GRADUATING THESIS.

TESTS ON THE EFFICIENCY OF THE POWER PLANT AT THE KANSAS STATE AGRICULTURAL COLLEGE.

BY

GLICK FOCKELE,

MURRAY S. COLE.

TESTS ON THE EFFICIENCY OF THE POWER PLANT AT THE KANSAS AGRICULTURAL COLLEGE.

The plant is designed to furnish heat and power for the various departments at the Kansas State Agricultural College of Manhattan, Kansas. It was originally intended by the writers to include in their work, tests on the heating power of the plant, but the arrangement of their other college work during the year, made it impossible for them to conduct the experiments at a time when the heating plant was in operation. Another drawback was the absence of suitable apparatus for the determination of the calorific power of the coal.

The heating plant consists of six externally fired, horizontal, multitubular boilers, designated as No. 1, 2, 3, 4, 5 and 6. Five are of 60 nominal horsepower and one, No. 6, is of 100 nominal horsepower. The tests were conducted upon No. 1, for the reason that it was the only high pressure boiler which was piped for individual feed water, and with this boiler is our interest concerned. None of the conneetions with other boilers could possibly affect results of these tests except in the test on April 28th, when No. 3 was turned in on account of the heavy load on the engine. In this case neither boiler made more steam than the engine could use, so the pressure in neither one was affected in the least and th conditions of the test were kept uniform. The boiler itself is 54" diameter, with 34 flues 3-3/4 inches in diameter and 16 feet long. The grates are 4-1/2' by 4-1/2'. The boiler was built by Joseph Bromich of Topeka, Kansas. It was installed in 1898. It was in very good condition for all tests.

The fuel used was the coal furnished by the state for use in the institution, and was of very poor quality. It comes from the state mines near Leavenworth, and is mined by the prisoners from the state penitentiary.

The engine tested was the one in general use as a source of power at the plant and was manufactured by A. L. Ide & Sons, of Springfield, Illinois. It is generally called the "Ideal," and is of 100 horsepower, and is direct connected with a 60 kilowatt dynamo. All apparatus used, such as thermometers and guages, were standard and were carefully tested as to correctness. By comparing the tachometer with an ordinary speed counter we found an error of nine revolutions per minute less than actual speed. The tabulated results are the corrected results.

The first boiler test was run on February 14, 1902. The steam generated was used in the heating system of the college. This test was run under the direction of W. M. Sawdon, Assistant in Engineering. The per cent of water was determined as recommended in "Smart's Laboratory Practice," the weight before exposure to heat being 14 lbs., 10-1/4 oz. and afterwards 13 lbs., 15-1/8 oz., showing a loss of 11-1/8 oz., or 4-3/4 per cent water.

Following are the data and results of the boiler tests. On the general forms:

Item 5 = 3 — (4 x 3) + 6

" 7 = 6 ÷ 3

" 9 = $\frac{\text{amount of water in steam + steam condensed}}{\text{steam condensed.}}$

" 10 = 8 x $\frac{\text{total heat (supposing all to be vaporized)}}{\text{heat of vaporization.}}$

" 11 = $\frac{\text{8 x heat of liquid + 8 x 9 x heat of vaporization}}{\text{heat of vaporization.}}$

" 14 = 8 ÷ 2

" 15 = 11 ÷ 2

" 16 = 15 ÷ area of surface

" 23 = 15 ÷ 34-1/2 lbs.

" 25 = 23 ÷ 24

Item 26 = 8 ÷ 3

" 27 = 11 ÷ 3

" 28 = 27 ÷ (100 % - 4)

" 29 = 11 ÷ 5

We will here take the opportunity of thanking Messrs. D. V. Corbin and Alexis J. Reed, of the Junior class, for the service rendered us in the taking of data on the boiler tests and also Messrs. C. E. Peterson and J. O. Baylor for their efficient services as firemen during the progress of the tests.

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	20¼	SQ. FT.
Water heating surface	606	" "
Ratio of grate to water heating surface	1:30	
Kind of fuel	LEAVENWORTH	

TOTAL QUANTITIES.

1.	Date of trial	FEB. 24, 1902	
2.	Duration of trial in hours	6	
3.	Weight of coal fired	1871	LBS.
4.	Per cent of water in coal	4¾	
5.	Total weight of coal consumed, in pounds	1550	
6.	Total ash and refuse	232	LBS.
7.	Percentage ash and refuse in coal	12.5	
8.	Total weight of water fed to boiler	9930½	LBS.
9.	Condition of steam	90.8%	
10.	Equivalent water apparently evaporated from and at 212° F.	11,059	LBS.
11.	Equivalent water actually evaporated from and at 212° F. (corrected for moisture in steam)	11,041.7	"

HOURLY QUANTITIES.

12.	Pounds coal consumed per hour	258½	
13.	Coal per hour per square foot of grate surface	12.7	LBS.
14.	Pounds feed water per hour	1655	"
15.	Equivalent water evaporated per hour from and at 212° F. (corrected for moisture in steam)	1840	"
16.	Equivalent water evaporated per square foot of heating surface per hour	2.76	"

AVERAGE BOILER PRESSURES, TEMPERATURES, ETC.

17.	Average boiler pressure, pounds per square inch, gage	59.8	
18.	Average boiler pressure, pounds per square inch, absolute	74.5	
19.	Average temperature of feed water, °Fahrenheit	49.8	
20.	Average temperature of boiler room, °Fahrenheit	65.16	
21.	Average temperature of outside air, °Fahrenheit		
22.	Barometer		

HORSE-POWER.

23.	Horse-power developed	53.3	
24.	Builders' rated horse-power	60	
25.	Percentage of builders' rated horse-power	89⅓	

ECONOMIC RESULTS.

26.	Water apparently evaporated per pound of coal under actual conditions	5.3	LBS.
27.	Equivalent water actually evaporated from and at 212° F., per pound of coal fired	5.9	"
28.	Equivalent evaporation from and at 212° F., per pound of dry coal	6.2	"
29.	Equivalent evaporation from and at 212° F., per pound of combustible	7.1	"

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

TEST MADE AT THE COLLEGE POWER PLANT, MANHATTAN, KANSAS.
ON BOILER No 1.
DATE FEB. 24, 1902.

LOG OF BOILER TRIAL.

OBSERVERS:
GLICK FOCKELE
MURRAY S. COLE.

Time.	Pressures.		Temperatures, °F.				Weights.									Remarks.
							Coal.			Cinders.			Water.			
	Barometer.	Steam Gage.	External Air.	Boiler Room.	Feed Water.	Flue Gases.	Gross.	Tare.	Net.	Gross.	Tare.	Net.	Gross.	Tare.	Net.	
10:15 AM		65		68	50		157	22	135				280	38	242	
10:30		60		62			163	22	141				280	40	240	
10:45		60		60	50		164	22	142				280	41	239	
11:00		60		62	47.3		165	22	143				284	42	239	
11:15		60		64	50		192	22	170				282½	40	242½	
11:30		61		65	53.6		188	22	166				282	52	230	
11:45		60		65	48.2								282	40½	242½	
12:00		60		66	47.3		188	22	166				283	41	242	
12:15 P.M.		60		65									282	42	240	
12:30		57½		66	47.3								281	46	235	
12:45		60		65									286	42	244	
1:00		58		67	47.3								285	40	245	
1:15		60		67			172	22	150				282½	48	233½	
1:30		63		65			189	22	167				284	44	240	
1:45		60		65	59.9								283	47	236	
2:00		59		66	47.3								281	46	235	
2:15		60		64			184	22	162				261	40	221	
2:30		60		67			128	22	106				279	45	234	
2:45		60		67	53.6								280	46	234	
3:00		60		66	48.2								281	50	230	
3:15		60		66	46.4		182	22	160				284	41½	232½	
3:30		61		65									282½	44	238½	
3:45		60		65									282½	47	235½	
4:00		59		65			100	37	63				282½	41½	241	
4:15		60		65									281	42½	238½	
										254	22	232	284½	43	241½	
													282	53	229	
					51.8								285	43	242	
													280	42½	237½	
					48.2								281	45	236	
													281	42½	238½	
					51.8								568½	83	485½	
													560	97½	462½	
													284½	52	232½	
													282½	40½	242	
					50								280	45½	234½	
													280	41½	238½	
													281½	43	238½	
													281	42½	238½	
													229	41	188	
Total,		1495		1629	896.4				1871	254	22	232			9930½	
Average,		59.8		65.16	49.8											

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

MADE AT THE COLLEGE POWER PLANT
MANHATTAN, KANSAS.
ON BOILER NO. 1
DATE FEB. 24 1902.

PRIMING LOG.
(SEPARATING CALORIMETER.)

OBSERVERS:
GLICK FOCKELE.
MURRAY S. COLE.

No.	Time.		Scale reading.		Amount of water in steam.	Weight on scales.		Condensed steam.	Quality of steam.	Remarks.
	Start.	Stop.	Start.	Stop.		Start.	Stop.			
			oz.	oz.	oz	lbs. oz.	lbs. oz.	lbs. oz		
1	11:35 A.M.	11:38 A.M.	3.1	4.6	1.5	16 — 14½	18 — 4¾	1 — 6½	98.1%	
2	1:17 P.M.	1:25 P.M	.7	1.5	.8	19 — 14¼	21 — 11	1 — 12¾	97¼%	
3	1:47	1:55	8.4	10.9	2.5	20 — 12¾	22 — 4	1 — 7¼	87.3%	
4	2:9	2:14	6.8	9.3	2.5	18 — 9	19 — 10¼	1 — 1¼	90.2%	
5	2:24	2:29	1.4	4.0	2.6	18 — 8	19 — 9	1 — 1	86.7%	
6	3:7	3:12	1.2	3.9	2.7	16 — 0	17 — 1	1 — 1	86.3%	
7	3:35	3:41	1.2	4.6	3.4	18 — 6¾	19 — 15	1 — 8¼	80.4%	
8	3:48	3:56	7.5	9.8	2.3	20 — 12½	22 — 4	1 — 7½	91.3%	
									90.8%	

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	20¼	SQ. FT.
Water heating surface	606	" "
Ratio of grate to water heating surface	1:30	
Kind of fuel	LEAVENWORTH	

TOTAL QUANTITIES.

1.	Date of trial	APR. 19,	1902
2.	Duration of trial in hours	8	
3.	Weight of coal fired	3985	LBS
4.	Per cent of water in coal	4¾	
5.	Total weight of coal consumed, in pounds	29902	
6.	Total ash and refuse	855½	LBS.
7.	Percentage ash and refuse in coal	21½	
8.	Total weight of water fed to boiler	18206	LBS.
9.	Condition of steam	87%	
10.	Equivalent water apparently evaporated from and at 212° F.	21571	LBS.
11.	Equivalent water actually evaporated from and at 212°F (corrected for moisture in steam)	164127	"

HOURLY QUANTITIES.

12.	Pounds coal consumed per hour	367½	
13.	Coal per hour per square foot of grate surface	18.14	LBS.
14.	Pounds feed water per hour	2275¾	
15.	Equivalent water evaporated per hour from and at 212° F. (corrected for moisture in steam)	2051.6	LBS.
16.	Equivalent water evaporated per square foot of heating surface per hour	3.87	"

AVERAGE BOILER PRESSURES, TEMPERATURES, ETC.

17.	Average boiler pressure, pounds per square inch, gage	65 3/11	
18.	Average boiler pressure, pounds per square inch, absolute	79.97	
19.	Average temperature of feed water, ° Fahrenheit	55.8	
20.	Average temperature of boiler room, ° Fahrenheit	69.2	
21.	Average temperature of outside air, ° Fahrenheit	51.58	
22.	Barometer		

HORSE-POWER.

23.	Horse-power developed	592½	
24.	Builders' rated horse-power	60	
25.	Percentage of builders' rated horse-power	99⅛	

ECONOMIC RESULTS.

26.	Water apparently evaporated per pound of coal under actual conditions	4.5	LBS.
27.	Equivalent water actually evaporated from and at 212° F., per pound of coal fired	4.1	"
28.	Equivalent evaporation from and at 212° F., per pound of dry coal	4.3	"
29.	Equivalent evaporation from and at 212° F., per pound of combustible	5.58	"

Department of Mechanical Engineering, K. S. A. C.

Log of Boiler Trial.

Test made at The College Power Plant
Manhattan, Kansas.
On Boiler No 1.
Date April 14, 1902

Observers:
Glick Fockele
Murray S Cole.

Time.	Pressures.		Temperatures, °F.				Weights.									Remarks.
							Coal.			Cinders.			Water.			
	Barometer.	Steam Gage.	External Air.	Boiler Room.	Feed Water.	Flue Gases.	Gross.	Tare.	Net.	Gross.	Tare.	Net.	Gross.	Tare.	Net.	
8:30 A.M.		60	50	61.5	57		150	22	128				471½	92	379½	
8:45		65	50	64	55.4		145		123				474	92	382	
9:—		70	45.5	63			147½		125½				476	91½	384½	
9:15		65	45.5	64			151½		128½				474	142½	331½	
9:30		67	46.4	65	53.6		144	22	122				472	99	373	
9:45		64	47.3	66			154		132				469½	95	374½	
10:—		67	47.3	67.5	53.6		147		125				472	97	375	CLEANED FIRE
10:15		65	49.1	70	55.4		151		129				474½	137½	337	
10:30		65	50.9	69			153		131				470½	96	374½	
10:45		65	50	68	53.6		152	22	130				478½	101	377½	
11:—		65	50	69.5			154		132				475	98	377	
11:15		65	51.8	69			145		123				473	95	378	CLEANED FIRE.
11:30		65	51.8	68	53.6		153	23	130	96	23½	72½	473	101½	371½	
11:45		70	51.8	69.5	53.6		147½		124½	138	23½	114½	476½	109	367½	
12:—		67	53.6	73			156		133	170	23½	146½	478	100	378	
12:15 P.M.		65	54.5	69	53.6		180		157				477½	105	372½	
12:30		65	54.5	70	53.6		182		159				480	87	373	CLEANED FIRE
12:45		60	54.5	68			181½		158½				476	103½	372½	
1:—		70	51.8	69	53.6		154		131				474	91	383	
1:15		65	51.8	69	52.7		152		129			30	460	90	370	
1:30		65	52.7	70			175	23	152				478	100	378	
1:45		65	55.4	72.5	53.6		200	23	177				476	101	375	
2:—		65	57.2	73			187		164				476	93	383	CLEANING FIRE.
2:15		65	55.4	75			188		165				475	100	375	
2:30		67	55.4	74			190	23	167				476	99	377	
2:45		65	53.6	72			171		148				465	99	366	
3:—		63	54.5	71			154	23½					953	194	759	
3:15		65	54.5	73	53.6		165	23	142				480	98	382	CLEANED FIRE.
3:30		65	55.4	71			158	23	85				477	97	380	
3:45		65	53.6	71	53.6								476	101	375	
4:—		63	53.6	71									955	194	761	
4:15		66	53.6	70	53.6								473	111	362	
4:30		65	53.6	70									470	101	369	
										160	23½	136½	947½	207	740½	
										147		123½	944½	169	775½	
										147		123½	946	159	787	
										162	23½	138½	945	156	789	
													942	163	779	
													947	181	766	
													475	81	394	
Total,		2154	1901.975	2085.5	892.8				3985			855½			18206	
Average,		65 3/11	51.575	69.2	55.8											

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

MADE AT THE COLLEGE POWER PLANT
MANHATTAN, KANSAS
ON BOILER NO. 1,
DATE APRIL 14, 1902

PRIMING LOG.
(SEPARATING CALORIMETER.)

OBSERVERS:
GLICK FOCKELE,
MURRAY S. COLE

No.	Time.		Scale reading.		Amount of water in steam.	Weight on scales.		Condensed steam.	Quality of steam.	Remarks.
	Start.	Stop.	Start.	Stop.		Start.	Stop.			
			oz.	oz.	oz	lbs. oz.	lbs. oz.	LBS. .OZ		
1	9 : 4	9 : 8	3	5	2	15 — 14	16 — 10½	0 — 12½	86%	
2	9 : 35	9 : 38½	3	4	1	20 — 11	21 — 6¼	0 — 12¼	91 9/10 %	
3	10 : 6½	10 : 10½	2.5	5	2.5	19 — 1¾	20 — 0¼	0 — 14½	85%	
4	11 : 4½	11 : 8½	2	4.5	2.5	19 — 2¼	19 — 15	0 — 12¾	83 3/5 %	
5	12 : 6	12 : 11	3.3	7.5	4.2	18 — 5½	19 — 7¼	1 — 1¾	80.86%	
6	1 : 34	1 : 38	3.3	4.2	0.9	18 — 12	19 — 9¼	0 — 13¼	93.7%	
7	2 : 3	2 : 7	2	4.9	2.9	21 — 2¾	22 — 0	0 — 13¼	82%	
8	2 : 52	2 : 56	2.4	5.9	3.4	21 — 0½	21 — 15	0 — 14½	80½%	
9	3 : 33	3 : 36	2.6	3.2	0.6	18 — 10	19 — 3¾	0 — 9¾	94 1/3 %	
10	4 : 21	4 : 25	3.3	5	1.7	21 — 13½	22 — 11	0 — 13½	88 2/3 %	
								AVERAGE	87 %	

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	20¼	SQ. FT.
Water heating surface	606	" "
Ratio of grate to water heating surface	1:30	
Kind of fuel	LEAVENWORTH	

TOTAL QUANTITIES.

1.	Date of trial	APRIL 28, 1902	
2.	Duration of trial in hours	7	
3.	Weight of coal fired	2445	LBS
4.	Per cent of water in coal	4¾	%
5.	Total weight of coal consumed, in pounds	1934.36	
6.	Total ash and refuse	349.5	"
7.	Percentage ash and refuse in coal	14⅓	%
8.	Total weight of water fed to boiler	13,218	"
9.	Condition of steam	84	%
10.	Equivalent water apparently evaporated from and at 212° F.	15,882.4	
11.	Equivalent water actually evaporated from and at 212° (corrected for moisture in steam)	11,548	

HOURLY QUANTITIES.

12.	Pounds coal consumed per hour	276.3	
13.	Coal per hour per square foot of grate surface	13.64	
14.	Pounds feed water per hour	1888.28	
15.	Equivalent water evaporated per hour from and at 212° F. (corrected for moisture in steam)	1649.7	LBS.
16.	Equivalent water evaporated per square foot of heating surface per hour	2.7	"

AVERAGE BOILER PRESSURES, TEMPERATURES, ETC.

17.	Average boiler pressure, pounds per square inch, gage	65.34	
18.	Average boiler pressure, pounds per square inch, absolute	80.04	
19.	Average temperature of feed water, Fahrenheit	56.3	
20.	Average temperature of boiler room, Fahrenheit	77	
21.	Average temperature of outside air, Fahrenheit	67.55	
22.	Barometer		

HORSE-POWER.

23.	Horse-power developed	47.8	
24.	Builders' rated horse-power	60.	
25.	Percentage of builders' rated horse-power	80	

ECONOMIC RESULTS.

26.	Water apparently evaporated per pound of coal under actual conditions	5.4	LBS.
27.	Equivalent water actually evaporated from and at 212° F., per pound of coal fired	4.72	"
28.	Equivalent evaporation from and at 212° F., per pound of dry coal	4.9	"
29.	Equivalent evaporation from and at 212° F., per pound of combustible	5.9	"

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

TEST MADE AT THE COLLEGE POWER PLANT.
MANHATTAN, KANSAS.
ON BOILER No. 1.
DATE APRIL 28, 1902

LOG OF BOILER TRIAL.

OBSERVERS:
GLICK FOCKELE,
MURRAY S. COLE.

Time.	Pressures.		Temperatures, °F.				Weights.									Remarks.
							Coal.			Cinders.			Water.			
	Barometer.	Steam Gage.	External Air.	Boiler Room.	Feed Water.	Flue Gases.	Gross.	Tare.	Net.	Gross.	Tare.	Net.	Gross.	Tare.	Net.	
8:15 A.M.		72½	69.8	72.5	57.2		176	23	153				458	78	380	
8:30 "		72	63.5	73.			182	23	159				470	78	392	
8:45 "		77½	65.3	73.	56.3		179	23	156				471½	99	372½	
9:00 "		72	65.75	75.5	55.85		194	23	181				472½	95½	377	
9:15 "		67½	65.75	75.			210	23	187				476	80	396	
9:30 "		62½	65.3	76			227½	23	204½				473½	79	394½	
9:45 "		75	65.3	74			243	23	220				471	92	379	
10:00 "		70	66.2	75	55.85		215	23	192				472½	94	378½	
10:15 "		67	68.	76			267	23	244	113	23	90	473	85	388	TURNED HIGH PRESSURE TO DAIRY.
10:30 "		57	67.1	76			240	23	217	141½	23	118½	471½	85½	386	CLEANED FIRE.
10:45 "		65	66.2	76			258	23	235				471½	78	393½	
11:00 "		67½	66.2	75.5	.		259	23	236				476	78	398	
11:15 "		70	66.2	75.5	56.3		210	23	187				478	78	400	
11:30 "		72½	68.	75.5	57.2		176	23	153	164	23	141	459½	78	381½	
11:45 "		66	69.8	77.	57.2		203	23	180				470	84	386	CLEANED FIRE.
12:00 M		55	71.6	78	56.3		155	23	132				473	95	378	
12:15 P.M.		52	68.9	78.5			200	23	167				467	78½	388½	
12:30 "		65	68.9	77.			265	23	242				472	76	396	
12:45 "		65	69.8	78									471	78	393	
1:00 "		65	72.5	78	56.3								477	74	403	
1:15 "		65	71.6	79.5									474	74	400	CLEANED FIRE.
1:30 "		58	71.6	80.									480	73	407	
1:45 "		57	71.6	80.									473	88	385	
2:00 "		50	70.7	79.5	57.2								484	85	399	TURNED IN No. 3
2:15 "		57	71.6	79.									474½	74½	400	AT SAME PRESSURE.
2:30 "		62½	72.5	80.									475	74½	400½	
2:45 "		72½	79.	71.6	57.2								475	88½	386½	
3:00 "		72	79½	71.6									475	79½	395½	
3:15 "		65	79.5	72.5									468	86	382	
					56.2								473	87	386	
													473½	80½	393	
													472	80½	391½	
					56.2								478	78½	399½	
													476	136½	339½	
TOTAL WEIGHED OUT									3445½							
WEIGHED BACK									1000½							
Total, FIRED		1895.	1958.95	2233	731.9				2445¼	418½	69	349½			13218	
Average.		65.34	67.55	77	56.3											

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

MADE AT THE COLLEGE POWER PLANT.
MANHATTAN, KANSAS.
ON BOILER NO. 1.
DATE APRIL 28, 1902.

PRIMING LOG.
(SEPARATING CALORIMETER.)

OBSERVERS:
GLICK FOCKELE
MURRAY S. COLE.

No.	Time. Start.	Time. Stop.	Scale reading. Start. oz.	Scale reading. Stop. oz	Amount of water in steam.	Weight on scales. Start. lbs. oz.	Weight on scales. Stop. lbs. oz.	Condensed steam. lbs. oz	Quality of steam.	Remarks.
1	9:4 A.M.	9:8 A.M.	0.6	6.5	5.9 oz.	18 - 6¼	19 - 8	1 - 1¾	75%	
2	9:51:30 "	9:54:30 "	3.5	8.6	5.1	18 - 5¼	19 - 8½	1 - 3¼	79%	
3	10:37 "	10:40 "	3.0	5.25	2.25	18 - 9½	19 - 10½	1 - 1	83+%	
4	11:36 "	11:39 "	3.9	9.9	6.0	15 - 6½	16 - 8¼	1 - 1¾	74.1%	
5	12:24 P.M.	12:27 P.M.	2.0	3.3	1.1	19 - 9	20 - 8	0 - 15	93.7%	
6	1:34 "	1:37 "	2.35	6.6	4.25	17 - 12½	18 - 11½	0 - 15	77.4	
7	2:24:30 "	2:27:30	4.05	4.9	0.85	16 - 5½	17 - 5½	1 - 0	95%	
8	2:33:30	2:36:30	1.6	2.8	1.2	19 - 15¾	21 - 2½	1 - 2¾	93.9%	
9	3:3:30	3:6:30	4.0	5.7	1.7	20 - 6½	21 - 8	1 - 1½	91.2%	
								AVERAGE	84%	

The discrepancy between the calorimeter logs for the boiler tests and those of the engine tests is explained by the fact that during the latter, two boilers were in use and thus vaporization was less rapid in each boiler than in the one in use during the boiler tests, and for this reason there was less tendency to priming.

Reference to the tables following will show the high quality of steam in use during the engine tests. It was originally the intention of the writers to derive the efficiency of the piping from the quotient of the quality at the engine by the quality at the boiler, but this was impracticable for the reason that we had but one calorimeter.

As is shown on the log of the engine trial opposite, the brake load was determined from the switch board in volts and amperes, and the brake horsepower was computed from the equation

$$B.\ H.\ P. = \frac{\text{volts x amperes}}{746}$$

In determining the indicated horsepower we made use of the equation:

$$I.\ H.\ P. = K \times M.\ E.\ P. \times r.\ p.\ m.$$

where K is the constant of cylinder, viz: .004022 and .003954 for the head and crank ends respectively. That is,

$$K\ (\text{crank end}) = \frac{\text{area of crank end piston in inches x stroke in feet}}{33000}$$

and $$K\ (\text{head end}) = \frac{\text{area of head end piston in inches x stroke in feet}}{33000}$$

The mean effective pressure was determined from the indicator cards in the usual way, by taking the quotient of the area by the length x strength of spring, 50 lbs. The efficiency, E, of the engine was computed as follows:

$$E = \frac{B.\ H.\ P.}{I.\ H.\ P.}$$

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

LOG OF ENGINE TRIAL.

TEST MADE AT THE COLLEGE POWER PLANT.
MANHATTAN, KANSAS.
ON THE IDEAL ENGINE
DATE MAY 21, 1902

CONSTANTS OF ENGINE.

Diameter of cylinder.... 12 in. Area of piston H. E..... 132.73 sq. in.
Diameter of piston rod.. 1 11/16 in. Area of piston C. E..... 130.49 sq. in.
Length of stroke ..... 1 ft. Engine constant for H. E., .004022
Engine constant for C. E., .003954

OBSERVERS:
GLICK FOCKELE,
MURRAY S. COLE.

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.		
1	1:00 P.M.	277	5.506	7.290	6.135	7.988	14.123	220	20	5.898	NO LOAD
2	1:15	277	5.764	5.619	6.424	6.156	12.580	221	22½	6.665	
3	1:30	276	7.781	9.222	8.639	10.070	18.709	220	50	14.712	LOAD ON
4	1:45	282	24.56	22.835	27.86	25.47	53.33	221	150	44.336	
5	2:00	274	26.87	25.865	29.60	28.035	57.645	220	167½	49.83	
6	2:15	280	20.895	21.329	23.525	23.625	47.150	222½	135	40.173	
7	2:30	277	21.43	20.43	23.7	23.470	47.17	220	135	39.722	
8	2:45	279	29.657	28.225	33.28	31.15	64.43	220	185	54.483	
9	3:00	279	28.357	26.36	31.825	29.09	60.915	220	175	51.42	
10	3:15	280	30.117	28.41	33.92	31.465	65.385	220	187½	55.169	
11	3:30	278	29.83	28.41	33.36	31.24	64.600	220	187½	55.169	
12	3:45	280	33.8	29.657	38.069	32.85	70.919	220	205	60.321	
13	4:00	280	24.49	23.035	27.582	25.515	53.097	220	150	44.235	
14	4:15	275	22.468	21.452	24.85	23.335	48.185	220	140	41.193	
15	4:30	275	23.325	21.722	25.80	23.63	49.43	220	145	42.764	
16	4:45	277	27.65	25.74	30.81	30.3	61.13	217½	150	43.633	
17	5:00	280	28.433	27.12	32.02	30.4	62.42	220	175	51.42	
	Maximum,	282	33.8	29.657	38.069	32.85	70.919	222½	205	60.321	
	Minimum,	275	5.506	5.619	6.135	6.156	12.580	217½	20	5.898	
	Total,	4126	390.933	373221	437.409	413.789	851.198	3742	2380	701.093	
	Average,	278	22.99	21.95	25.729	24.34	50.068	220.1	140	41.24	

AVERAGE EFFICIENCY 82.3%

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

MADE AT THE COLLEGE POWER PLANT
MANHATTAN, KANSAS.
ON THE IDEAL ENGINE
DATE MAY 21, 1902

PRIMING LOG.
(SEPARATING CALORIMETER.)

OBSERVERS:
GLICK FOCKELE
MURRAY S COLE.

No.	Time. Start.	Time. Stop.	Scale reading. Start. oz	Scale reading. Stop. oz	Amount of water in steam. .oz	Weight on scales. Start. lbs. oz.	Weight on scales. Stop. lbs. oz.	Condensed steam. LBS. .oz.	Quality of steam.	Remarks.
1	1-21:15	1:24:15	4.3	5.9	1.6	17 - 12¼	18 - 7½	0 - 11¼	87½%	
2	1:50	1:53	2.6	3.6	1.0	19 - 9¾	20 - 10½	0 - 16¾	93%	
3	2:19	2:22	2.0	2.6	0.6	19 - 1½	20 - 9	1 - 7½	97½%	
4	2:47	2:50	5.2	6.2	1.0	19 - 14	20 - 14¼	1 - 0¼	94%	
5	3:21	3:24	3.5	4.6	1.1	18 - 15¾	20 - 0½	1 - 0¾	94%	
6	3:56	3:59	7.4	7.8	0.4	18 - 12¼	19 - 14	1 - 1¾	98%	
7	4:32	4:35	6.6	7.6	1.0	20 - 2	21 - 8	1 - 6	95½%	
								AVERAGE	94.3%	

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

LOG OF ENGINE TRIAL.

TEST MADE AT THE COLLEGE POWER PLANT
MANHATTAN, KANSAS.
ON THE IDEAL ENGINE
DATE MAY 31, 1902

CONSTANTS OF ENGINE.

Diameter of cylinder.... 13 in. Area of piston H. E..... 132.72 sq. in.
Diameter of piston rod.. 1 11/16 in. Area of piston C. E..... 130.99 sq. in.
Length of stroke ..... 1 ft. Engine constant for H. E., .004022
Engine constant for C. E., .003954

OBSERVERS:

GLICK FOCKELE
MURRAY S. COLE.

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.		
1	8:—AM	277	12.83	12.39	14.295	13.578	27.873	220	85	25.11	
2	8:15	277	12.54	12.975	13.97	14.22	28.19	220	85	25.11	
3	8:30	280	14.434	14.14	16.256	15.66	31.916	220	90	26.54	
4	8:45	281	10.55	11.56	11.925	11.738	23.663	220	75	22.11	
5	9:—	277	11.595	13.044	12.92	14.295	27.215	219	85	24.95	
6	9:15	281	10.64	11.66	12.026	12.96	24.986	220	68	20.05	
7	9:30	277	9.325	9.906	10.39	10.855	21.245	219	60	17.72	
8	9:45	280	9.621	9.468	10.835	10.487	21.322	220	60	17.69	
9	10:—	281	8.822	10.59	9.971	11.77	21.741	220	28	8.257	
10	10:15	280	3.6445	5.976	4.1045	6.18	10.2845	219	62.5	17.93	
11	10:30	280	9.481	11.556	10.679	12.8	23.479	221	62.5	18.51	
12	10:45	277	10.00	11.322	11.143	12.46	23.603	220	62.5	18.43	
13	11:—	280	8.565	10.375	8.646	11.49	20.136	220	59	17.4	
14	11:15	280	10.735	11.765	12.09	13.03	25.12	219	72.5	21.28	
15	11:30	280	13.235	14.119	14.905	15.64	30.545	220	87	25.66	
16	11:45	281	10.994	13.404	12.422	14.9	27.322	220	76	22.41	
17	12:—	278	11.178	11.323	12.50	12.45	24.95	220	68	20.05	
18	12:15 P.M	273	11.195	12.538	12.294	13.54	25.834	220	70	20.64	
19	12:30	285	2.985	6.269	3.422	7.0678	10.4898	220	22	6.488	NO LOAD EXCEPT AT THE DAIRY.
20	12:45	281	2.187	5.394	2.472	5.995	8.467	220	21	6.192	
21	1:—	281	3.0075	5.564	3.3995	6.184	9.5835	220	23	6.782	
22	1:15	283	2.5565	5.564	2.91	6.228	9.138	220	18	5.308	
23	1:30	279	5.294	6.765	5.9905	7.463	13.4035	220	32	9.437	POWER FOR SHOPS THROWN ON
24	1:45	277	11.26	19.26	12.546	20.11	32.656	218	75	21.91	
25	2:—	277	8.089	9.8465	9.012	10.79	19.802	220	57	16.81	
26	2:15	281	8.8215	9.8465	9.97	10.945	20.915	220	57	16.81	
27	2:30	280	8.746	9.323	9.85	10.325	20.275	220	57	16.81	
28	2:45	280	8.746	9.767	9.85	10.818	20.768	220	57	16.81	
29	3:—	277	8.455	9.184	9.42	10.073	19.493	220	56	16.52	
30	3:15	279	8.384	10.295	9.409	10.36	20.769	220	58	17.1	
31	3:30	277	8.746	9.622	9.745	10.543	20.288	220	60	17.69	
32	3:45	277	8.601	9.765	9.584	10.7	20.284	220	58	17.1	
33	4:—	280	9.826	9.926	11.18	10.995	22.175	220	57	16.81	
	Maximum,	285	14.434	19.26	16.256	20.11	32.656	221	90	26.54	
	Minimum,	273	2.187	5.394	2.472	5.995	8.467	218	18	5.308	
	Total,		305.196	333.502	330.0115	359.5468	689.5583	7255	1964	561.614	
	Average,		9.248	10.106	10.0003	10.895	20.8953	219.85	59.51	17.18	

AVERAGE EFFICIENCY 82%

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

MADE AT THE COLLEGE POWER PLANT
MANHATTAN, KANSAS.
ON THE IDEAL ENGINE
DATE MAY 31, 1902

PRIMING LOG.
(SEPARATING CALORIMETER.)

OBSERVERS:
GLICK FOCKELE
MURRAY S COLE

No.	Time. Start.	Time. Stop.	Scale reading. Start.	Scale reading. Stop.	Amount of water in steam.	Weight on scales. Start.	Weight on scales. Stop.	Condensed steam.	Quality of steam.	Remarks.
			oz.	oz.	oz.	lbs. oz.	lbs. oz.	LBS OZ		
1	8:49	8:52	1.5	2.8	1.3	17 – 13	18 – 8¼	0 – 11¼	89 2/9 %	
2	9:55:30	9:59:30	2.8	4.0	1.2	19 – 3¼	20 – 6½	1 – 3¼	99 %	
3	10:53	10:56	2.6	3.6	1.0	21 – 3¼	22 – 3½	0 – 13	93 %	
4	11:55:30	11:58:30	2.5	3.5	1.0	20 – 9½	21 – 9¼	0 – 15¾	94 %	
5	1:9:30	1:12:30	2.5	3.0	0.8	18 – 6½	19 – 6½	0 – 16	96 %	
6	2:5	2:8	4.2	4.8	0.6	19 – 2	19 – 14½	0 – 12½	95.5 %	
7	2:49	2:52	3.3	4.9	1.1	19 – 9½	20 – 7¼	1 – 2¾	94.5 %	
8	3:48	3:51	2.3	3.5	1.2	18 – 3¾	19 – 8	1 – 9¼	94.5 %	
								AVERAGE	93.8 %	

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

LOG OF ENGINE TRIAL.

TEST MADE AT THE COLLEGE POWER PLANT
MANHATTAN, KANSAS.
ON THE IDEAL ENGINE
DATE JUNE 2, 1902

CONSTANTS OF ENGINE.

Diameter of cylinder.... 13 in. Area of piston H. E..... 132.73 sq. in.
Diameter of piston rod.. 1 11/16 in. Area of piston C. E..... 130.49 sq. in.
Length of stroke ..... 1 ft. Engine constant for H. E., .004022
Engine constant for C. E., .003954.

OBSERVERS:

GLICK FOCKELE
MURRAY S COLE.

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.		
1	7:30 A.M.	281	8.018	8.746	9.062	9.722	18.784	220	52.5	15.48	
2	7:45	281	6.852	8.892	7.744	9.884	17.628	220	50	14.74	
3	8:—	280	7.726	8.892	8.701	9.848	18.549	220	50	14.74	
4	8:15	277	8.309	9.329	9.258	10.223	19.481	220	55	16.22	
5	8:30	277	10.295	10.148	11.970	11.112	22.582	220	65	19.16	
6	8:45	277	10.205	10.642	11.370	11.440	22.810	220	67.5	19.91	
7	9:—	279	9.766	11.080	10.960	12.228	23.188	220	65	19.16	
8	9:15	280	7.872	9.184	8.866	10.173	19.039	218	52.5	15.34	
9	9:30	277	8.746	10.205	9.796	11.182	20.928	220	60	17.69	
10	9:45	277	9.329	10.158	10.395	11.130	21.525	220	62.5	18.43	
11	10:—	277	7.872	8.309	8.772	9.1045	17.8765	220	55	16.22	
12	10:15	275	10.205	11.080	11.335	12.050	23.385	218	70	20.45	
13	10:30	277	8.235	8.911	9.143	9.216	18.359	220	55	16.22	
14	10:45	279	12.500	11.970	14.030	12.660	26.690	220	75	22.12	
15	11:—	280	9.559	11.177	10.765	12.380	23.145	222	70	20.83	
16	11:15	277	9.411	11.177	10.987	12.247	22.734	220	60	17.69	
17	11:30	279	11.765	12.648	13.204	13.958	27.162	220	70	20.64	
18	11:45	278	9.912	10.642	11.085	11.702	22.787	220	80	23.59	
19	12:—	280	12.648	13.235	14.245	14.660	28.905	220	85	25.11	
20	12:15 P.M.	277	10.492	10.295	11.637	11.280	22.917	218	67	19.57	WISTLE BLEW FOR NOON
21	12:30	281	2.041	5.394	2.307	5.996	8.303	220	20	5.898	
22	12:45	277	2.993	5.147	3.280	5.640	8.920	220	45	13.97	
23	1:—	281	2.9155	4.3735	3.2955	4.861	8.1565	220	23	6.783	
24	1:15	281	1.7495	4.665	1.9775	5.185	7.1625	220	20	5.898	LOAD THROWN ON AGAIN.
25	1:30	281	4.082	6.706	4.6145	7.454	12.0685	216	35	10.13	
26	1:45	280	9.184	9.912	10.343	10.980	21.323	220	65	19.16	
27	2:—	277	9.330	10.250	10.397	11.230	21.627	220	60	17.69	
28	2:15	279	7.581	9.767	8.509	10.780	19.289	220	50	14.74	
29	2:30	279	7.297	9.855	8.132	10.855	18.987	220	50	14.74	
30	2:45	280	8.840	10.000	9.956	10.075	20.031	220	57.5	17.45	
31	3:—	281	7.682	9.275	8.682	10.310	19.992	220	52.5	15.48	
32	3:15	280	8.796	11.225	9.843	11.325	21.168	220	70	20.64	
33	3:30	277	12.320	12.900	13.730	14.135	27.865	220	75	22.12	
	Maximum,	281	12.648	13.235	14.245	14.66	28.905	222	85	25.11	
	Minimum,	277	1.7495	5.147	1.9775	4.861	7.1625	216	20	5.898	
	Total,		274.329	316.189	308.341	345.0255	653.366	7252	1890	568.009	
	Average,		8.313	9.581	9.343	10.455	19.798	219.7	57.27	17.212	

AVERAGE EFFICIENCY 86.9%.

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

MADE AT THE COLLEGE POWER PLANT
MANHATTAN, KANSAS.
ON THE IDEAL ENGINE
DATE JUNE 2, 1902.

PRIMING LOG.

(SEPARATING CALORIMETER.)

OBSERVERS:

GLICK FOCKELE
MURRAY S. COLE.

No.	Time.		Scale reading.		Amount of water in steam.	Weight on scales.		Condensed steam.	Quality of steam.	Remarks.
	Start.	Stop.	Start.	Stop.		Start.	Stop.			
			oz.	oz	oz	lbs. oz.	lbs. oz.	LBS oz		
1	7:48	7:51	3.7	4.0	0.3	19 — 14	21 — 9	1 — 11	99%	
2	7:55	7:58	4.4	4.7	0.3	19 — 3½	20 — 5	1 — 1½	98.5%	
3	8:56	8:59	2.3	2.8	0.5	19 — 12½	21 — 2¾	1 — 6¼	98%	
4	10:5	10:8	1.6	2.5	0.9	18 — 2½	19 — 11½	1 — 9	96.5%	
5	11:5	11:8	1.7	2.8	1.1	20 — 9¾	21 — 15	1 — 5¼	95%	
6	12:5	12:8	1.3	1.9	0.6	19 — 19¼	21 — 4¾	1 — 6½	97.5%	
7	1:7	1:10	3.1	3.5	0.4	20 — 2½	21 — 5½	1 — 3	98%	
8	2:20	2:23	2.3	2.9	0.6	19 — 0½	20 — 8½	1 — 8	97.5%	
								AVERAGE	97.5%	