calculation given on page 3.

The detailed data of the test are shown in Tables I. to XIII. The results show a water consumption of 13.50 lbs. of steam per hour per indicated horse power with 125 lbs. boiler pressure, 0.30 cut-off in high cylinder, steam 14.6 degrees of super-heated at the throttle-valve, and 65.2 revolutions of the engine per minute.

The feed water for the engine was drawn from the city supply at forty degrees Fahr., and passed through a nest of tubes, aggregating 400 square feet of surface, lodged in a cylinder through which the exhaust steam was discharged into the condenser. By means of this exhaust heater the temperature of the feed water was raised to 131.3 degrees. The feed water then passed through a drip tank, in which it was mixed with the steam from the dead end of the steam pipe, whereby its temperature was raised to 142.7 degrees.

In the ordinary operation of the mill the condensed steam from the slashers, etc., also mixes with the feed water in the drip tank, whereby a temperature upwards of 160 degrees Fahr. is given to the feed water. At this temperature of feed water the boilers, which were of the Bigelow-Manning type, evaporate $10\frac{1}{3}$ lbs. of water per pound of Pocohantas bituminous coal.

The plant as a whole, therefore, affords the remarkable economy of $1\frac{1}{3}$ lbs. of coal per indicated horse power per hour, with an unjacketed compound engine expanding steam about thirteen times.

The writers are indebted to the courtesy of Mr. Chas. C. Diman, Superintendent of the mill, for the opportunity to test the engine, and for his cordial co-operation in dispensing with the use of live steam in the mill, during the period of the measurements, for all purposes except the operation of the engine.

CALCULATION OF STEAM CONSUMED PER HOUR, AND PER HOUR PER HORSE POWER.

The total weight of water registered by the meter in four and one-half hours was 1529.1 x 64.70 = 98933 lbs., or 21985 lbs. per hour. From this there is to be deducted the leakage of the blow-off valves of the boilers, which amounted to 165 lbs. per hour, the steam which passed through the Barrus calorimeter and the steam which flowed from a dead end in one of the steam pipes in order to prevent water collecting in the same. The amount of steam returned from the dead end is calculated from the rise in temperature of the feed water, assuming that the steam is dry. This will give too low a correction on account of the amount of moisture that may be present in the steam, but as the whole correction is a small one the error involved is not of importance.

The error involved by neglecting any moisture contained in the steam thus returned to the feed water will be against the economy of the engine.

The increase of temperature of the feed water due to the returned steam was 142.7 − 131.3 = 11.4 degrees Fahr. The heat units imparted to the feed water per hour will be 11.4 (21985 − x) in which x is the amount of steam condensed. Each pound of steam parts with 1221 − 142.7 = 1078.3 B. T. U., so that we have 1078.3 x = 11.4 (21985 − x), from which obtain

x = 230 lbs. per hour.

The amount of steam passing through the Barrus calorimeter was 102 lbs. per hour. The calorimeter was in operation four hours and five minues, so that the total steam passing through it was 416.5 lbs., or the average rate was 416.5 ÷ 4½ = 93 lbs. per hour.

The total amount to be deducted from the water passing through the meter is, therefore, 165 + 230 + 93 = 488 lbs., and the net steam consumed by the engine per hour is 21985 − 488 = 21497 lbs.

The steam per hour per horse power is 21497 ÷ 1592.2 = 13.50 lbs.

CALIBRATION OF INDICATOR SPRINGS.

The standard of pressure for the springs used on the high pressure cylinder was the Utica Steam Gauge Company's

weight device, which as was stated in the paper on the Comparison of Indicators presented at the last meeting of this Society, was found to agree with the mercury column at the Brooklyn Navy Yard.

The standard of pressure used for the low pressure indicators was a mercury column, the reading of which were verified by a distilled-water column in order to make sure that the density of the mercury, which was the ordinary mercury of commerce, did not vary from the standard figure.

The readings of the mercury column agreed precisely with the readings of the distilled-water column, so that the density of the commercial mercury was the same as for chemically-pure mercury.

The same mercury was employed in the column used for measuring the vacuum in the engine test as was employed in the tests for standardizing the springs.

The general method of standardizing the indicators, and calculation of the equivalent scales of the springs so as to allow for all variations in the scales at different heights on the diagrams, is the same as was given in detail in the paper on the Comparison of Indicators already mentioned.

The results of tests of the springs are given in detail in tables VII. and VIII., and the calculation of the equivalent scales in tables IX. to XIII.

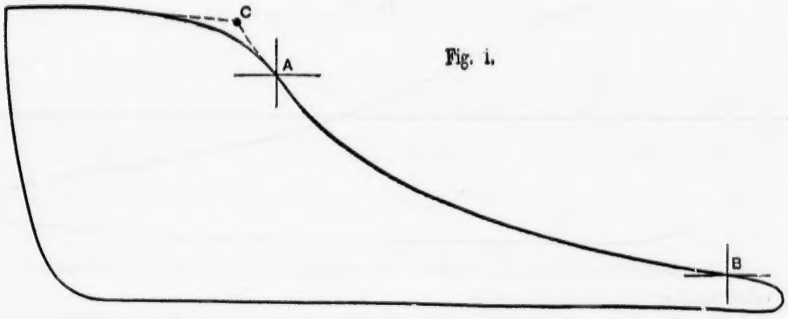
TABLE I.

FINAL RESULTS OF TEST.

Horse power			1592.2
Steam per hour per horse power, lbs			13 50
Average pressure at engine throttle, lbs. per square inch above atmosphere			123.0
Average superheating at engine throttle, degrs. Fahr			14.6
Average vacuum, inches of mercury			25.6
Lbs. of steam per hour per horse power calculated from indicator cards.	High pressure cylinder.	Near cut-off	11.81
		Near release	12.02
	Low pressure cylinder.	Near cut-off	10.95
		Near release	11.99
Steam not accounted for at cut-off of high pressure cylinder, per cent			12.5
Revolutions per minute			65.21
Piston speed in feet per minute			783
Ratio of expansion			13.4
Ratio of actual mean effective pressure to mean effective pressure for Marriotte curve and two pounds back pressure			0.79

AVERAGE INDICATOR DIAGRAMS.

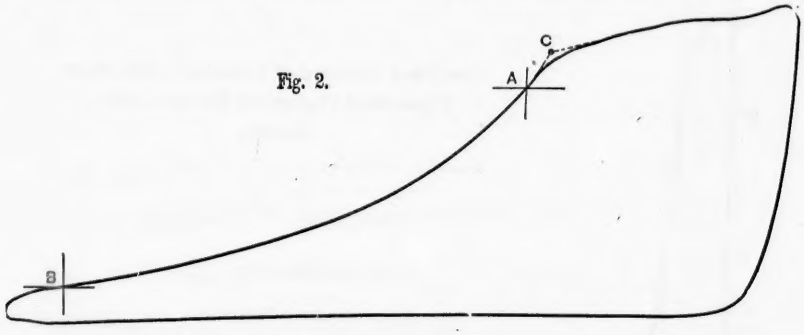
Fig. 1.



Head end of high-pressure cylinder. The steam accounted for by indicator is calculated at the points *A* and *B*.

Spring D.—Equivalent scale, 60.29. M.E.P., 48.55. Horse-power, 407.6.

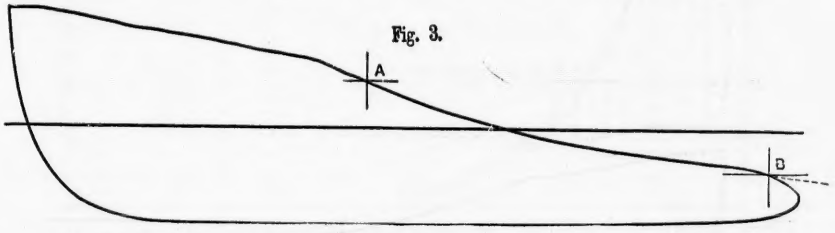
Fig. 2.



Crank end of high-pressure cylinder. The steam accounted for by indicator is calculated at the points *A* and *B*.

Spring C.—Equivalent scale, 60.13. M.E.P., 48.64. Horse-power, 397.6.

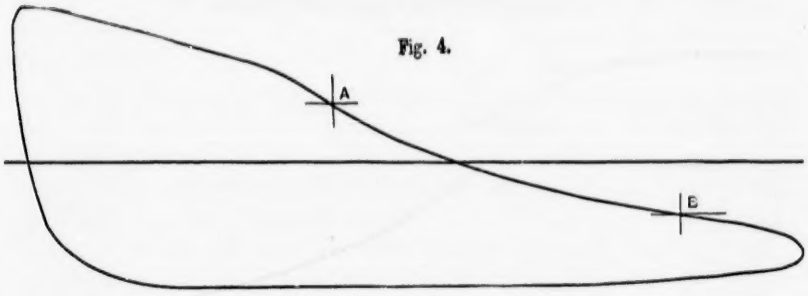
Fig. 3.



Head end of low-pressure cylinder. The steam accounted for by indicator is calculated at the points *A* and *B*.

Spring B.—Equivalent scale, 20.61. M.E.P., 13.65. Horse-power, 397.4.

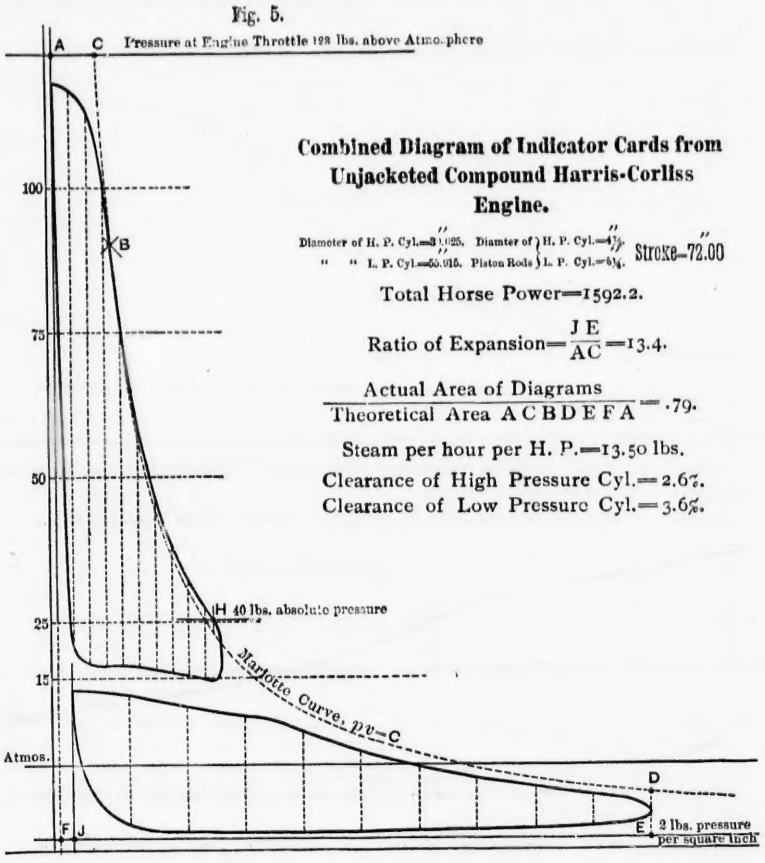
Fig. 4.



Crank end of low-pressure cylinder. The steam accounted for by indicator is calculated at the points *A* and *B*.

Spring A.—Equivalent scale, 16.74. M.E.P., 13.50. Horse-power, 389.6.

Fig. 5.



Combined Diagram of Indicator Cards from Unjacketed Compound Harris-Corliss Engine.

Diameter of H. P. Cyl.=31.025″. Diamter of Piston Rods } H. P. Cyl.=4″. L. P. Cyl.=6¼″. Stroke=72.00″

Diameter of L. P. Cyl.=50.015″.

Total Horse Power=1592.2.

Ratio of Expansion $= \frac{JE}{AC} = 13.4$.

$$\frac{\text{Actual Area of Diagrams}}{\text{Theoretical Area } ACBDEFA} = .79.$$

Steam per hour per H. P.=13.50 lbs.

Clearance of High Pressure Cyl.=2.6%.

Clearance of Low Pressure Cyl.=3.6%.

TABLE II.

NET AREAS OF CYLINDERS AND HORSE-POWERS.

	Net area in square inches.	Stroke × area × revolutions ÷ 33,000.	Horse-power.
High-pressure cylinder, head end	708.04	8.3948	407.6
High-pressure cylinder, crank end	689.37	8.1735	397.6
Average and total	698.70		805.2
Low-pressure cylinder, head end	2,455.54	29.1138	397.4
Low-pressure cylinder, crank end	2,433.89	28.8571	389.6
Average and total	2,444.71		787.0

Ratio of volume of low-pressure cylinder to volume of high-pressure cylinder = 3.50.
Total horse-power = 805.2 + 787.0 = 1,592.2.

TABLE III.

DATA TAKEN AT ENGINE.

Time. P. M.	Revolution counter.	Steam Pressure in Lbs. per Square Inch above Atmosphere.		Vacuum in inches of mercury by mercury column.	Temperature of Steam 3 Ft. from Engine, in Deg. Fahr.		Superheating in degrees Fahr.
		In main steam pipe 3 ft. from engine.	Receiver.		Actual reading of thermometer.	Reading of thermometer for satur. steam	
1.00	936,536	123.5	14.0	25.4	363	348	15
1.30	938,492	123	13.5	25.7	362	348	14
2.00	940,450	123	13.3	25.7	363	348	15
2.30	942,406	122	13.6	25.7	363	347	16
3.00	944,362	123	13.3	25.7	365	348	17
3.30	946,319	123	13.4	25.7	363	348	15
4.00	948,277	123	13.5	25.7	361	348	13
4.30	950,233	123.5	13.6	25.4	362	348	14
5.00	952,188	123	13.7	25.4	361	348	13
5.30	954,143	123.5	13.4	25.3	362	348	14
Per minute and average.	65.21	123.0	13.5	25.6	362.5	347.9	14.6

TABLE IV.

DATA TAKEN AT BOILERS.

Time, P.M.	Meter readings.	Temperature at meter.	Temperature at drip-tank.	Gauge on boiler No 1.	Water Levels, in Inches.								Corrected meter readings.*	Half-hourly rates by meter.
					No. 8.	No. 7.	No. 6.	No. 5.	No. 4.	No. 3.	No. 2.	No. 1.	Sum.		
1.00	31,905	147	131	125	16.0	10.0	11.8	12.5	7.5	9.5	11.5	8.3	87.1	31,905	.....
1.30	32,084	142	129	124	15.0	12.5	12.5	14.5	8.5	10.5	11.5	7.8	92.8	32,078.5	173 5
2.00	32,243	141	129	125	10.0	11.3	12.5	11.0	8.0	10.5	11.0	8.0	82.3	32,247.6	169.1
2.30	32,425	141.5	131	124	12.0	11.0	12.0	12.5	12.0	11.5	13.8	9.5	94.3	32,418.1	170.5
3.00	32,576	143.5	131.5	125	12.0	7.0	11.5	9.5	11.5	10.8	8.0	7.2	77.5	32,585 2	167.1
3.30	32,751	139.5	129.5	126	12.5	10.0	9.8	9.0	10.0	13.0	11 5	9.0	84.8	32,753.2	168.0
4.00	32,926	141 5	131.5	126	11.3	12.0	12.0	12.0	13.2	10.2	11.0	9.8	91.5	32,921.8	168.6
4,30	33,094	143	133	126	10.0	11.5	11.2	12.0	12.2	12.0	11.5	9.5	89.9	33,091.3	169.5
5.00	33,262	143	133	126	10.5	10.5	15.0	9.0	12)	9.0	10.5	8.5	85.0	33,264.0	172.7
5.30	33,429	145	134.5	126	11.2	8.4	13.2	8.0	11.2	11,0	11.0	7.8	81.8	33,434.1	170.1
	Average	142.7	131.3	125.3									86.7	Total	1.529.1

* One inch height in boiler = 0.96 cubic foot registered by meter.

TABLE V.

MEAN EFFECTIVE PRESSURES AND HORSE-POWERS.

Time. P.M.	High-Pressure Cylinder—Head.					High-Pressure Cylinder—Crank.					Low-Pressure Cylinder—Head.					Low-Pressure Cylinder—Crank.				
	Mean Height of Diagram.			Scale of spring.	Mean effective pressure.	Mean Height of Diagram.			Scale of spring.	Mean effective pressure.	Mean Height of Diagram.			Scale of spring.	Mean effective pressure.	Mean Height of Diagram.			Scale of spring.	Mean effective pressure.
	Computer No. 1.	Computer No. 2.	Average.			Computer No. 1.	Computer No. 2.	Average.			Computer No. 1.	Computer No. 2.	Average.			Computer No. 1.	Computer No. 2.	Average.		
1:05	0.8333	0.8321	0.8327	60.29	50.20	0.8218	0.8225	0.8222	60.13	49.44	0.8404	0.8380	0.8392	16.73	14.04	0.6609	0.6621	0.6615	20.60	13.63
1:30	0.7724	0.7697	0.7710	60.29	46.48	0.8034	0.8019	0.8026	60.13	48.26	0.8365	0.8341	0.8353	16.73	13.97	0.6578	0.6582	0.6580	20.60	13.55
2:00	0.8089	0.8089	0.8089	60.29	48.77	0.7962	0.7947	0.7954	60.13	47.83	0.8166	0.8170	0.8168	16.73	13.67	0.6540	0.6544	0.6542	20.60	13.48
2:30	0.8096	0.8067	0.8082	60.29	48.73	0.8056	0.8063	0.8060	60.13	48.46	0.8201	0.8209	0.8205	16.73	13.73	0.6545	0.6568	0.6557	20.60	13.51
3:00	0.8364	0.8341	0.8352	58.89	49.18	0.8088	0.8069	0.8079	60.13	48.58	0.8221	0.8189	0.8205	16.73	13.73	0.6551	0.6522	0.6537	20.60	13.47
3:30	0.8400	0.8356	0.8378	58.89	49.34	0.8142	0.8111	0.8127	60.13	48.87	0.6419	0.6430	0.6425	20.61	13.24	0.8002	0.8006	0.8004	16.74	13.40
4:00	0.8119	0.8100	0.8110	58.89	47.76	0.8131	0.8108	0.8119	60.13	48.82	0.6560	0.6545	0.6552	20.61	13.50	0.8084	0.8069	0.8076	16.74	13.52
4:30	0.8123	0.8107	0.8115	58.89	47.79	0.8119	0.8096	0.8108	60.13	48.75	0.6552	0.6557	0.6560	20.61	13.52	0.8037	0.8032	0.8034	16.74	13.45
5:00	0.7939	0.7951	0.7945	58.89	46.79	0.7900	0.7877	0.7888	60.13	47.43	0.6644	0.6612	0.6628	20.61	13.66	0.8060	0.8037	0.8049	16.74	13.47
5:30	0.8586	0.8551	0.8569	58.89	50.46	0.8321	0.8299	0.8310	60.13	49.97	0.6520	0.6534	0.6527	20.61	13.45	0.8057	0.8063	0.8060	16.74	13.49
Average					48.55	Average				48.54	Average				13.65	Average				13.50
Horse power					407.6	Horse power				397.6	Horse power				397.4	Horse power				389.6

TABLE VI.

CALCULATION OF STEAM ACCOUNTED FOR BY INDICATOR CARDS.

Time.	Cut-off in High-Pressure Cylinder in per cent of Stroke.*		Ratio of net volumes of Cylinders filled with Steam at the Pressures given below.							
			High-pressure Cylinder.				Low-pressure Cylinder.			
			Near Point of Cut-off at 105 lbs. Absolute Pressure.		Near Point of Release at 40 lbs. Absolute Pressure.		Near Point of Cut-off at 20 lbs. Absolute Pressure.		Near Point of Release at 10 lbs. Absolute Pressure.	
P. M.	Head End.	Crank End.	Head End.	Crank End.	Head End.	Crank End.	Head End.	Crank End.	Head End.	Crank End.
1:05	0.307	0.306	0.355	0.356	0.879	0.907	0.460	0.430	0.948	09.40
1:30	0.283	0.285	0.321	0.325	0.809	0.854	0.446	0.412	0.934	0.861
2:00	9.296	0.290	0.350	0.328	0.882	0.857	0.438	0.421	0.935	0.880
2:30	0.297	0.301	0.345	0.340	0.871	0.884	0.438	0.412	0.930	0.856
3:00	0.304	0.288	0.353	0.340	0.900	0.866	0.431	0.428	0.923	0.936
3:30	0.301	0.289	0.349	0.337	0.862	0.830	0.446	0.402	0.968	0.820
4:00	0.299	0.294	0.346	0.339	0.860	0.853	0.444	0.407	0.947	0.846
4:30	0.308	0.307	0.341	0.338	0.850	0.846	0.457	0.402	0.961	0.822
5:00	0.302	0.283	0.334	0.325	0.834	0.821	0.461	0.406	0.966	0.838
5:30	0.322	0.312	0.361	0.349	0.921	0.860	0.464	0.416	0.977	0.853
Average	0.302	0.296	0.346	0.388	0.867	0.858	0.448	0.414	0.949	0.865
	0.299		0.342		0.862		0.431		0.907	

Ratio of Expansion { From point marked C in Figs. 1 and 2 ..... 11.7
From the initial pressure point C, Fig. 5 ..... 13.4

High-Pressure Cylinder.

Average mean effective pressure in lbs. per square inch 48.59
Equivalent M. E. P. of low-pressure cylinder, 13.57×3.50 ..... 47.49
Total M. E. P. reduced to high-pressure cylinder 96.08

Steam per hour per horse-power } = { Ratio × density × 13.750 ÷ total M. E. P. }

$$\text{Near cut-off} = \frac{0.342 \times 0.2414 \times 13750}{96.08} = 11.81$$

$$\text{Near release} = \frac{0.862 \times 0.0074 \times 13750}{96.08} = 12.02$$

Steam not accounted for by indicator { Near cut-off 12.5%
Near release 11.0%

Low-Pressure Cylinder.

Average mean effective pressure in lbs. per square inch 13.57
Equivalent M. E. P. of high-pressure cylinder, 48.59×3.50 ..... 13.88
Total M. E. P. reduced to low-pressure cylinder 27.45

Steam per hour per horse power } = { Ratio × density × 13.750 ÷ total M. E. P. }

$$\text{Near cut-off} = \frac{0.431 \times 0.0507 \times 13750}{27.45} = 10.95$$

$$\text{Near release} = \frac{0.907 \times 0.0264 \times 13750}{27.45} = 11.99$$

Steam not accounted for by indicator { Near cut-off 18.9%
Near release 11.2%

* Apparent cut-off measured at points marked C, Figs. 1 and 2.

TABLE VII.

TESTS OF SPRINGS IN INDICATORS USED ON LOW-PRESSURE CYLINDER.

Spring.	Number of Card.	Heights measured on Diagrams, in Inches, from Atmospheric Line to Pressures given below.					
		Above Atmosphere.			Below Atmosphere.		
		5	10	15	4	8	12
A	1	0.245	0.500	0.750	0.190	0.385	0.570
A	2	0.245	0.505	0.750	0.190	0.380	0.575
A	3	0.250	0.495	0.745	0.195	0.380	0.575
A	4	0.250	0.500	0.750	0.190	0.385	0.575
A	5	0.250	0.500	0.745	0.195	0.385	0.575
Average		0.248	0.500	0.748	0.192	0.383	0.574
Scale		20.16	20.00	20.05	20.83	20.89	20.91
B	1	0.290	0.615	0.935	0.235	0.475	0.705
B	2	0.310	0.620	0.935	0.240	0.470	0.705
B	3	0.295	0.625	0.930	0.235	0.475	0.705
B	4	0.310	0.625	0.945	0.240	0.475	0.710
B	5	0.310	0.615	0.935	0.240	0.470	0.700
Average		0.303	0.620	0.936	0.238	0.473	0.705
Scale		16.50	16.13	16.03	16.81	16.91	17.02

TABLE VIII.

TESTS OF SPRINGS IN INDICATORS USED ON HIGH-PRESSURE CYLINDER.

Spring.	Number of Card.	Heights in inches measured on Diagrams starting from Lines 15 lbs. per square inch above the Atmosphere to Lines for Pressures given below.					Distance from atmospheric line to lines for 15lbs. pressure.
		25	50	75	100	120	
C	1	0.165	0.585	1.000	1.405	.....	.....
C	2	0.165	0.585	1.005	1.415	.....	0.265
C	3	0.165	0.585	0.995	1.410	1.745	0.260
C	4	0.170	0.585	1.000	1.405	1.745	0.260
C	5	0.170	0.590	0.995	1.410	1.745	0.255
Average		0.167	0.586	0.999	1.409	1.745	0.260
Scale		59.88	59.73	60.06	60.33	60.17	.....
D	1	0.160	0.575	0.990	1.420	1.770	0.230
D	2	0.155	0.575	1.000	1.425	1.775	0.220
D	3	0.155	0.575	1.000	1.405	1.765	0.225
D	4	0.155	0.565	0.995	1.400	1.760	0.235
D	5	0.155	0.580	0.990	1.425	1.775	0.220
Average		0.156	0.574	0.995	1.415	1.769	0.226
Scale		64.10	60.98	60.30	60.07	59.36	.....
E	1	0.155	0.575	1.005	1.455	1.810	0.230
E	2	0.160	0.575	1.005	1.460	1.825	0.225
E	3	0.155	0.575	1.000	1.455	1.815	0.235
E	4	0.160	0.585	1.015	1.470	1.820	0.225
E	5	0.155	0.575	1.010	1.475	1.810	0.230
Average		0.157	0.577	1.007	1.463	1.816	0.229
Scale		63.69	60.66	59.58	58.10	57.82	.....

TABLE IX.

SPRING A.—Calculations of Equivalent Scale Corrected for all Variations in the Hot Scale of the Spring.

AVERAGE CARD, HEAD END OF LOW-PRESSURE CYLINDER.

Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.
A1	+0.275	+0.629	20.03	+5.508	B1	−0.083	−0.190	20.83	−1.729
A2	+0.233	+0.533	20.01	+4.662	B2	−0.217	−0.497	20.90	−4.535
A3	+0.198	+0.453	20.04	+3.968	B3	−0.232	−0.531	20.91	−4.851
A4	+0.155	+0.355	20.09	+3.114	B4	−0.234	−0.536	20.91	−4.893
A5	+0.105	+0.240	20.16	+2.117	B5	−0.236	−0.540	20.91	−4.935
A6	+0.047	+0.108	20.16	+0.948	B6	−0.236	−0.549	20.91	−4.935
A7	−0.013	−0.030	20.83	−0.271	B7	−0.234	−0.536	20.91	−4.893
A8	−0.047	−0.108	20.83	−0.979	B8	−0.230	−0.526	20.90	−4.807
A9	−0.085	−0.195	20.33	−1.771	B9	−0.225	−0.515	20.90	−4.703
A10	−0.110	−0.252	20.85	−2.294	B10	−0.203	−0.465	20.90	−4.243
Totals...	+0.758	... .	.....	+15.002	Totals...	−2.130	.....	.....	−44.524

Equivalent scale = (15.001 + 44.524) ÷ (0.758 + 2.130) = 20.61.

AVERAGE CARD, CRANK END OF LOW-PRESSURE CYLINDER.

Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.
A1	+0.303	+0.693	20.04	+6.072	B1	−0.119	−0.272	20.86	−2.482
A2	+0.255	+0.584	20.02	+5.105	B2	−0.229	−0.524	20.90	−4.786
A3	+0.223	+0.510	20.00	+4.460	B3	−0.233	−0.533	20.91	−4.872
A4	+0.163	+0.373	20.08	+3.273	B4	−0.233	−0.533	20.91	−4.872
A5	+0.078	+0.178	20.16	+1.572	B5	−0.233	−0.533	20.91	−4.872
A6	+0.013	+0.030	20.16	+0.262	B6	−0.231	−0.529	20.90	−4.828
A7	−0.037	−0.085	20.83	−0.771	B7	−0.229	−0.524	20.90	−4.786
A8	−0.069	−0.158	20.83	−1.437	B8	−0.224	−0.513	20.90	−4.682
A9	−0.093	−0.211	20.84	−1.917	B9	−0.220	−0.503	20.90	−4.598
A10	−0.125	−0.286	20.86	−2.608	B10	−0.203	−0.465	20.90	−4.243
Totals...	+0.712	.....	.....	+14.011	Totals...	−2.154	.....	.....	−45.021

Equivalent scale = (14.011 + 45.021) ÷ (0.712 + 2 154) = 20.60.

TABLE X.

SPRING B.—Calculation of Equivalent Scale Corrected for all Variation in the Hot Scale of the Spring.

AVERAGE CARD, HEAD END OF LOW-PRESSURE CYLINDER.

Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.
A1	+.325	.759	16.08	+5.226	B1	−.073	.171	16.81	−1.227
A2	+.288	.659	16.12	+4.546	B2	−.263	.614	16.98	−4.466
A3	+.245	.572	16.19	+3.967	B3	−.285	.666	17.00	−4.845
A4	+.201	.470	16.30	+3.276	B4	−.291	.680	17.01	−4.950
A5	+.132	.308	16.49	+2.177	B5	−.291	.680	17.01	−4.950
A6	+.048	.112	16.50	+0.792	B6	−.290	.678	17.01	−4.933
A7	−.015	.035	16.81	−0.252	B7	−.287	.671	17.00	−4.879
A8	−.060	.140	16.81	−1.009	B8	−.284	.664	17.00	−4.828
A9	−.098	.229	16.81	−1.647	B9	−.280	.654	16.99	−4.757
A10	−.135	.315	16.84	−2.273	B10	−.257	.600	16.97	−4.361
Totals....	+.925	.....	.....	+14.803	Totals ...	−2.601	.....	.....	−44.196

Equivalent scale = (14.803 + 44.196) ÷ (.925 + 2.601) = 16.73.

TABLE X.—*Continued.*

AVERAGE CARD, CRANK END OF LOW-PRESSURE CYLINDER.

Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.
A1	+.345	.797	16.07	+5.544	B1	−.146	−.337	16.85	−2.460
A2	+.298	.688	16.11	+4.801	B2	−.284	−.656	16.99	−4.825
A3	+.255	.589	16.16	+4.121	B3	−.298	−.688	17.01	−5.069
A4	+.187	.432	16.35	+3.057	B4	−.298	−.688	17.01	−5.069
A5	+.082	.189	16.50	+1.353	B5	−.298	−.688	17.01	−5.069
A6	0	0	16.66	0	B6	−.298	−.688	17.01	−5.069
A7	−.063	.145	16.81	−1.059	B7	−.297	−.686	17.01	−5.052
A8	−.098	.226	16.81	−1.647	B8	−.293	−.677	17.00	−4.981
A9	−.125	.289	16.83	−2.104	B9	−.284	−.656	17.00	−4.825
A10	−.168	.388	16.88	−2.836	B10	−.267	−.617	16.98	−4.534
Totals	+.713			+11.230	Totals	−2.763			−46.953

Equivalent scale = (11.230 + 44.953) ÷ (.713 + 2.763) = 16.74.

TABLE XI.

SPRING C.—Calculations of Equivalent Scale Corrected for all Variations in the Hot Scale of the Spring. Areas measured from line 15 lbs. above the atm.

LARGEST CARD, CRANK END OF HIGH-PRESSURE CYLINDER.

Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.
A1	0.755	1.736	60.17	45.428	B1	+0.178	0.409	59.79	+10.643
A2	0.714	1.641	60.22	42.997	B2	+0.017	0.039	59.88	+ 1.018
A3	0.670	1.540	60.27	40.381	B3	+0.015	0.034	59.88	+ 0.898
A4	0.549	1.262	60.24	33.072	B4	+0.015	0.034	59.88	+ 0.898
A5	0.382	0.878	59.97	22.909	B5	+0.014	0.032	59.88	+ 0.838
A6	0.280	0.644	59.78	16.738	B6	+0.009	0.021	59.88	+ 0.539
A7	0.205	0.471	59.77	12.253	B7	+0.008	0.018	59.88	+ 0.479
A8	0.148	0.340	59.82	8.853	B8	+0.002	0.005	59.88	+ 0.120
A9	0.105	0.241	59.85	6.284	B9	−0.004	0.009	59.88	− 0.240
A10	0.075	0.172	59.88	4.491	B10	−0.009	0.021	59.88	− 0.539
Totals	3.883			233.406	Totals	+0.245			+14.654

Equivalent scale = (233.406 − 14.654) ÷ (3.883 − 0.245) = 60.130.

SMALLEST CARD, CRANK END OF HIGH-PRESSURE CYLINDER.

Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.
A1	0.752	1.729	60.18	45.255	B1	+0.175	0.402	59.80	+10.465
A2	0.710	1.632	60.22	42.756	B2	+0.017	0.039	59.88	+ 1.018
A3	0.665	1.529	60.27	40.080	B3	+0.015	0.034	59.88	+ 0.898
A4	0.504	1.159	60.17	30.326	B4	+0.015	0.034	59.88	+ 0.898
A5	0.348	0.800	59.90	20.845	B5	+0.014	0.032	59.88	+ 0.838
A6	0.245	0.563	59.74	14.636	B6	+0.009	0.021	59.88	+ 0.539
A7	0.180	0.414	59.79	10.762	B7	+0.005	0.011	59.88	+ 0.299
A8	0.128	0.294	59.84	7.660	B8	+0.001	0.002	59.88	+ 0.060
A9	0.087	0.200	59.87	5.209	B9	−0.002	0.005	59.88	− 0.120
A10	0.057	0.131	59.88	3.413	B10	−0.003	0.007	59.88	− 0.180
Totals	3.676			220.942	Totals	+0.246			+14.715

Equivalent scale = (220.942 − 14.715) ÷ (3.676 − 0.246) = 60.124.
Average equivalent scale = (60.130 + 60.124) ÷ 2 = 60.13.

TABLE XII.

SPRING D.—Calculation of Equivalent Scale Corrected for all Variations in the Hot Scale of the Spring. Areas measured from line 15 lbs. above the atm.

AVERAGE CARD, HEAD END OF HIGH-PRESSURE CYLINDER.

Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.
A1.....	.698	1.631	59.64	41.629	B1.....	+.173	.404	62.25	+10.769
A2.....	.680	1.589	59.72	40.610	B2.....	+.006	.014	64.10	+ .385
A3.....	.652	1.523	59.85	39.022	B3.....	+ 003	.007	64.10	+ .192
A4.....	.525	1.227	60.17	31.589	B4.....	+.003	.007	64.10	+ .192
A5.....	.370	.864	60.51	22.389	B5.....	+.002	.005	64.10	+ .128
A6.....	.249	.582	60.97	15.182	B6.....	−.002	.005	64.10	− .128
A7.....	.168	.393	62.32	10.470	B7.....	−.006	.014	64.10	− .385
A8.....	.117	.273	63.22	7.397	B8.....	−.012	.028	64.10	− .769
A9.....	.078	.182	62.91	4.985	B9.....	−.015	.034	64.10	− .962
A10.....	.047	.110	64.10	3.013	B10.....	−.018	.042	64.10	− 1.154
Totals...	3.584	.....	.....	216.286	Totals...	+.134	.....	.....	+ 8.268

Equivalent scale = (216.286 − 8.268) ÷ (3.854 − .134) = 60.29.

TABLE XIII.

SPRING E.—Calculations of Equivalent Scale Corrected for all Variations in the Hot Scale of the Spring. Areas measured from line 15 lbs. above the atm.

LARGEST CARD, HEAD END OF HIGH-PRESSURE CYLINDER.

Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.
A1	.738	1.724	57.89	42.723	B1	+.181	.423	61.78	+11.182
A2	.703	1.642	57.95	40.739	B2	+.005	.012	63.69	+ .318
A3	.672	1.570	58.01	38.983	B3	+.004	.009	63.69	+ .255
A4	.567	1.325	58.55	33.198	B4	+.004	.009	63.69	+ .255
A5	.398	.930	59.77	23.788	B5	+.003	.007	63.69	+ .191
A6	.278	.650	60.47	16.811	B6	0	0	63.69	0
A7	.202	.472	61.42	12.407	B7	−.002	.005	63.69	− .127
A8	.151	.353	62.28	9.404	B8	−.004	.009	63.69	− .255
A9	.098	.227	63.18	6.192	B9	−.005	.012	63.69	− .318
A10	.071	.166	63.67	4.521	B10	−.018	.042	63.69	− 1.146
Totals...	3.878	.....	.....	228.766	Totals..	+.168	.....	.....	+10.355

Equivalent scale = (228.766−10.355) ÷ (3.878−0.168) = 58.87.

SMALLEST CARD, HEAD END OF HIGH PRESSURE CYLINDER.

Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Correspond'g Scale.	Area × Scale.
A1	.710	1.663	57.94	41.137	B1	+.169	.396	61.97	+10.473
A2	.681	1.595	57.99	39.491	B2	+.005	.012	63.69	+ .318
A3	.662	1.550	58.03	38.416	B3	+.004	.009	63.69	+ .255
A4	.531	1.244	58.81	31.228	B4	+.004	.009	63.69	+ .255
A5	.349	.817	60.05	20.957	B5	+.004	.009	63.69	+ .255
A6	.238	.557	60.81	14.473	B6	0	0	63.69	0
A7	.172	.403	61.92	10.650	B7	−.004	.009	63.69	− .255
A8	.115	.269	62.89	7.232	B8	−.005	.012	63.69	− .318
A9	.075	.176	63.54	4.766	B9	−.007	.016	63.69	− .446
A10	.047	.110	63.69	2.993	B10	−.018	.042	63.69	− 1.146
Totals...	3.580	.....	.....	211.343	Totals...	+.152	.....	.....	+ 9.391

Equivalent scale = (211.343−9.391) ÷ 3.580−0.152) = 58.91.

Average equivalent scale = (58.87 + 58.91) ÷ 2 = 58.89.