

COPPER RANGE COMPANY

Adams Township, MI

Champion Mine
Plant

Tests on 1 - 391 H.P. Badenhausen boiler to determine pressure drop thru superheater at various ratings:

Test No.	3	1	6	2	4	5
Date	2/25/18	2/23/18	2/26/18	2/25/18	2/25/18	2/26/18
Duration in Hours	1	1.75	2	1.25	2.25	1.0
Boiler H.P. developed	400	435	490	605	613	795
Percent of rated capacity	102%	111%	125%	155%	157%	204%
Pressures:-						
Avg. St.Press.in boiler drum	170	170	171	173.4	175	177
" " " at Suphtr.outlet	161.7	161.4	161.25	162.5	162.7	162.9
" drop thru superheater	8.3	8.6	9.75	10.9	12.2	14.1
Max. & Min. Pressures:-						
Max. drop thru suphtr.	10.5	12	12	12.	13.5	15
Min. " " "	6.5	6	8.5	9.5	8.0	12.5
Max. St. Press. carried on boiler drum						
Max.	173½	174	175	176	177	179
Min. " " " "	164½	168	167.5	171	170	172
Max. " at suphtr.outlet						
Max.	164.5	164	163.5	164.5	164.5	164.5
Min. " "						
Min.	157.5	152	158.5	161.5	159.5	159.5
Temperatures:-						
Feed Water	190°	191°	202	185	188	200
Flue Gas	503°	479°	563	525	560	605
Superheat	100°	107.7	106.2	107.3	106	109
Drafts:-						
Under Fire		+ .9"	+ 1.4"	+ 1.4	+ 1.9"	+ 2.2"
Over Fire		-.03"	+ .02"	-.03"	+ .03"	+ .03"
At Damper		-.19"		-.54"	-.37"	-.52"
CO ₂		10.8%	13.3%	8%	13.5%	14.6%

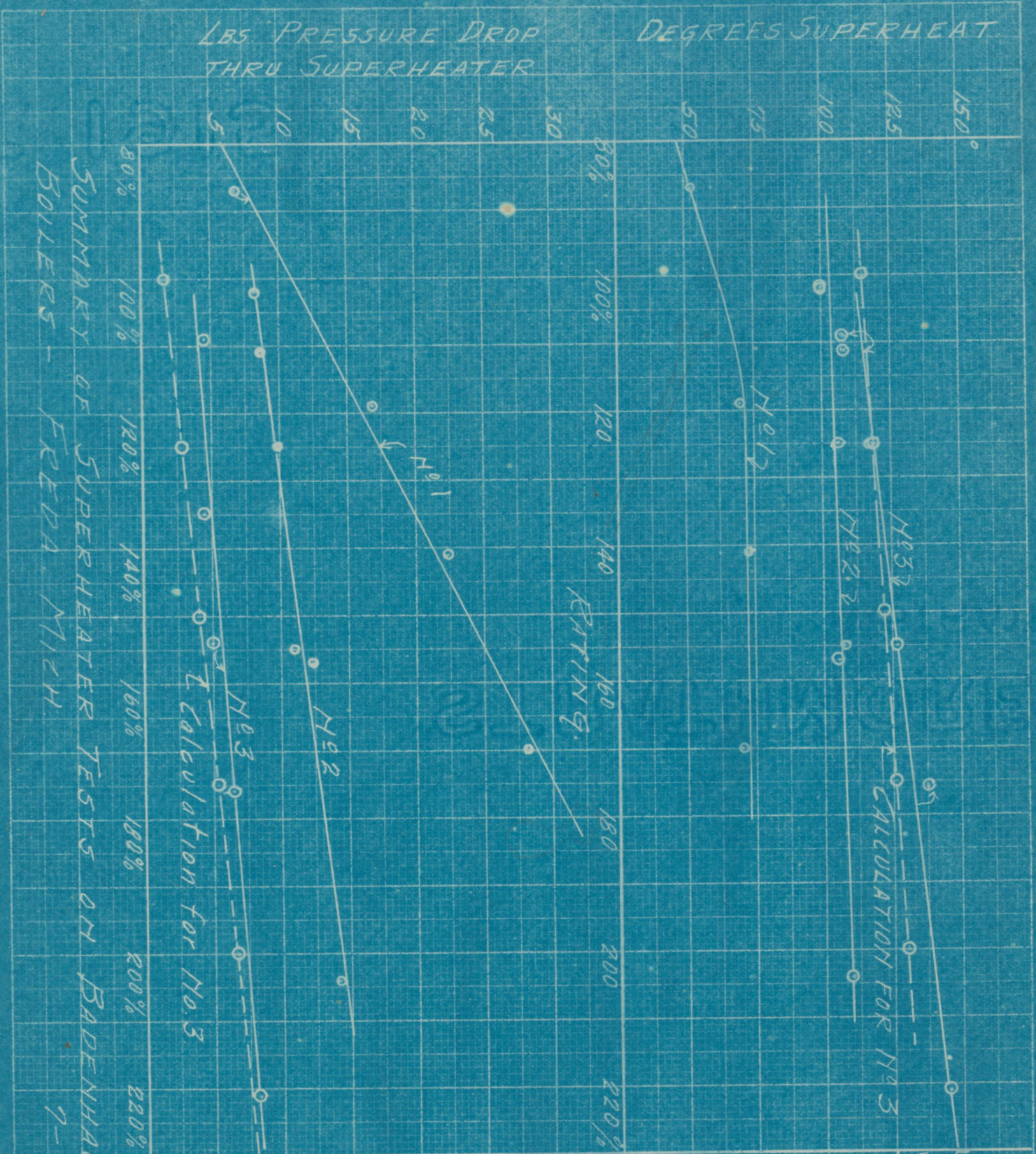
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Duration in Hours	1	1.75	2	1.25	2.25	1.0
Boiler H.P. developed	400	435	490	605	613	795
Percent of rated capacity	102%	111%	125%	155%	157%	204%
Pressures:-						
Avg. St.Press.in boiler drum	170	170	171	173.4	175	177
" " " at Suphtr.outlet	161.7	161.4	161.25	162.5	162.7	162.9
" drop thru superheater	8.3	8.6	9.75	10.9	12.2	14.1
Max. & Min. Pressures:-						
Max. drop thru suphtr.	10.5	12	12	12.	13.5	15
Min. " " "	6.5	6	8.5	9.5	8.0	12.5
Max. St. Press. carried on boiler drum	173#	174	175	176	177	179
Min. " " " "	164#	168	167.5	171	170	172
Max. " at suphtr.outlet	164.5	164	163.5	164.5	164.5	164.5
Min. " " "	157.5	152	158.5	161.5	159.5	159.5
Temperatures:-						
Feed Water	190°	191°	202	185	188	200
Flue Gas	503°	479°	563	525	560	605
Superheat	100°	107.7	106.2	107.3	106	109
Drafts:-						
Under Fire		+ .9"	+ 1.4"	+ 1.4	+ 1.9"	+ 2.2"
Over Fire		- .03"	+ .02"	- .03"	+ .03"	+ .03"
At Damper		- .19"		- .54"	- .37"	- .32"
CO ₂		10.8%	13.3%	8%	13.5%	14.6%



SUMMARY OF SUPERHEATER TESTS ON BADENHAUSEN BOILERS - FRED A. MICH

7-14-19

MJE/M

CASE	NO. OF TUBES.			SIZE OF TUBES.				Sq. FT. SUPHTR SURFACE
	1ST PASS	2ND PASS	3RD PASS	I.D.	O.D.	THICKNESS	LENGTH	
No. 1	4	4	4	1 3/8"	2 1/4"	3/16"	8'-6"	61.2
No. 2	9	8	0	1 5/8"	2"	3/16"	11'-6"	102.2
No. 3	12	14	0	"	"	"	Ave. 9'-3"	123.0
CALC.	"	"	"	"	"	"	"	"

COPPER RANGE COMPANY
 TESTS ON 1 - 391 H. P. BADENHAUSEN BOILER TO DETERMINE
 PRESSURE DROP THRU SUPERHEATER AT VARIOUS RATINGS. NO. 3 BOILER
 AT CHAMPION MILL.

TEST NO.	1	2	3	4	5
Date	7/11/19	7/11/19	7/11/19	7/12	7/12
Duration in hours	2	2	2	1½	¾
Boiler H.P. developed	426	528	602	688	864
Percent of rated capacity	109%	135%	154%	176%	221%
Pressures:-					
Avg. St. Press. in Boiler drum	163	164.7	166.0	164.9	165.6
" " " at Suphtr. outlet	158.5	160.3	161.	158.4	157.4
Avg. drop thru superheater	4.5	4.4	5.0	6.5	8.2
Max. " " "	5.5	6.0	6.0	11.0	11.0
Min. " " "	3.5	3.0	3.0	4.0	6.5
Max. St. Press. carried on boiler drum	166	170	169	170	168
Min. " " " " "	159	162	163	162	163
Max. " " " at supr. outlet	162	165	163	162.5	160
Min. " " " " "	155	157	157.5	155	155
Temperatures:-					
Feed Water	242	200	192	195	190
Flue Gas	495	520	520	530	575
Superheat	108°	118°	127°	137°	145°
Windbox Drafts:-					
Windbox	+ 2.6"	+ 3.4"	+ 4.0"	+ 4.4"	+ 4.8"
Over Fire	-0.05"	-0.13"	-0.1"	-.13"	-.02"
CO ₂	12.5%	12.3%	13.5%	14.7%	16.5%

COFFEE RANGE COMPANY
 Tests on 1 - 591 H.P. Badenhausen Boiler to Determine
 Pressure Drop Thru Superheater at Various Ratings. No. 3 Boiler
 at Champion Mill.

Test No.	1	2	3	4	5
Date	7/11/19	7/11/19	7/11/19	7/12/19	7/12/19.
Duration in Hours	2	2	2	1½	2
Boiler H.P. Developed	426	528	602	688	864
Percent of Rate Capacity	109%	155%	154%	176%	221%
Pressures:					
Avg. St. Press. in Boiler Drum	163	164.7	166.0	164.9	165.6
" " " at Suphtr. Outlet	158.5	160.3	161.	158.4	157.4
Avg. Drop Thru Superheater	4.5	4.4	5.0	6.5	8.2
Max. " " "	6.5	6.0	6.0	11.0	11.0
Min. " " "	3.5	3.0	3.0	4.0	6.5
Max. St. Press. Carried on Boiler Drum	166	170	169	170	168
Min. " " " " " "	159	162	163	162	153
Max. " " " at Supr. Outlet	162	165	163	162.5	160
Min. " " " " " "	155	157	157.5	155	153
Temperatures:					
Feed Water	242	200	192	195	190
Flue Gas	495	520	520	530	575
Superheat	106°	118°	127°	137°	145°
Drafts:					
Windbox	+ 2.6	+ 3.4	+ 4.0	+ 4.4	+ 4.8
Over Fire	-0.05"	-0.15"	-0.1"	- .15"	- .02"
CO ₂	12.5%	12.5%	13.5%	14.7%	16.5%

COFFIN RANGE COMPANY

Tests on 1 - 391 H.P. Badenhausen Boiler to Determine
Pressure Drop Thru Superheater at Various Ratings. No. 5 Boiler
at Champion Mill.

Test No.	1	2	3	4	5
Date	7/11/19	7/11/19	7/11/19	7/12/19	7/12/19.
Duration in Hours	2	2	2	1½	2
Boiler H.P. Developed	426	528	602	688	664
Percent of Rate Capacity	109%	135%	154%	176%	221%
Pressures:					
Avg. St. Press. in Boiler Drum	163	164.7	166.0	164.9	165.6
" " " at Suphtr. Outlet	158.5	160.3	161.	159.4	157.4
Avg. Drop Thru Superheater	4.3	4.4	5.0	6.5	8.2
Max. " " "	5.5	6.0	6.0	11.0	11.0
Min. " " "	3.5	3.0	3.0	4.0	6.5
Max. St. Press. Carried on Boiler Drum	166	170	169	170	168
Min. " " " " " "	159	162	163	162	163
Max. " " " at Supr. Outlet	162	163	163	162.5	160
Min. " " " " " "	155	157	157.5	155	155
Temperatures:					
Feed Water	242	200	192	195	190
Flue Gas	495	580	580	530	575
Superheat	108°	118°	127°	137°	145°
Windbox Drafts:					
Windbox	+2.6	+3.4	+4.0	+4.4	+4.8
Over Fire	-0.05"	-0.13"	-0.1"	-.15"	-.02"
CO ₂	12.5%	12.5%	12.5%	14.7%	16.5%

COPPER RANGE COMPANYCHAMPION MILL PLANT

TESTS ON 1 - 391 H.P. BADENHAUSEN BOILER TO DETERMINE PRES-
SURE DROP THRU SUPERHEATER AT VARIOUS RATINGS AND APPROXIMATE
EFFICIENCY OF BOILER - FURNACE AND GRATE.

Test No.	1.	2.	3.	4.
Date	6/21/17	6/22/17	6/23/17	6/22/17
Duration in Hours	2	2	3	1½
Boiler H.P. Developed	340	465	551	665
Rated capacity in evaporation from & at 13500 2120				
Builders Rating in B.H.P.	391	391	391	391
Percent of rated capacity developed	87	119	141	170
Water Heating Surface				
Superheating "				
Kind and size of Coal				
Kind of furnace - 4 Retort, Taylor.				
Kind of Draft - Natural - Concrete stack.				

AVERAGE PRESSURES:

Steam pressure in boiler drum by gauge	164.4	170	179	184
" " at Suphtr.Outlet " "	157.7	153.2	156.8	156
" " in Main line	156	153.5	156.8	154.8
Draft at Boiler Damper	0.046	0.153	0.25	0.425
" over fire	0.030	0.03	0.03	0.047
Air pressure under fire	1.0	0.82	1.3	1.45
Draft at base of stack	0.91	0.90	0.92	0.905

MAX. AND MIN. PRESSURES

	1.	2.	3.	4.
Max. St. Press. carried in boiler drum	167.5	174.5	187	190
Min. " " " "	162	163.5	169	178.5
Max. St. Press. at Suphtr. Outlet	158.5	157.5	160	157.5
Min. " " " "	156.5	150.	153.5	152.5

PRESSURE DROP THRU SUPERHEATER

Average Drop	6.7#	16.8#	22.2#	28.1
Max.	9.5	19.5	27.5	32.5
Min.	5.0	11.0	15.5#	22.5#

AVERAGE TEMPERATURES.

Temp. of steam leaving superheater	422.1	438°	441°	439°
Feed Water Temperatures	205	206	205	205
Superheat in Steam	52.2	70.5°	72°	70

TOTAL QUANTITIES

Weight of coal as fired in lbs.	2600	3200	5600	3400
Percent Moisture in Coal	10.8	5%?	5%?	5%?
Weight of dry coal	2327	3040	5320	3230
Percent Ash	7.5			
Weight of Combustible	2155			
Weight of water fed to boiler	22260	30320	54272	32436
Factor of evaporation	1.055	1.055	1.056	1.0563
Factor of evaporation including Supht.	1.086	1.094	1.094	1.094
Total exaporation from and at 212° F	23460	31980	57300	34340
" " " " " "				
Inclu. Supht.	24150	33150	59250	35510

HOURLY QUANTITIES

	1.	2.	3.	4.
Dry coal consumed per hour	1165			
Water evaporated per hour	11130	15160	18090	21620
Equivalent evaporation per hour from and at 212°F	11730	15990	19100	22890
Equivalent evaporation per hour from and at 212°F, Includ. Supht.	12075	16575	19750	22670

ECONOMY RESULTS

Water fed per lb. coal fired	8.57	9.48	9.66	9.55
Water evaporated into dry steam per pound of dry coal	9.55	9.97	10.2	10.1
Equivalent Evap. dry steam from and at 212°F per lb. dry coal	10.1	10.5	10.75	10.65
Equiv. Evap. dry st. f @ at 212° per lb. combustible	11.65			
Equiv. Evap. dry st. f @ at 212° per lb. dry coal with Suprht.	10.35			
Equiv. Evap. dry St. f @ at 212° per lb. combustible with super.	11.21			
CO ₂ - Flue gas analysis	14.7	14.4	16.2	16.1

EFFICIENCY RESULTS

Coloritic Value of 1 lb. dry coal	12.932	13500	13500	13500
" " " Combustible	13,980	?	?	?
Efficiency of boiler, furnace & grate	75.7	75.5	77.2	76.5
" " " and furnace	76.5			
Over-all efficiency on dry coal, Supht.	76.7			
" " " on combustible	78.0			
" " " Incl. supht.				

NO 1 TEST.

Feb-23-1918

Time	Gauges		DROP	TEMP OF Sup.	Feed Water	Flue Gas	CO ₂	Meter Readings	DRAFTS			Remarks.
	Boiler Drum	Sup. Outlet							Wind Box	Over Fire	AT Damper	
10 ³⁰	170	161	9	466			12 ^{1/2} %	731	.9	+00	-.25	
40	170	163	7	475		490	12%	747	.7	+01	-.24	
50	170	163	7			490			.8	-01	-.26	
11 ¹⁵	168	162	6	470		485	11.8	766	.8	+05	-.15	
10	167	160	7	470			10.8	782	.8	-01	-.24	
20	170	163	7		188°	470			1.0	+03	-.20	
20	160	152	8	458	200	470	12.0	798	.4	-05	-.24	
40	174	162	12	464			8.2	814	1.8"	-06	-.32	
50	174	166	8		188	475			.8	-04	-.10	
12 ⁰⁰	168	161	7	470			10.8	831	.6	-04	-.9	
12	168	160	8		190	475			.9	-02	-.10	
12 ¹⁵	171	164	7	464			9.0	847	.9	03	-.11	
								DIEF = 116000#				
Ave	170	161.4	8.6	467	191°	479	10.8%		+ .9	- .03	-.19"	

2" Meter factor = .212

Water Boiled = 116000# x .212 = 14000# per Hour.

Factor of Evaporation = 1.07

Water evaporated from and at 212° = 14980#
= 434 H.P.

Rating = 111% = 111% Rating.

Superheat = 107.7°

DROP = 8.6#

CO₂ = 10.8%

No 3 Test - on drop thru Superheater
Badenhausen Boiler - Feb-25-18

Time	Gauges			Temperatures			CO ₂	Meter Readings.	Drafts.		
	Boiler Drum	Sup. Outlet	Press. Drop.	Feed H ₂ O	Flue Gas	Super Heat					
3 ⁰⁰	164	157.5	6.5	190	470	472		673			
3 ¹⁰	173	164.5	8.5	190	490		Not taken	688	Not taken	-	-
3 ²⁰	170	162	8.0	188	500						
3 ³⁰	169	162	7.0	192	505			713			
3 ⁴⁰	172	164.5	7.5	190	570	468		718			
3 ⁵⁰	170	159.5	10.5	190	525				734		
4 ⁰⁰	170	162	8.0	190	520						
Ave	170 [#]	161.7 [#]	8.0 [#]	190	503°	470°		61000 [#]			

$$\text{lbs water boiled per Hour} = .212 \times 61000 = 12,900 \#$$

Factor of evaporation = 1.07.

$$\text{Lbs water from and at } 212^{\circ} = 13,800 \#$$

$$\text{Rating of Boiler} = 102\% - \text{Drop} = 8.0 \#$$

$$\text{Superheat} = 99.7^{\circ}$$

No 4 Test - Pressure Drop thru Superheater Badenhausen Boiler, Feb-25-18

Time	Boiler Drum	Sup. Gauge	Drop	CO ₂	Temp.			DRAFTS			Meter Readings	Mill Ga
					Feed	Flue Gas	SuperHt.	Under Fire	Over Fire	Damper		
4:15				14.6							754	
20	172	162	10		184	540	472	1.5	+0.3	-31		
30	170	139.5	10.5	12.2	186	540		1.5	+0.3	-31	779	
40	170	162	8		190	535	478	1.8	.03		800	
50	173	162	13	11.2	188	560	482	2.5	03	-26		
5:00	177	164.5	12.5	15.6	190	555		2.1	03	25	820	165#
10	177	163.5	13.5		186	560	476	1.8	03	36	843	
21	173	162	13.0	14.8	188	560	478	1.6	04	20		
30	173	162	13.0	13.0	188	550	478	2.3	03	34	866	165
40	177	163.5	13.5		190	565		2.0	03	46	889	
30	177	164.5	12.5	14.2	192	575	478	1.9	03	43		
6:00	177	164.5	12.5	12.2	190	570	478	1.9	03	43	913	160
10	174	163.5	12.5		190	575		2.2	03	52		
20	177	164.5	12.5	13.6	188	580	480	2.2	03	53	937	
6:30	174	160.5	13.5		188	575		2.0	03	48		161
	#	#	#	%	0	0	0	1.9"	+0.3"	-37"	965	
Ave	173	162.7	12.2	13.5	188	560	478				DIFF 211000	#164

Meter factor = .212

Lbs water evaporated = 44.700 #
 = 19.900 # per Hour
 Factor of evaporation = 1.07
 Lbs water f. and at = 21.300 = 157% Rating

No 5 Test - Pressure Drop thru Super heater
 Badenhausen Boiler - Feb - 26th 18

Time	Gauges			Temp.			CO ₂	Meter Reading	DRAFTS			Mill Ga.
	Boiler Drum	Sup. Outlet	DROP	Feed H ₂ O	Flue Gas	Super heat			Under Fire	Over Fire	AT Damper	
8 ¹⁰	175	162	13	192	670	470			2.1"	+03		160
15						470	14.8	024	2.1"	+03	-124	
20	177	162	15	194	610				2.5	+03	-30	
30	177	162.5	14.5	200	615	474	15.0	031	2.5	+04	-36	160
40	179	164.5	14.5	204	610	486	14.2	038	2.7	+04	-38	
50	179	164.5	14.5	204	610				2.5	+03	-60	
9 ¹⁰	179	164.5	14.5	204	610	484	14.6		2.0	+01	-31	160
10	178	163.5	14.5	202	610	486		050	1.9	+02	-30	
20	172	159.5	12.5	202	610		14.6		1.5	+02	-23	
30									1.8	+02	-21	155
Ave	177	162.9	14.1	210°	605°	482	14.6	# 26000	+2.2"	+027	-32"	

Factor of evaporation = 1.06
 Meter factor = 1.0

Lbs water evaporated from and at

212° per Hour = 27,600 #
 = 204% Rating

Drop = 14.1 #
 CO₂ = 14.6
 Super heat = 110°

No 6 Test - Pressure Drop thru Superheater - Badenhansen - Boiler - 2-26-18

Time	Gauges			Temp.			CO ₂	Meter Rds	Drafts			Mill Ga	
	Boiler Drum	Sup. Outlet	Drop	Feed H ₂ O	Flue Gas	Super heat.			Under Fire	Over Fire	At Damper		
11:00	169	158.5	10.5	204	550	476	11.0	088	1.1	+02	TAKEN	160	
10	167.5	158.5	9.0	202	555	474	14.0	091.5	1.1	+02		165	
20	170	160.5	9.5	200	550	486	14.6	95.5	1.2	+02		165	
30	169	160.5	8.5	200	560	486	14.6	95.5	1.8	+02		165	
40	172	162.0	10.0	200	565	466	13.2	99.5	1.6	+03		165	
50	168	158.5	9.5	202	565	476	13.6	103.5	1.5	+03		165	
12:00	171	161.5	9.5	202	570	476	13.6	103.5	1.4	+03		165	
10	172	162	10.0	202	565	478	14.6	110	1.4	+04		HOP	165
20	170	160.5	9.5	206	565	478	14.6	110	1.6	+03			165
30	174	162	12	204	560	480	16.6	115	1.5	+02			165
40	174	162	12	202	570	470	16.6	119	1.4	+02	165		
50	175	163.5	11.5	202	575	470	16.6	119	1.5	+02	165		
1:00	174	162	12.0	204	570	484	15.4	124	1.5	+02	165		
Ave 1st Hour	# 169.5	# 160	# 9.5	° 201	° 560	° 476	% 13.3	# 15.500	" 1.4	" +02			
2nd 50'	172.7	162.7	10#	203°	567°	478°	15.8	14000	1.5"	+02			

Lbs water evaporated (11-12) = 15,500 #

Meter factor = 1.0.

Factor of evaporation = 1.063

Lbs water evaporated from and at 212° = 16,500 #

Rating = 123% - Drop - 9.5# CO₂ = 13.3

2nd 50 min = Lbs water evaporated = 14,000 #

Lbs water from and at = 14,840 #

= 17,300 # per Hour

Rating = 128%

Drop = 10# CO₂ = 15.8%

No 3 BOILER - FREDA M.H.

Adams Township, MI

SUPERHEATER TEST - BADENHAUSEN BOILERS

No 1 - JULY - 10TH 1919.

- READINGS -

Time P.M	Boiler Drum Ga.	Sup. Outlet Ga.	Press. Drop	Temperatures.				Wind box draft	Over Fire draft	CO ₂	Meter
				Super -heat	Feed Water	Feed Water	Flue Gas				
3 ¹⁰	162.0	157.5	4.5	483	202	250	505	2.6	.02	12%	827505
3 ²⁰	166.0	162	4.0	482	201	250	510	2.7	.04	12.5	
3 ³⁰	165.0	159.5	3.5	478	198	250	490	2.6	.04	12.2	
3 ⁴⁰	166.0	160.5	5.5	478	197	246	488	2.7	.07		827541
3 ⁵⁰	160.0	155.5	4.5	476	196	248	498	2.7	.07	13.2	
4 ⁰⁰	165.0	161.5	3.5	474	193	238	500	2.6	.07	11.5	
4 ¹⁰	166.0	160.5	5.5	468	193	236	475	2.6	.09	12.6	827574
4 ²⁰	160.0	156.0	4.0	472	197	238	475	2.6	.10	14.6	
4 ³⁰	164.0	160.5	3.5	480	189	236	510	2.2	.04	12.6	
4 ⁴⁰	159.0	155	4.0	478	188	234	490	2.6	.05	14.2	827608
4 ⁵⁰	160.0	156	4.0	482	210	238	500	2.7	.03	12.0	
5 ⁰⁰	165.0	161	4.0	480	208	238	500	2.6	.04	11.4	
5 ¹⁰	159.0	155	4.0	478	202	244	485	2.6	.04	11.4	827642
Ave.	162.9	158.5	4.4	478	198	242	495	2.6	.05	12.5	137000

Meter Factor = .212 ; Lbs Water boiled = 29.044[#]

Factor of evaporation = 1.016

Lbs Water from and at 212° per Hour = 14754[#]

Rating of Boiler 13500[#] f. and at 212°F

Rating developed = 109.3% CO₂ = 12.5%

Press. Drop thru Suphr = 4.4[#] at damper.

Super heat = 108.2° F.

No 3 BOILER - FRED A, MICH.
 SUPERHEATER TEST - BADENHAUSEN BOILERS
 No 2 - JULY 11 - 1919
 READINGS.

Time A.M	Gauges (Corrected)		Press. Drop	Temperatures			Drafts		CO ₂ %	Meter Readings	
	Boiler Drum	Suphr Ga.		Super -heat	Feed Water	Correct Rdg.	Flue Gas	Wind box			Over Fire
9 ¹⁰	164	160	4	486	200		525	2.4	.19	11.0	828279
20	165	161	4	488			535	2.9	.14		828281
30	162	158	4	486	197		520	2.0	.18	11.4	
40	165	159	6	486			525	3.7	.20	12.2	828285
50	164	160	4	486	191		525	3.9	.20		828289.5
10 ⁰⁰	163	159	4	486			510	3.7	.04	12.6	
10	166	163	3	490	201		510	3.6	.10	12.4	828294
20	168	163	5	492			520	3.4	.10		828298.5
30	163	158	5	490	203		520	3.5	.09	12.4	
40	163	159	4	492			520	3.7	.10	13.4	828303
50	166	162	4	492	203		520	3.4	.11		828307.5
11 ⁰⁰	162	157	5	490			515	3.7	.10	12.6	
11 ¹⁰	170	165	5	490	203		500	3.7	.10	12.4	828311.5
	#	#	#	°	°		°	"	"	%	#
Ave	164.7	160.3	4.4	489	200		519°	3.35"	.13	12.3	34.500

Factor of evaporation - 1.0597

Lbs. Water f. and at 212° F. per Hour = 18.280

Rating developed = 135.4%
 Press. Drop thru Superheater = 4.4# } CO₂ - 12.3%
 Superheat. - 118.2° } at Damper.

No 3 Boiler - Freda, Mich
 Superheater Test - Badenhansen Boiler
 No 4 Test - July 12 - 1919.

Time A.M	Gauges (Corrected)		Press. Drop	Temperatures			Drafts		CO ₂	Kenturi Meter
	Boiler Drum	Sup. Out. Ga		Super -heat	Feed Water	Flue Gas	Wind box	Over fire.		
8 ³⁰	163	155	8.0	500	200	530	5.7	-.07		829001.5
4 ⁰	170	162	8.0	498	200	530	4.8	-.11	15.2	829007.0
5 ⁰	164	155.5	8.5	508		530	5.0	-.04		
9 ⁰⁰	169	162	7.0	514	195	550	5.1	-.07	16.0	829013.0
1 ⁰	162	155.5	6.5	514	195	530	3.3	-.22	15.2	829019.0
2 ⁰	164	159.5	4.5	506		530	4.7	-.15	15.2	
3 ⁰	166	155	11.0	510	195	535	3.4	-.22		829025.0
4 ⁰	166	162	4.0	506	190	525	3.8	-.24	12.0	829030.0
5 ⁰	160	155	5.0	500		515	4.1	-.16	14.5	
10 ⁰⁰	165	162.5	5.5	510	190	530	4.3	-.06		829035.0
11 ⁰⁰	163	155	8.0	510	195	530				
	#	#	#	of	of	of	#	"	%	#
Ave.	164.9	158.4	6.5	507	195	530	4.4	-.13	14.7	33,500

Factor of evaporation. 1.065

Lbs water from and at 212° per Hour
 = 22300 x 1.065 = 23750

Rating developed = 176%

Press. drop thro Superheater - 6.5 #

Superheat - 139°

CO₂ at Damper - 14.7%

No 3 Boiler - Freda, Mich
 Superheater Test - Badenhansen Boiler
 No 5 Test - July 12-1919

Time A.M.	Gauges (Corrected)		Press. Drop	Temperatures			Drafts		CO ₂ %	Venturi Meter
	Boiler Drum	Sup. Outlet		Super- heat	Feed Water	Flue Gas	Wind Box.	Over Fire		
10 ¹⁵					200°			"	16%	829040.5
10 ²⁰	163	155	8	314		575	4.9	-0.01	17%	
10 ³⁰	165	157.5	7.5	312	190	565	5.1	-0.01	17%	829047.5
10 ⁴⁰	166	159.5	6.5	316		580	5.7	+0.02	16 1/2%	
10 ⁴⁵					180					829054.5
10 ⁵⁰	166	155	11.0	378		580	4.5	-0.05	17%	
11 ⁰⁰	168	160	8.0	312	190	580	4.1	-0.07		829061.5
	#	#	#	OF	OF	o	"	"	%	#
Ave	165.6	157.4	8.2	314.5	190	576	4.8	-0.02	16.5	21000

Maximum Capacity Test - Damper wide open Fan at high speed - 1800 R.P.M. with by pass closed.

Factor of Evaporation - 1.065
 Lbs. water from and at 212°F = 28000 #
 $\times 1.065 = 29820 \#$

Rating developed = 221 #
 Press. drop thru Superheater - 8.2 #
 Superheat - 145°
 CO₂ at Damper - 16.5%

COPPER RANGE COMPANY

Champion Mill Plant.

Tests on 1 - 391 H.P. Badenhausen Boiler to Determine
Pressure Drop Thru Superheaters at
Various Ratings.

Test No.	1	2	3	4
Date	6/21/17	6/22/17	6/23/17	6/22/17
Duration in Hours	2	2	3	1½
Boiler H.P. Developed	340	465	551	665
Percent of rated capacity	87%	119%	141%	170%
Pressures:				
Avg. St. Press. in Boiler Drum	164.4	170	179	184
" " " at Suphtr. Outlet	157.7	153.2	156.8	156
Avg. Drop Thru Superheater	6.7	16.8	22.2	28.1
Max. " " "	9.5	19.5	27.5	32.5
Min. " " "	5.0	11.0	15.5	22.5
Max. St. Press. Carried on Boiler Drum	167.5	174.5	187	190
Min. " " " " " "	162	163.5	169	178.5
Max. " " at Supr. Outlet	158.5	157.5	160	157.5
Min. " " " " "	156.5	150	153.5	152.5
Temperatures:				
Feed Water	205	206	205	205
Superheat in Steam	52.2°	70.5°	72°	70°
Drafts:				
Air Pressure under Fire	1.0	0.82	1.3	1.45
Draft Over Fire	0.030	0.03	0.03	0.047
" at Boiler Damper	0.046	0.153	0.25	0.425
CO ₂	14.7	14.4	16.2	16.1

COPPER RANGE COMPANY

Champion Mill Plant.

Tests on 1 - 391 H.P. Badenhausen Boiler to Determine
Pressure Drop Thru Superheaters at
Various Ratings.

Test No.	1	2	3	4
Date	6/21/17	6/22/17	6/23/17	6/22/17
Duration in Hours	2	2	3	1½
Boiler H.P. Developed	340	465	551	665
Percent of rated capacity	87%	119%	141%	170%
Pressures:				
Avg. St. Press. in Boiler Drum	164.4	170	179	184
" " " at Suphtr. Outlet	157.7	153.2	156.8	156
Avg. Drop Thru Superheater	6.7	16.8	22.2	28.1
Max. " " "	9.5	19.5	27.5	32.5
Min. " " "	5.0	11.0	15.5	22.5
Max. St. Press. Carried on Boiler Drum	167.5	174.5	187	190
Min. " " " " " "	162	163.5	169	178.5
Max. " " at Supr. Outlet	158.5	157.5	160	157.5
Min. " " " " "	156.5	150	153.5	152.5
Temperatures:				
Feed Water	205	206	205	205
Superheat in Steam	52.2°	70.5°	72°	70°
Drafts:				
Air Pressure under Fire	1.0	0.82	1.3	1.45
Draft Over Fire	0.030	0.03	0.03	0.047
" at Boiler Damper	0.046	0.153	0.25	0.425
CO ₂	14.7	14.4	16.2	16.1

COPPER RANGE COMPANY

Champion Mill Plant.

Tests on 1 - 591 H.P. Badenhausen Boiler to Determine
Pressure Drop Thru Superheaters at
Various Ratings.

Test No.	1	2	3	4
Date	6/21/17	6/22/17	6/23/17	6/22/17
Duration in Hours	2	2	3	1½
Boiler H.P. Developed	340	465	551	665
Percent of rated capacity	87%	119%	141%	170%
Pressures:				
Avg. St. Press. in Boiler Drum	164.4	170	179	186
" " " at Suphr. Outlet	157.7	153.2	156.8	156
Avg. Drop Thru Superheater	6.7	16.8	22.2	28.1
Max. " " "	9.5	19.5	27.5	32.5
Min. " " "	5.0	11.0	15.5	22.5
Max. St. Press. Carried on Boiler Drum	167.5	174.5	187	190
Min. " " " " " "	162	163.5	169	176.5
Max. " " at Supr. Outlet	158.5	157.5	160	157.5
Min. " " " " "	156.5	150	153.5	152.5
Temperatures:				
Feed Water	205	206	205	205
Superheat in Steam	52.2°	70.5°	72°	70°
Drafts:				
Air Pressure under Fire	1.0	0.82	1.3	1.45
Draft Over Fire	0.030	0.03	0.03	0.047
" at Boiler Damper	0.046	0.153	0.25	0.425
CO ₂	14.7	14.4	16.2	16.1

Badenkansen Calculation for drop this
 Superheater tubes - letter of Nov 21-18 - applied
 to 1st and 2nd set of Superheaters

1st set superheaters.

Rating	Actual drop	Calculated drop by Badenk. Form	Previously calculated drop
87%	6.7#	10.2# X	8.25'
119%	16.8		15.4
141%	22.2	X	21.1
170%	28.1	27.5'	29.8
200%	—	35.0 X	43.0

2nd set superheaters.

Rating	Actual drop	Calc. drop by Badenk. Form.	Previously calc drop
102%	8.3	4.3# X	4.16
111%	8.6		4.92
125%	9.75'		6.25'
153%	10.90		9.60
157%	12.2		9.9
200%		11.97# X	—
204%	14.1	12.5# X	16.7

Temperatures in Setting of Badenhausen Boilers - Freda, Mich.

July 14 - 1917

Rating	Boiler Gauge	Suphiti Gauge	Draft under Fire	Draft over Fire	Draft at Damper	Flue Gas Temp.	Temp. at Suphiti	Temp of steam Suphit	Degrees of Superhit
130%	184.5	163	0.91	.08	.20	590	1220	447	75
..	183.0	163	1.33	.03	.20	595	1225	445	73
..	183.0	164	1.00	.19	.20	610	1190	451	78.5
121%	181	163	.94	.095	.32	600	1225	442	70°
"	180	162	.84	.07	.24	575	1180	445	73.5
"	185	164	.85	.19	.47	617	1220	447	74.5

Average Readings throughout Setting.
as follows -

At Damper - 550° F

End of 2nd Pass - between Tubes 15 & 16

and below 3" x 12" x 12" baffle Tile - 650° F

Middle of 2nd Pass - in front of Tube No 13

close to 3" x 12" x 24" baffle - 760° F

Beginning 2nd Pass - above 2" x 12" x 24"

Tile - 27" from No 4 Drum - 500° F

1
COPPER RANGE COMPANY

Adams Township, MI

CHAMPION MILL PLANT

Tests on 1-391 H.P. Badenhausen Boiler to determine Pressure Drop thru Superheater at various Ratings and approximate efficiency of Boiler-Furnace and Grate.

Test No	1	2	3	4
Date	6/21/17	6/22/17	6/22/17	6/23/17
Duration in Hours	2	2	3	1½
Boiler H.P. developed.	340	465	551	665
Rated Capacity in evaporation from and at	13500	13500	13500	13500
Builders Rating in B.H.P. ^{212°}	391	391	391	391
Per Cent of Rated Capacity developed	87	119	141	170
Water Heating Surface				
Super heating				
Kind and Size of Coal				
Kind of Furnace - 4 Retort Taylor				
Kind of Draft - Natural - Concrete Stack - Corrosional Fan				
<u>Average Pressures.</u>				
Steam Pressure in Boiler Drum by Gauge	164.4	170.	179	184
" " at Supht'r Outlet " "	157.7	153.2	156.8	156
" " in Main Line " "	156.	153.5	156.8	154.8
Draft at Boiler Damper	0.046"	0.153"	0.25"	0.425
" over Fire	0.030"	0.03"	0.03"	0.047
Air Pressure under Fire	1.0"	0.82"	1.3"	1.45"
Draft at Base of Stack	0.91"	0.90"	0.92"	0.905

2

<u>Max. and Min. Pressures.</u>	1	2	3	4
Max. St. Press. carried in Boiler Drum	167.5	174.5	187.	190
Min " " " " " "	162	163.5	169.	178.5
Max. St. Press at Suph't'r Outlet.	158.5	157.5	160	157.5
Min " " " " " "	156.5	150	153.5	152.5
<u>Pressure Drop THRU Suph't'r</u>				
Average DROP.	6.7 [#]	16.8 [#]	22.2 [#]	28.1 [#]
Max. " " " " " "	9.5	19.5	27.5 [#]	32.5 [#]
Min " " " " " "	5.0	11.0	15.5 [#]	22.5 [#]
<u>Average Temperatures</u>				
Temp. of Steam leaving Suph't'r	422.1	438°	441°	439°
Feed Water Temperatures	205	206	205	205.5
Superheat in Steam	52.2°	70.5°	72°	70°
<u>Total Quantities</u>				
Weight of Coal as fired in lbs.	2600	3200	5600	3400
Per cent Moisture in Coal	10.8	5%?	5%	5%?
Weight of Dry Coal	2327	3040	5320	3230
Per Cent Ash	7.5			
Weight of Combustible	2155			
Weight of Water fed to Boiler	22760	30320	54272	32436
Factor of evaporation	1.055	1.055	1.056	1.0563
Factor of evaporation including	1.086	1.094	1.094	1.094
Total Evaporation from and at 212° F ^{Superheat}	23460	31980	57300	34310
" " including Superheat.	24150	33150	59250	

3

HOURLY QUANTITIES.

	1	2	3	4
Dry Coal consumed per Hour	1165	1520	1773	2153
Water evaporated per Hour	11130	15160	18090	21620
Equivalent evaporation per Hour from and at 212° F	11730	15990	19100	22890
Equivalent evaporation per Hour from and at 212° F, including Superh.	12075	16575	19750	22670

Economy Results

Water fed per lb coal fired	8.57	9.48	9.66	9.55
Water evaporated into dry steam per pound of dry coal.	9.55	9.97	10.2	10.1
Equivalent Evap. Dry steam from and at 212° F per lb. dry coal.	10.1	10.5	10.75	10.65
Equiv. Evap. Dry st. f. @ at 212° per lb combustible	11.05			
Equiv. Evap. Dry st. f. @ at 212° per lb dry coal with Superh ^t	10.35			
Equiv. Evap. Dry st. f. @ at 212° per lb combustible with Super.	11.21			

CO₂ - FLUE GAS ANALYSIS 14.7 14.4 16.2 16.1

4

EFFICIENCY RESULTS	1	2	3	4
Calorific Value of 1 lb. dry coal	12.932	13500	13500	13500
" " " - combustible	13.980	L?	L?	L?
Efficiency of Boiler-Furnace and Grate	75.7	75.5	77.2	76.5
" " " and Furnace	76.5			
Over all efficiency on dry coal	76.7			
" " including Superheater on combustible				
including Supht ^r	78.0			

RUN NO 1 - 87% RATING.

JUNE - 21 - 1917

Time	Gauge Boiler Drum	Gauge Sup. Outlet	Gauge Main Line	Gauge 1/4 IN. FRANK on Boiler Drum 5" Water	Suphr Temp F	Fd. H ₂ O TEMP	Meter Readings Factor = X .212	REMARKS
9 ⁴⁰	167.5	158	156.5	172	418	206	18157	
5 ⁰	165.5	158	156.5	170	422	204		
10 ⁰⁰	165.5	158.	157.5	173	430			2600# Coal
10 ¹⁰	167.0	158	156	171	420	204	18183	- Total.
10 ²⁰	16.2	157	156	166	426	206		Stoker ran
10 ³⁰	163.5	157	156	169	420			1 Rev. in
10 ⁴⁰	162.5	157.5	155	166	420	206	18211	136 secs.
10 ⁵⁰	163.5	158	156	169	428	202		
11 ⁰⁰	163.5	157.5	155	169	422			
11 ¹⁰	163.5	158.5	157	168	420	204	18237	
2 ⁰	163.5	157.5	155	168	424	206		
3 ⁰	163.5	156.5	154	168	420			
11 ⁴⁰	166.5	158.5	156	171	418	206	18262	
Ave	164.4	157.7	156	169.2	422.1	205 ⁰	105 thousand lbs. X .212 # = 22,260	

Ave. Drop between Boiler and Superheater = 6.7#
 Min " " " " = 5.0#
 Max " " " " = 9.5#
 Lbs. of Water from and at 212° F = 23462#

RUN No 1 - 87% RATING

JUNE 21-1917

	Over Fire	In Sup'hr	Begin 2 nd Pass	End 2 nd Pass	Begin 3 rd Pass	End 3 rd Pass	Base Stack	UNDER FIRE
Time	1	2	3	4	5	6	7	8
9.40	.02	.00	.01	.01	.09	.05	.90	1.3
9.55	.02	.00	.00	.00	.06	.04	.89	0.9
10.10	.03	.00	.00	.01	.07	.03	.91	0.8
25	.03	.00	.01	.00	.08	.04	.90	0.8
40	.03	.00	.01	.00	.08	.04	.92	0.8
10.55	.03	.00	.00	.00	.08	.03	.90	0.9
11.10	.01	.00	.00	.00	.05	.02	.93	1.2
11.25	.05	.00	.04	.03	.13	.08	.92	1.2
11.40	.06	.02	.06	.03	.13	.08	.91	1.1
Ave	.03	.00	.014	.01	.086	.046	.909	1.0"

CO₂.

Time	Time	Duration	CO ₂
Start	Finish		
9.40	9.55	15 min.	13.4
9.57	10.12	15 "	15.2
10.15	10.25	10	15.8
10.28	10.40	12	15.2
10.42	10.55	13	13.2
10.57	11.10	13	13.8
11.15	11.25	10	15.2
11.27	11.40	13	16.0

Ave = 14.7%

Run No 2 - 119 % Rating

JUNE 22-1917

	Gauge	Gauge	Gauge	Gauge	Venturi	H ₂ O	Remarks.
	Boiler	Sup.	Main	Gauge	Meter	Glass	
Time	Drum.	Outlet	Line	5 Ft. 2 Leg Stirling	Reading Factor: 212	Inches	
2 15	171*	155					
	171*	155*	155.5	161	20452	5 1/2	* Cross Checked Gauges.
20	163.5	157.5	153	1			
25	167	154	154.5	159			
30	168	157.5	153				3700 # Coal - Total.
35	168	157.5	153	159			
40	167	157	157.5				
45	169	153	153	160	20489	7 1/2	
50	170.5	154	154				Ave Drop. Drum to Sup' h' r = 16.8 #
55	169	157.5	157.5	158			Min " " " = 11.0 #
3 00	174	155	155				Max " " " = 19.5 #
5	177	154	154	160			
10	177	157.5	157.5				Water evaporated f. and
15	171	153	153	159	20521	5 1/2	at 212° F = 31983 #
20	169	150	150.5				= 15990 # per Hr.
25	169	157	151.5	155			
30	174	157.5	158				
35	170.5	151	151	158			
40	169	150	150				
45	167	151	150	157	20559		
50	168	152	152			5 1/4	
55	169	157.5	152	160			
4 -	169	153	153				
05	172	156	155.5	163			
10	174	156	156				
4 15	174.5	157*	157	163			
*	173.5	156			20595	7"	
Ave.	170 #	153.2	153.5	DIFF	143000	=	30,316 #
					x .212		

RUN NO 2-119 % RATING

JUNE 22. 1917

Time	Over Fire	In Subht'r	Begin 2 nd pass	End 2 nd pass	Begin 3-pass	End 3-pass	Base Stack	Under Fire	Feed H ₂ O	Subht'r Temp	F	Time
	1	2	3	4	5	6	7	8	Temp F	F		
2 ¹⁵	.07	0.0	.08	0.17	0.17	0.14	0.91	.80	706	438		2 ¹⁵
30	.07	0.0	.09	0.14	0.18	0.15	0.89	.80	706	440		2 ³⁰
45	.03	0.0	.11	0.15	0.19	0.15	0.90	.90	706	436		2 ⁴⁵
3 ⁻	.03	0.0	.10	0.14	0.18	0.15	0.90	.85	706	440		3 ⁰⁰
15	.04	0.0	.11	0.16	0.19	0.16	0.90	.85	706	430		3 ¹⁵
30	.07	0.0	.09	0.13	0.17	0.15	0.91	.80	706	434		3 ³⁰
45	.04	0.0	.11	0.15	0.19	0.16	0.90	.80	706	438		3 ⁴⁵
4 ⁻	.04	0.0	.11	0.15	0.19	0.16	0.90	.80	706	442		4 ⁰⁰
15	.03	0.0	.10	0.15	0.20	0.16	0.90	.80	706	442		4 ¹⁵
Average	.03	0.0	.10	0.143	0.184	0.153	0.90	.87	706	438		

Time Start	Time Finish	Duration	CO ₂ %
2 ¹⁵	2 ³⁰	15	11.8
2 ³²	2 ⁴⁵	13	17.7
2 ⁴⁷	3 ⁰⁰	13	13.7
3 ⁰³	3 ¹⁵	12	15.0
3 ¹⁷	3 ³⁰	13	15.7
3 ³²	3 ⁴⁵	13	15.4
3 ⁴⁷	4 ⁰⁰	13	14.8
4 ⁰²	4 ¹⁵	13	17.6
		Aver	14.4

RUN NO 3 - 141% Rating.

Time	Gauge Boiler Drum	Gauge Suphtr Outlet	Gauge Main Line	°F Suphtr Temp	°F Feed H ₂ O	stirling	Meter Reading Factor = X.212	Inches H ₂ O Glass	
11 ³⁰				444	206	*	22216	7 $\frac{1}{4}$	
11 ³⁰	169	153.5	153.5	442	205	160			
11 ⁴⁰	174.5	157	157	444		163			
11 ⁵⁰	175.5	157	157	430	205	163	22251	9 $\frac{1}{4}$	Coal
11 ⁵⁵	176.5	155.5	155.5						5600 # Total.
12 ⁻	176.5	154.5	154.5	432		161			1 Rev - 94 Secs.
12 ⁰⁵	180.0	162.0	162		205				
12 ¹⁰	176.5	158.0	158	432		164			
12 ¹⁵	184.0	157	157						
12 ²⁰	185	162	162	444	204	167	22287	5 $\frac{1}{2}$	
12 ²⁵	184	158	158						
12 ³⁰	180	157	157	444		161			
12 ³⁵	182	158	158		206				
12 ⁴⁰	187	160	160	444		165			
12 ⁴⁵	184	158	158						
12 ⁵⁰	187.5	157	157	442	205	163	22331	3"	
12 ⁵⁵	180	157.5	157.5						
1 ⁻	180	156.5	156.5	442		161			
1 ⁰⁵	184	158.5	158.5		206				
1 ¹⁰	177.5	156.5	156.5	442		159			
1 ¹⁵	173.5	158	158						
1 ²⁰	175.5	154.5	154.5	444	206	161	22385	9"	
1 ²⁵	175.5	155.5	155.5						

Run No 3 - 14 1/8 Rating

Time	Gauge Boiler Drum	Gauge Suphtr Outlet	Gauge Main Line	°F Sub Temp	°F Feed H ₂ O	Gauge Stirling	Meter Readings x Factor = x .212	Inches H ₂ O Glass
1 ³⁰	173	154.5	154.5	440		158		
35	182	160.0	160.0		405			
40	183	156.5	156.5	434		163		
45	180	154.5	154.5					
50	181	154.5	154.5	442	405	158	22478	7 1/4
55	174.5	153.5	153.5					
2 ⁻	176.5	154.5	154.5	446		162		
05	178	154.5	154.5		404			
10	179	157	157	442		162		
15	178	157	157					
20	179	155	157	442	404	161	22472	7 1/4
Aver	179.0	156.8	156.8	441	405	162	DIFF = 256 thousand lbs x .212 = 54.272 #	
	179							

Run No 3 - 141% Rating

Adams Township, MI

	Over Fire	In Supht'r	Begin 2 nd pass	End 2 nd pass	Begin 3 rd pass	End 3 rd pass	Base Stack	Under Fire
Time	1	2	3	4	5	6	7	8
11 ²⁰	.04	.00	.10	.15	.18	.16	.90	1.00
35	.02	.00	.06	.09	.12	.11	.92	.95
50	.00	.00	.06	.12	.15	.14	.94	1.30
12 ⁰⁵	.00	.00	.05	.10	.15	.13	.93	1.30
20	.01	.00	.14	.21	.26	.25	.94	1.5
35	.03	.00	.20	.28	.32	.31	.94	1.3
50	.04	.00	.21	.29	.33	.31	.94	1.3
1 ⁰⁵	.02	.00	.16	.22	.27	.25	.91	1.4
20	.01	.00	.16	.23	.28	.26	.94	1.3
35	.02	.00	.15	.21	.26	.25	.91	1.4
50	.04	.03	.27	.32	.37	.34	.90	1.6
2 ⁰⁵	.07	.02	.25	.33	.36	.33	.92	1.4
20	.08	.04	.28	.36	.40	.38	.91	1.5
Aver.	.03	.01	.16	.23	.27	.25	.92	1.3

Run No 3 - 141% Rating

Adams Township, MI

Time			
Start	Finish	Duration	CO ₂
11 20	11 35	15	16.0
11 40	50	10	15.7
57	12 05	8	16.7
12 07	20	13	16.0
23	35	12	16.4
36	50	14	15.8
52	1 05	13	16.6
1 07	20	13	15.8
25	35	10	17.6
37	50	13	16.6
52	2 05	13	16.7
2 07	20	13	16.7
Aver.			16.7

Run No 4 - 170% Rating

JUNE 22-1917

Time	Gauge Boiler Drum	Gauge Sup. Outlet	Gauge Main Line	Superh. Temp.	Meter Read. Factor = X.212	Fd. H ₂ O Temp.	H ₂ O Glass Inches	Remarks.
10 ⁴⁵	185	155	154.5	438°F	20126	206°F	2 1/2"	* Cross-check Gauges.
50	185	155	154.5					
55				444				
11 ⁰⁰	183	156	154.5			206°		
11 ⁰⁵				440	20163		4"	
10	185 [#]	155	154.					#1 Boiler blew off.
15				440		206°		
20	185	157.5	156.5		20188		4"	
25	185	157.5	156.5	438				
30	187.5	157.0	156.			206°		
35	180	152.5	151.	430	20211		3 1/2"	
40	180	157.5	155.5					#1 Boiler blew off 1/2 Min. Press. increased 2# in #2
45	187	157.5	156.5	440	20228	204°	3"	
50	190	157.5	156.5		20236		3"	
11 ⁵⁵	182	156.	155.5	438				
12 ⁰⁰	182	155.	154.5			206°		
12 ⁰⁵	182	156	155.5	442	20263		3"	
12 ¹⁰	179	152.5	152.0					
12 ¹⁵	178.5	153.0	153.	440	20279	204°	2 1/2"	
C.C.	178	1540 *			DIFF			
Ave.	184.0	155.9	154.8	439°	=153000	205.4°		
Arc Drop =	28.1 #				X.212			
Max	" = 32.5 #				= 32.436 #			
Min	" = 22.5 #				= 34337 #	f. & at 212°F		

RUN No 4 - 170% RATING.

JUNE 22-1917

	Over Fire	In Suptkr.	Begin 2 nd Pass.	End 2 nd Pass.	Begin 3-Pass	End 3-Pass.	Base Stack	Under Fire
Time	1	2	3	4	5	6	7	8
10 ⁴⁵	.02	.00	.07	.12	.16	.11	.90	0.7
11 ⁰⁰	.08	.04	.32	.42	.46	.45	.91	1.3
11 ¹⁵	.06	.02	.26	.37	.41	.39	.92	1.5
11 ³⁰	.07	.04	.28	.38	.40	.38	.90	1.5
11 ⁴⁵	.07	.04	.35	.46	.51	.49	.91	1.6
12 ⁰⁰	.01	.00	.30	.42	.47	.42	.89	1.5
12 ¹⁵	.02	.00	.30	.42	.47	.42	.90	1.3
Ave.	.047	.023	.30	.411	.453	.425	.905	1.45"

Time Start	Time Finish	Duration	CO ₂
10 ⁴⁰	10 ⁴³	3' Min.	15.4
10 ⁴⁸	11 ⁰⁰	12' ..	16.2
11 ⁰¹	11 ¹⁵	14' ..	17.6
11 ¹⁸	11 ³⁰	12' ..	16.2
11 ³²	11 ⁴⁵	13	16.4
11 ⁴⁷	12 ⁰⁰	13	16.4
12 ⁰⁵	12 ¹⁵	10	14.8

Ave = 16.1%

COPPER RANGE COMPANY

Adams Township, MI

CHAMPION MILL PLANT

Tests on 1-391 H.P. Badenhausen Boiler to determine Pressure Drop thru. Superheater at various Ratings and approximate efficiency of Boiler-Furnace and Grate

Test No	1	2	3	4
Date	6/21/17	6/22/17	6/23/17	6/22/17
Duration in Hours	2	2	3	1 1/2
Boiler H.P. developed	340	465	551	665
Rated Capacity in evaporation from and at 13500	13500	13500	13500	13500
Builders Rating in B.H.P. ^{212°}	391	391	391	391
Per Cent of Rated Capacity developed	87	119	141	170
Water Heating Surface				
Superheating				
Kind and Size of Coal				
Kind of Furnace - 4 Retort Taylor				
Kind of Draft - Natural - Concrete Stack				
<u>Average Pressures</u>				
Steam Pressure in Boiler Drum by Gauge	164.4	170	179	184
" " at Suphtr Outlet " "	159.7	153.2	156.8	156
" " in Main Line	156	153.5	156.8	154.8
Draft at Boiler Damper	0.046	0.153	0.25	0.425
" over Fire	0.030	0.03	0.03	0.047
Air Pressure under Fire	1.0	0.82	1.3	1.45
Draft at Base of Stack	0.91	0.90	0.92	0.90

2

<u>Max and Min Pressures.</u>	1	2	3	4
Max. St Press. carried in Boiler Drum	167.5	174.5	187	190
Min	162	163.5	169	178.3
Max. St Press at Supht'r Outlet	158.5	157.5	160	157.5
Min	156.5	150	153.5	152.5
<u>Pressure Drop THRU Supht'r</u>				
Average DROP	6.7 [#]	16.8 [#]	22.2 [#]	28.1 [#]
Max	9.5	19.5	27.5 [#]	32.5 [#]
Min	5.0	11.0	15.5	22.5
<u>Average Temperatures</u>				
Temp of Steam leaving Supht'r	422.1	438°	441°	439°
Feed Water Temperatures	205	206	205	205.5
Superheat in Steam	52.2	70.5°	72°	70
<u>Total Quantities</u>				
Weight of Coal as fired in lbs.	2600	3200	5600	3400.
Per cent Moisture in Coal	10.8	5% ⁻²	5% ⁻²	5% ⁻²
Weight of Dry Coal	2327	3040	5320	3230
Per Cent Ash	7.5			
Weight of Combustible	2155			
Weight of Water fed to Boiler	22760	30320	54272	32436
Factor of evaporation	1.055	1.055	1.056	1.0563
Factor of evaporation including	1.086	1.090	1.094	1.094
Lat. Evaporation from and at ^{Superheat} 212° F	23460	31980	57310	34340
including Superheat	24150	33150	59250	35510

3

HOURLY QUANTITIES.

	1	2	3	4
Dry Coal consumed per Hour	1165			
Water evaporated per Hour	11130	15160	18090	21620
Equivalent evaporation per Hour from and at 212° F	11730	15990	19100	22890
Equivalent evaporation per Hour from and at 212° F, including Superh.	12075	16575	19750	22670
<u>Economy Results</u>				
Water fed per lb coal fired	8.57	9.48	9.66	9.55
Water evaporated into dry steam per pound of dry coal	9.55	9.97	10.2	10.1
Equivalent Evap. Dry steam from and at 212° F per lb. dry coal	10.1	10.5	10.75	10.65
Equiv. Evap. Dry st. f@ at 212° per lb combustible	11.05			
Equiv. Evap. Dry st. f@ at 212° per lb dry coal with Superh ^t	10.35			
Equiv. Evap. Dry st. f@ at 212° per lb combustible with Super	11.21			
CO ₂ - FLUE GAS ANALYSIS	14.7	14.4	16.2	16.1

4

EFFICIENCY RESULTS	1	2	3	4
Calorific Value of 1 lb. dry coal	12.932	13500	13500	13500
" " " - combustible	13.980	62	62	62
Efficiency of Boiler-Furnace and Grate	75.7	75.5	77.2	76.5
" " " and Furnace	76.5			
Over all efficiency on dry coal	76.7			
including Superheater on combustible	78.0			
including Superhtr				

RUN No 1 - 87% RATING

JUNE 21-1917

	Over Fire	In Sup'hr	Begin 2 nd Pass	End 2 nd Pass	Begin 3 rd Pass	End 3 rd Pass	Base Stack	UNDER FIRE
Time	1	2	3	4	5	6	7	8
9.40	.02	.00	.01	.01	.09	.05	.90	1.3
9.55	.02	.00	.00	.01	.06	.04	.89	0.9
10.10	.03	.00	.00	.01	.07	.03	.91	0.8
25	.03	.00	.01	.00	.08	.04	.90	0.8
40	.03	.00	.01	.00	.08	.04	.92	0.8
10.55	.03	.00	.00	.00	.08	.03	.90	0.9
11.10	.01	.00	.00	.00	.05	.02	.93	1.2
11.25	.05	.00	.04	.03	.13	.08	.92	1.2
11.40	.06	.02	.06	.03	.13	.08	.91	1.1
Ave	.03	.00	.014	.01	.086	.046	.909	1.0"

CO₂.

Time	Time		CO ₂
Start	Finish	Duration	
9.40	9.55	15 min	13.4
9.57	10.12	15 "	15.2
10.15	10.25	10	15.8
10.28	10.40	12	15.2
10.42	10.55	13	13.2
10.57	11.10	13	13.8
11.15	11.25	10	15.2
27	11.40	13	16.0

Ave = 14.7%

RUN NO 1 - 87% RATING

JUNE - 21 - 1917

Time	Gauge Boiler Drum	Gauge Sup. Outlet	Gauge Main Line	Gauge in Frame on Boiler Drum <small>5" Water</small>	Suphr Temp ^F	Fd. H ₂ O TEMP	Meter Readings Factor = X.212	REMARKS
9 ⁴⁰	167.5	158	156.5	172	418	206	18157	
5 ⁰	165.5	158	156.5	170	422	204		
10 ⁰⁰	165.5	158	157.5	173	430			2600# Coal
10 ¹⁰	167.0	158	156	171	420	204	18183	- Total
10 ²⁰	162	157	156	166	426	206		Stoker ran
10 ³⁰	163.5	157	156	169	420			1 Rev. in
10 ⁴⁰	162.5	157.5	155	166	420	206	18211	136 secs.
10 ⁵⁰	163.5	158	156	169	428	202		
11 ⁰⁰	163.5	157.5	155	169	422			
11 ¹⁰	163.5	158.5	157	168	420	204	18237	
2 ⁰	163.5	157.5	155	168	424			
3 ⁰	163.5	156.5	154	168	420	206		
11 ⁴⁰	166.5	158.5	156	171	418	206	18262	
Ave	164.4	157.7	156	169.2	422.1	205°F	105 thousand lbs X.212 = 22,260 #	

Ave. Drop between Boiler Drum + Superheater = 6.7#

Min " " " " = 5.0#

Max " " " " = 9.5#

Lbs. of Water from and at 212°F = 23462#

Run No 2 - 119 % Rating

JUNE 22-1917

	Gauge	Gauge	Gauge	Gauge	Venturi	H ₂ O	Remarks
Time	Boiler Drum	Sup Outlet	Main Line	5 th Log Stirling	Meter Reading Factor .212	Glass Inches	
2 15	171*	155*	155.5	161	20452	5 1/2	* Cross Checked Gauges.
20	163.5	157.5	153	1			
25	167	154	154.5	159			
30	168	157.5	153				3700 # Coal - Total.
35	168	157.5	153	159			
40	167	157	157.5				
45	169	153	153	160	20489	7 1/2	
50	170.5	154	154				Ave Drop. Drum to Suptr = 16.8 #
55	169	157.5	157.5	158			Min " " " = 11.0 #
3 00	174	155	155				Max " " " = 19.5 #
5	177	154	154	160			
10	177	157.5	157.5				Water evaporated f. + at
15	171	153	153	159	20521	5 1/2	212°F = 319.83 #
20	169	150	150.5				= 15990 # per Hr.
25	169	157	151.5	155			
30	174	157.5	158				
35	170.5	151	151	158			
40	169	150	150				
45	167	151	150	157	20559		
50	168	152	152			5 1/4	
55	169	157.5	152	160			
4 -	169	153	153				
05	172	156	155.5	163			
10	174	156	156				
4 15	174.5	157*	157	163			
*	173.5	156			20595	7"	
Ave	170 #	153.2	153.5	DIFF	143440	=	30,316 #
				X.212			

Run No 2 - 119 % Rating

JUNE 22. 1917

Time	Over Fire	In Subht'r	Begin 2 nd pass	End 2 nd pass	Begin 3-pass	End 3-pass	Base Stack	Under Fire	Feed H ₂ O	Subht. Temp	F	Time
	1	2	3	4	5	6	7	8	Temp F°			
2 ¹⁵	.02	0.0	.08	0.12	0.17	0.14	0.91	.80	706	438		2 ¹⁵
30	.02	0.0	.09	0.14	0.18	0.15	0.89	.80	706	440		2 ³⁰
45	.03	0.0	.11	0.15	0.19	0.15	0.90	.90	706	436		2 ⁴⁵
3 ⁻	.03	0.0	.10	0.14	0.18	0.15	0.90	.85	706	440		3 ⁰⁰
15	.04	0.0	.11	0.16	0.19	0.16	0.90	.85	706	430		3 ¹⁵
30	.02	0.0	.09	0.13	0.17	0.15	0.91	.80	706	434		3 ³⁰
45	.02	0.0	.11	0.15	0.19	0.16	0.90	.80	706	438		3 ⁴⁵
4 ⁻	.04	0.0	.11	0.15	0.19	0.16	0.90	.80	706	442		4 ⁰⁰
15	.03	0.0	.10	0.15	0.20	0.16	0.90	.80	706	446		4 ¹⁵
Average	.03	0.0	.10	0.143	0.184	0.153	0.90	.87	706	438		

Time Start	Time Finish	Duration	CO ₂ %
2 ¹⁵	2 ³⁰	15	11.8
2 ³²	2 ⁴⁵	13	12.2
2 ⁴⁷	3 ⁰⁰	13	13.2
3 ⁰³	3 ¹⁵	12	15.0
3 ¹⁷	3 ³⁰	13	15.2
3 ³²	3 ⁴⁵	13	15.4
3 ⁴⁷	4 ⁰⁰	13	14.8
4 ⁰²	4 ¹⁵	13	17.6
		Aver	14.4

RUN NO 3 - 141% RATING.

Time	Gauge Boiler Drum	Gauge Substr Outlet	Gauge Main Line	°F Substr Temp	°F Feed H ₂ O	stirling	Meter Reading Factor = X.212	Inches H ₂ O Glass	
11 ³⁰				444	206	1	22216	7 $\frac{1}{4}$	
11 ³⁰	169	153.5	153.5	442	205	160			
11 ⁴⁰	174.5	157	157	444		163			
11 ⁵⁰	175.5	157	157	430	205	163	22251	9 $\frac{1}{4}$	Coal
11 ⁵⁵	176.5	155.5	155.5						5600 [#] Total.
12 ⁻	176.5	154.5	154.5	432		161			1 Rev - 94 Secs.
12 ⁰⁵	180.0	162.0	162		205				
12 ¹⁰	176.5	158.0	158	432		164			
12 ¹⁵	182.0	157	157						
12 ²⁰	185	162	162	444	204	167	22287	5 $\frac{1}{2}$	
12 ²⁵	184	158	158						
12 ³⁰	180	157	157	444		161			
12 ³⁵	182	158	158		206				
12 ⁴⁰	187	160	160	444		165			
12 ⁴⁵	184	158	158						
12 ⁵⁰	182.5	157	157	442	205	163	22331	3"	
12 ⁵⁵	180	157.5	157.5						
1 ⁻	180	156.5	156.5	442		161			
1 ⁰⁵	182	158.5	158.5		206				
1 ¹⁰	177.5	156.5	156.5	442		159			
1 ¹⁵	173.5	158	158						
1 ²⁰	175.5	154.5	154.5	444	206	161	22385	9"	
1 ²⁵	175.5	155.5	155.5						

Run test 3 - 1.41% Rating

	Gauge	Gauge	Gauge	°F	°F	Gauge	Meter Readings	Inches
Time	Boiler Drum	Suphr Outlet	Main Line	Sub Temp	Feed H ₂ O	Stirling	x Factor = X.212	H ₂ O Glass
1 ³⁰	173	154.5	154.5	440		158		
35	182	160.0	160.0		205			
40	183	156.5	156.5	434		163		
45	180	154.5	154.5					
50	181	154.5	154.5	442	205	158	22478	7 ¹ / ₄
55	174.5	153.5	153.5					
2 ⁰⁰	176.5	154.5	154.5	446		162		
05	178	154.5	154.5		204			
10	179	157	157	442		162		
15	178	157	157					
20	179	155	157	442	204	161	22472	7 ¹ / ₄
Aver	179	156.8	156.8	441	205	162	DIFF = 256000 X.212 = 54.270#	

RUN NO 3 - 141% RATING

Adams Township, MI

	Over Fire	In Supht'r	Begin 2 nd pass	End 2 nd pass	Begin 3 rd pass	End 3 rd pass	Base Stack	Under Fire
Time	1	2	3	4	5	6	7	8
11 ²⁰	.04	.00	.10	.15	.18	.16	.90	1.20
35	.02	.00	.06	.09	.12	.11	.92	.95
50	.00	.00	.06	.12	.15	.14	.94	1.30
12 ⁰⁵	.00	.00	.05	.10	.15	.13	.93	1.30
20	.01	.00	.14	.21	.26	.25	.92	1.5
35	.03	.00	.20	.28	.32	.31	.92	1.3
50	.04	.00	.21	.29	.33	.31	.92	1.3
1 ⁰⁵	.02	.00	.16	.22	.27	.25	.91	1.4
20	.01	.00	.16	.23	.28	.26	.92	1.3
35	.02	.00	.15	.21	.26	.25	.91	1.4
50	.04	.03	.27	.32	.37	.34	.90	1.6
2 ⁰⁵	.07	.02	.25	.33	.36	.33	.92	1.4
20	.08	.04	.28	.36	.40	.38	.91	1.5
Aver.	.03	.00	.16	.23	.27	.25	.92	1.3

240

RUN NO 3 - 141% RATING.

Time				
Start	Finish	Duration	CO ₂	
11 20	11 35	15	16.0	
11 40	50	10	15.7	
57	12 05	8	16.7	
12 07	20	13	16.0	
23	35	12	16.4	
36	50	14	15.8	
52	1 05	13	16.6	
1 07	20	13	15.8	
25	35	10	17.6	
37	50	13	16.6	
52	2 05	13	16.7	
2 07	20	13	16.7	
Aver			16.7	

Run No 4 - 170% Rating

JUNE 22-1917

	Gauge	Gauge	Gauge		Meter Read.	Fd. H ₂ O	H ₂ O Glass	
Time	Boiler Drum	Sup. Outlet	Main Line	Superh Temp	Factor = X.212	Temp.	Inches	REMARKS.
10 ⁴⁵	185	155	154.5	438F	20126	206° F	2 1/4"	* Cross-check Gauges.
50	183	155	154.5					
55				444				
11 ⁰⁰	183	156	154.5			206°		
11 ⁰⁵				440	20163		4"	
10	185 [#]	155	154.					- #1 Boiler blew off.
15				440		206°		
20	185	157.5	156.5		20188		4"	
25	185	157.5	156.5	438				
30	187.5	157.0	156.			206°		
35	180.	152.5	151.	430	20211		3 1/2"	
40	180	157.5	155.5					#1 Boiler blew off 1/2 Min.
45	187	157.5	156.5	440	20228	204°	3"	
50	190	157.5	156.5		20236		3"	Press. increased 2# in #2
11 ⁵⁵	182	156.	155.5	438				
12 ⁰⁰	182	155.	154.5			206°		
12 ⁰⁵	182	156	155.5	442	20263		3"	
12 ¹⁰	179	152.5	152.0					
12 ¹⁵	178.5	153.0	153.	440	20279	204°	2 1/2"	
C.C.	198	154.0	*		DIFF			
Ave.	184	155.9	154.8	439°	=153000	205.4		
Ave Drop	= 28.1	#			X.212	#		
Max	" = 32.5	#			= 32.436	#		
Min	" = 22.5	#			= 34337	# f. and at 212° F.		

RUN NO 4 - 178% RATING.

JUNE 22-1917

	Over Fire	In Supht'r	Begin 2 nd Pass.	End 2 nd Pass.	Begin 3-Pass	End 3-Pass.	Base Stack	Under Fire
Time	1	2	3	4	5	6	7	8
10 ⁴⁵	.02	.00	.07	.12	.16	.11	.90	0.7
11 ⁰⁰	.08	.04	.32	.42	.46	.45	.91	1.3
11 ¹⁵	.06	.02	.26	.37	.41	.39	.92	1.5
11 ³⁰	.07	.04	.28	.38	.40	.38	.90	1.5
11 ⁴⁵	.07	.04	.35	.46	.51	.49	.91	1.6
12 ⁰⁰	.01	.00	.30	.42	.47	.42	.89	1.5
12 ¹⁵	.02	.00	.30	.42	.47	.42	.90	1.3
Ave.	.047	.023	.30	.411	.453	.425	.905	1.45"

Time Start	Time Finish	Duration	CO ₂
10 ⁴⁰	10 ⁴³	3' Min	15.4
10 ⁴⁸	11 ⁰⁰	12'	16.2
11 ⁰¹	11 ¹⁵	14'	17.6
11 ¹⁸	11 ³⁰	12'	16.2
11 ³²	11 ⁴⁵	13'	16.4
11 ⁴⁷	12 ⁰⁰	13'	16.4
12 ⁰⁵	12 ¹⁵	10'	14.8

Ave = 16.1%

2 RUN D RIGHT HAND ENGINE CRANK END

Card #	Term. Press	S.V.	Card #	T.P.	S.V.	Card #	T.P.	S.V.	Card #	T.P.	S.V.	Card #	T.P.	S.V.
1	15	0728	27	27	0998	59	28		92	29		21	29	
2	23	0908	28	28	1020	60	29		93	29		22	29	
3	24	0931	29	26	0976	61	28		94	28		23	28	
4	23	0908	30	27	0998	62	29		95	28		24	28	
5	24	0931	31	26	0976	63	28		96	27		25	27	
6	25	0953	32	26	0976	64	28		97	27		26	29	
7	25	0953	33	26	0976	65	28		98	27		27	29	
8	27	0998	34	26	0976	66	28		99	27		28	30	
9	27	0998	35	24	0931	67	28		100	27		29	30	
10	26	0976	36	25	0953	68	28					30	30	
11	23	0908	37	25		69	28					31	30	
12	23	0908	38	25		70	28					32	30	
13	24	0931	39	25		71	28					33	31	
14	24	0908	40	26	0976	72	28					34	31	
15	23	0908	41	28	1020	73	27							
16	24	0931	42	28		74	28							
17	24	0908	43	28		75	27							
18	23	0908	44	28		76	27							
19	25	0953	45	28		77	27							
20	28	1020	46	28		78	27							
21	28	1020	47	28		79	27							
22	28	1020	48	28		80	28							
23	28	1020	49	28		81	28							
24	28	1020	50	28		82	29							
25	27	0998	51	28	1020	83	28							
26	27	0998	52	28	1020	84	28							
			53	28		85	28							
			54	28		86	29							
			55	30	1065	87	29							
			56	28	1020	88	28							
			57	28		89	28							
			58	28		90	28							
			59	28		91	28							

avg 27.5 #
S.V. 1000

4 RUN D R. H. HEAD END

RUN D. L. H. ENGINE C. END.

Card #	T.P.	S.V.	S.V.
1-5 inc	30	.1065	5325
6-16 inc	35.3	.1131	2441
17-35 inc	35	.1175	22325
36-39	33	.1131	4524
40-81	36	.1197	57456
88-127	37.5	.1219	48760
128-133	40	.1285	7710
134	6	.0521	10521
			15,906
			AVG. 1186

Ap. V.
 R.N. Sup CE = .1000
 " " N.E. = .1186
 " " E.E. = .1163
 " " N.E. = 1230
 Ave # = .1145

Card #	T.P.	S.V.	AVG.
1	32	.1065	
2-35	33	.1131	
36-38	35	.1175	.1163
39	37	.1131	
40-74	36	.1197	
75-131	35	.1175	
132	6	.0521	

Cut lbs per acre = 1.603 c.f.
 " " in 134 rows
 = 859.2 cwt
 = 98.4 #

6 RUN D L.H. ENG H.E.

WITH TAIL ROPE

7

1st / 10 pers.

COND #	T.P.	S.I.	R.H. Eng. C.E.	L.H. Eng. C.E.	Run	Arc and of stroke	Cur #	St. Press	Time	Strokes	St. Lbs.
1	42	.1329	289	32.9	D	27.5	35.8	85	108"	134	.733
2-5	27	.0998	25.4	30.5	E	26.5	37.6	79	112.5"	134	.933
6-16	37	.1219	21.0	28.6	C	29.4	35.6	93	92"	134	.726
17-103	38	.1241		31.4			34.5	33.5			
104-133	40	.1285									
134	10	.0614	36.8	45.3	H	28.8	40.4	95	71"	132	.773
			35.0	34.2	I	26.5	37.5	95	78"	130	.731
			36.3	47.5	J	26.4	39.4	95	72"	130	.752
				54.2			36.0	39.6			
				50.4			34.2	33.9			
				51.6			36.5	36.8			
				46.9			34.5	33.9			
				41.6			34.2	33.9			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
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				46.3			34.5	33.5			
				47.5			34.5	33.5			
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				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
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				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			
				50.4			34.5	33.5			
				51.6			34.5	33.5			
				46.9			34.5	33.5			
				41.6			34.5	33.5			
				46.3			34.5	33.5			
				47.5			34.5	33.5			
				51.6			34.5	33.5			
				54.2			34.5	33.5			

Barkhausen Boilers

1st set of superheaters following
Barkhausen boiler calculations

$$W = e \sqrt{\frac{w p d^5}{L}}$$

where W = weight
 w = density

p = drop

d = internal dia
pipe

L = length pipe
in feet

$$C = 87 \sqrt{\frac{1}{1 + \frac{3}{d^4}}}$$

= 64.8 for 5" dia

$$= 49.8 \text{ for } 2 \text{ " tubes, } C = \text{constant}$$

Assuming long pipe bend over as straight

$$= 3-2-0$$

" then equals 25 dia

$$1-5 \text{ " } 20 = \frac{8-0}{60 \text{ ft}}$$

$$M = \frac{391 \text{ HP} \times 30 \text{ ft} \times 2}{60} = 391 \text{ # steam per min}$$

$$p = \frac{(391)^2 \times 60}{1,425 \times 25^4 \times (64.8)^2} = 2.02 \text{ # drop}$$

2" tube

.425 density superheated

.363 " " actual

$$2 \sqrt{1988}$$

.394 = average density

$$\frac{391 \text{ #}}{4} = 98 \text{ # per tube}$$

8'-6" of straight tube

3'-6" = 20 times (2") per bend

$$\frac{12-0 \text{ "}}{12-0 \text{ "}} = \text{total length}$$

$$p = \frac{W^2 L}{w d^5 C^2} = \frac{(98)^2 \times 12.0}{.394 \times (1.875)^5 \times (49)^2} = 5.34 \text{ #}$$

For 3 banks of tubes = 1617 #

Experimental data: drop entering and leaving 2" tube 5" boiler

Velocity = 391 # steam per min

98 # per tube

$$\frac{98 \times 2.75}{.0145} = 18600 \text{ feet per min}$$

As Bordenham calculation

$$10200 : \frac{1.29}{.33} :: 18600 : \frac{x}{.39}$$

$$10200 : 3.9 :: 18600 : 7.1$$

$$x = 2.8 \#$$

This occurs 6 times = 16.8 #

Total sleep
 = 2.02 + 16.17# + 16.8 = 35.0 #

For 2nd set of superheaters,

Assuming long pipe same as straight

outside of tubes = 24'-0"

1 elbow (20 x 5) = 8'-6"

inside header = 27'-6"

avg 60'-0"

$$p = \frac{(391)^2 \times 60}{.425 \times 25 \times 40 \times (64.8)^2} = 1.95 \#$$

$$\frac{391 \#}{9} = 44 \# \text{ per tubes.}$$

$$p = \frac{(44)^2 \times 15}{.394 \times (11.25)^5 \times (49)^2} = \text{Straight tube} = 11'-6"$$

$$\text{Bent tube} = 3'-6"$$

$$15'-0"$$

$$= \frac{1936 \times 15}{.394 \times 11.33 \times 2401} = \frac{29040}{10718} = 2.71 \#$$

Two Banks of tubes = 5.42 #

Experimental data: deep entering and leaving 2" tubes 8" leaders

10200 : $\frac{1.29}{.33}$: 8400 : $\frac{x}{.39}$

velocity = $\frac{391}{9} = 44$ lbs per min.

$44 \times 2.75 = 83.50$ feet.

$\frac{.0145}{.39} = .0372$

= 10200 : .39 : 8400 : .352

$x = 1.15$

this means 4 times = 4.6 #

Total for all measurements

= 1.95 + 5.42 + 4.6 = 11.97

pay - 12 #

1st set of superheater tubes at 170% rating.

for 5" pipe 200% rating deep = 2.02 #

for $\frac{289}{400} \times 2.02 = 1.44$ #

For 2" tubes. 170% rating deep = .72 x 16. 17# = 11.64 #

For 2" tubes entering and leaving velocity

170% Rating = 85% of 391# = 332 #

or vel. = 85% of 18600

and deep = 85% of 2.8 = 2.38 #

Total deep for entering and leaving = 6 x 2.38 = 14.28

Total deep for 170% Rating

= 1.44 + 11.64 + 14.28 = 27.5 #

For 200% Rating 2nd vel

for 5" pipe 200% Rating

$$= 1.004 \times \text{dup} = 2.1 \#$$

$$\text{For 2" tubes} = 5,42 \times 1.004 = 5,64 \#$$

$$\text{For vel. dup} = 1.02 \times 4.6 = 4.7$$

$$\text{Total dup} = 12.5 \#$$

For 102% Rating

$$= .26 \times 2,02 = .525 \#$$

$$(2^{\text{nd}}) = .26 \times 5,42 = 1,409$$

$$= \frac{2,346}{4,280}$$

$$= 4,3 \#$$

For Superheat 1st cut up

26'-0" of tube length at .3-09

per foot surface = 15.3 sq. ft

per tube = 61.2 sq. ft total.

Heat transmission = 150 B.T.U. per

$$29.1 \text{ ft} = 61.2 \times 150 = 9180 \text{ B.T.U.}$$

with 391# steam per min.

$$= \frac{9180}{391} = 23.5 \text{ B.T.U. added}$$

per lb steam.

Original heat of steam 180# per

$$= 1197.7$$

$$\text{add } \frac{23.5}{1221.2} = 180 \# @ 40' \text{ sup.}$$

$$@ 100\% \text{ rating} = 47 \text{ B.T.U. added}$$

$$= 1197.7$$

$$47.0$$

$$\frac{1244.7}{\text{B.T.U.}} = 80 \text{ sup.}$$

$$\text{at } 178\% \text{ rating} = 27.5 \text{ B.T.U. added}$$

$$= 44 \text{ sup.}$$

Heat consumption by 1st section actual data @ 178% Rating = 71°

Steam press 189 # exhausted = 1198.0
" " 158 # 70° sup = 1237.2

$$\frac{1198.0 + 1237.2}{2} = 39.2$$

$$\text{Steam} = 391 \times 30 \times 1.7 = 19940 \text{ lbs} = 332 \# \text{ per min}$$

$$\frac{332 \times 39.2}{61.2} = 5.42 \times 39.2 = 212.13 \text{ T.M. per sq. foot.}$$

87% Rating 1st case.

At press boiler drum = 164.4 = 1196.3

" " at superheater 157.7 at 50° sup = 1226.2
Diff added = 29.9

$$\text{Steam} = \frac{391 \times 30 \times .87}{61.2} = 178 \# \text{ per min.}$$

$$\frac{170 \times 29.9}{61.2} = 83.13 \text{ T.M. per sq. ft.}$$

Case 2 - 17 tubes length = 11'-6"

= 195.5' x .523 = 102.2 #

204 % Rating

One at press Boiler drum = 199 # = 1199.4

at sup. water

= 162.9 = 1258.5
1090 sup 60.1

204 % Rating = 400 # steam per min.

400 x 60.1 = 23613 T.H. hrs.
102.2

102 % Rating = 200 # at. per min

All press estimated = 170 # = 1196.8

161.7 @ 100 sup = 12539
14.2
176.9
59.1

= 5.9 B.T.U.

Heat Transmission

= $\frac{59 \times 200}{102.2} = 111$ B.T.U.
per sq. ft.

Required superheater

153 sq ft

at 180 % load B.T.U. Transmission

= 153 x 109 = 16677 B.T.U.

for 100 % load = 195 # per min

= $\frac{16677}{195} = 85$ B.T.U. min.

180 # at out = 1197.7

add $\frac{1282.7}{85.0} = 180$ # at - 1350 superheat.

155% = 195 x 1.55 = 302.25 # of.

ave of prices = 173.4 out = 1197.1

dup of = 162.5 @ 107.3 = 1257.1
147
175.12
60.00

302 x 60.20 = 178.03 B.T.U.
102.2

157% = 195 x 1.57 = 306.1 # of

ave of prices = 175.5 = 1197.3

dup. outlet = 162.7 = 1259.0
@ 10.6 = 89.9

39.7 x 306.1 = 177.3 B.T.U.
102.2

Case No 1

119% Rating = 1.19 x 195 = 232 #

ave of prices = 170 = 1196.8

dup. prices = 153.2 = 1236.7
@ 70.5 = 38.9

Ap. feet = 61.2
232 x 34 = 147.8 B.T.U.
61.2

141% Rating = 1.41 x 195 = 275 #

At prices = 179.0 = 1197.6

dup = 152.8 = 1237.1
@ 72 = 39.5

39.5 x 275 = 177.5 B.T.U.
61.2

Velocity @ diff. ratings

Case	FT per Run
87 1/2	8090
100 1/2	9300
119 1/2	11100
141 1/2	13100
170 1/2	15800
200 1/2	18600

Box 2 Case FT per Run

100 1/2	4200
102 1/2	4300
111 1/2	4660
125 1/2	5250
133 1/2	6518
157 1/2	6600
200 1/2	8400
204 1/2	8600

Purposed Super-lester

125% load = 195' x 1 1/2" = 293 # per Run

150% load = 195' x 1 1/2" = 293 " "

153 09.44 B. Td. Turns per 19.

from curve No 2.

= 170

$\frac{153 \times 170}{293} = 89$ added.

180# outwashed = 1197.7

add $\frac{1286.7}{89.8}$

= 1600 purp.

$\frac{133 \times 140}{244} = 88.8$

$\frac{1197.7}{1285.7}$

= 1600 purp

See Superheater that will
superheat 1250 @ 150% Rating

B.T.U. Transfer per sq. ft. per
hour = 178

1250 - 180 # steam =

180 # out steam = 1197.7 B.T.U.

180 # - 1250 = $\frac{1269.3}{71.6}$ B.T.U.

71.6 B.T.U per lb steam

150% Rating = $195 \times 1.5 = 292$ lbs

steam

B.T.U. added per lb steam = 71.6

$\frac{292 \times 71.6}{170} = 123$ sq. ft.

153 sq ft = 11'-6" long tube
123 " " = 9'-3" " "

For 180 sup.

180 # saturated steam = 1197.7 B.T.U.
180 # 180° sup = $\frac{1256.4}{578.7}$

150% Rating = 292 # steam per hr.

$\frac{292 \times 578.7}{170} = 180$ sq. ft.

153 sq ft = 11'-6" long
180 " " = 9'-6" long

26 tubes - 8'-6" long = 221 feet.

221 x .523 \square surface = 116 sq. ft.

For 123 sq. ft surface.

at 125% Rating Find superheat?

195 # at x 1.25 = 244 # steam

$\frac{123 \times 140 \text{ (ht transfer)}}{244} = 70.5$ B.T.U. added

And steam @ 180 # = $\frac{1197.7}{70.5}$

= 180 # - 123° sup. $\frac{1268.7}{1268.7}$

at 140% Rating the steam = 195° #

$$\frac{125 \text{ sq ft} \times 185}{195} = 66.2 \text{ BTU}$$

$$180 \# \text{ out} = \frac{1197.7}{1263.9} = 115^{\circ} \text{ out}$$

200% Rating the steam = 391 #

$$\frac{123 \times 235}{391} = 74 \text{ BTU added}$$

$$180 \# \text{ out} = \frac{1197}{1271} = 130^{\circ}$$

150% Rating

$$\frac{123 \times 170}{292} = 71.6$$

$$\frac{1197.7}{1269.3} = 125^{\circ}$$

For 180 sq ft Rating our free superheat will be as follows.

$$100\% \text{ Rating} = \frac{180 \times 105}{195} = 53.8$$

$$\frac{1197.7}{1251.5} = 90^{\circ} \text{ out}$$

$$125\% \text{ Rating} = \frac{180 \times 140}{244} = 57.4$$

$$\frac{1255.1}{1} = 99^{\circ} \text{ out}$$

$$150\% \text{ Rating} = \frac{180 \times 170}{292} = 58.2$$

$$\frac{1255.9}{1} = 180^{\circ} \text{ out}$$

$$200\% \text{ Rating} = \frac{180 \times 235}{391} = 60.0$$

$$\frac{1197.7}{1257.7} = 101^{\circ} \text{ out}$$

Resistive this tubes - 9'3" long

$$= \frac{9'3 \text{ string} \text{ tubes}}{13'0}$$

$$= \frac{13}{14.5} \times \frac{1'1}{1} = 1 \#$$

∴ 2 # deep for two banks of tubes

Total deep for sampler = 6.3 #

7-6 tubes deep = 6.1 #

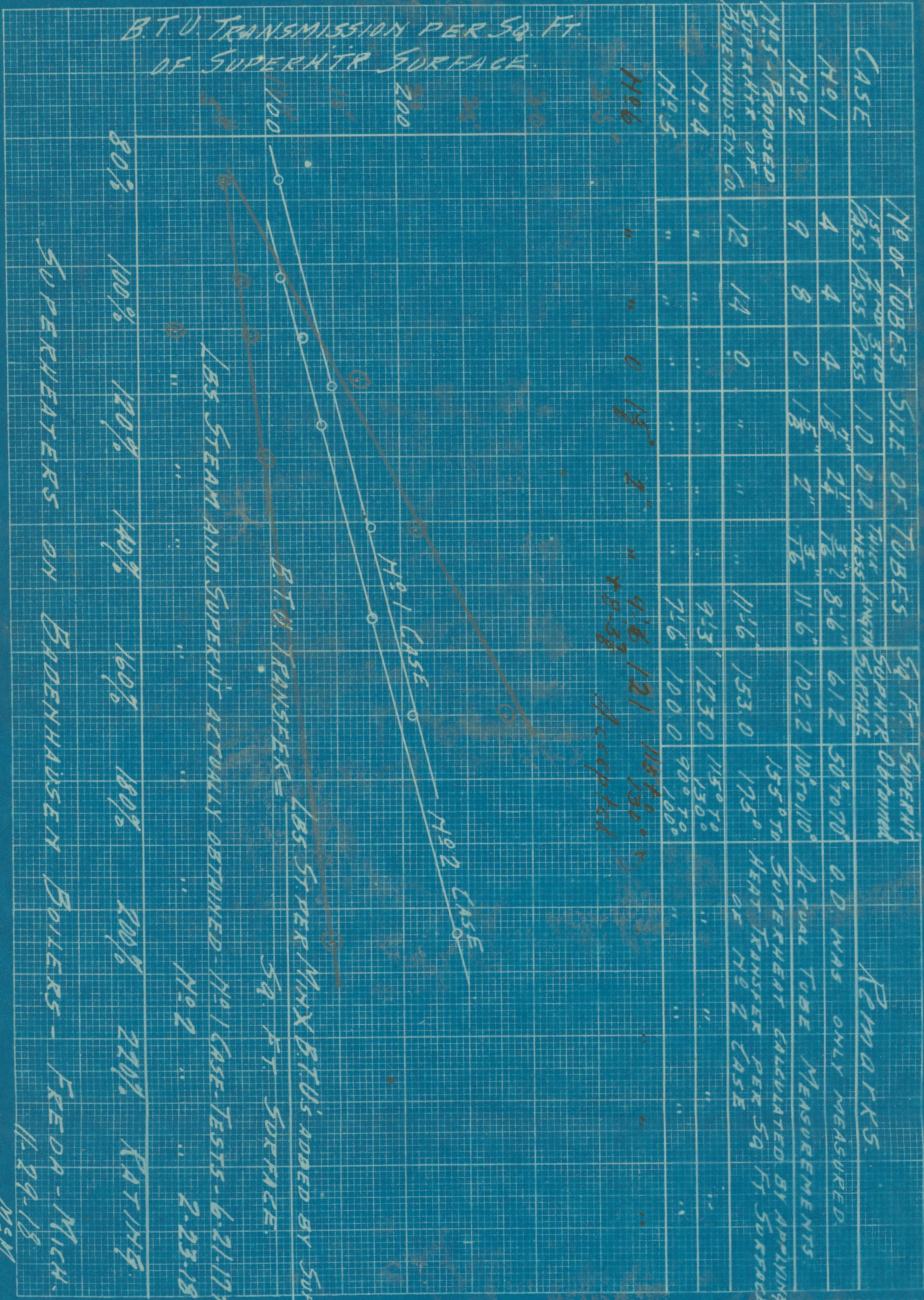
TEST OF NEW RIVER COAL FROM APRIL 23 TO APRIL 30, 1918 AT
 FEEDA, MICH: 4 BADENHAUSEN BOILERS AND STOKERS: HOURLY READINGS TAKEN.

DATE	STEAM PRESSURE	INDICATED BOILER HORSE BY METER	AVERAGE B.H.P BY WATER WEIGHT	FEED WATER TEMPERATURE	STEAM TEMPERATURE	SUPERHEAT	FLUE GAS TEMPERATURE	AVE. DRAFT PRESS. IN INS. WATER UNDER FIRE	AVE. DRAFT PRESS. IN INS. WATER OVER FIRE	COAL USED IN LBS	COAL USED IN TONS	WATER EVAPORATED IN LBS.	ACTUAL LBS. WATER EVAPORATED PER LB. COAL	HOURS ASH-BLOWER USED	HEAD HOURS-TOTAL	AVERAGE HEADS PER HOUR	HOURS TURBINE TOOK LIVE STEAM.
4-23	161.2	2080	2080	196.0	443°	71.7°	550°	1.5"	.19	162,045	81.02	1,643,000	10.14	2	112.0	4.67	1 3/4
4-24	160.2	2026	1990	202.5	439	68.2	535	1.75"	.09	161,700	80.85	1,565,000	9.68	2	85.5	3.56	7 1/2
4-25	160.1	2010	2000	201.5	438	68.0	520	1.6	.09	147,520	73.76	1,581,000	10.72	2	94.5	3.52	1 1/2
4-26	160.6	2060	2090	201.1	439	68.5	535	2.1	.04	159,760	79.88	1,652,000	10.34	2	109.0	4.54	50 MIN
4-27	160.3	1950	1980	202.5	441	70.0	525	1.8	.12	147,100	73.55	1,564,000	10.63	2	98.0	4.08	4.50'
4-28	SUNDAY -	N/O	N/O	REA	DINGS	TAKEN.				37,640	18.82	434,000	11.50		0	0	0
4-29	160.0	1800	1795	196.0	438	68.0	560	2.2	.15	144,780	72.39	1,389,000	9.59	2	82.5	4.58	15 MIN
4-30	161.1	2130	2160	201.5	447	75.7	555	1.9	.14	168,310	84.15	1,699,000	10.10	2	117.5	4.9	NONE
Ave.	160.9	2008	2011	1993	441°	70.0°	540.4	1.8"	.12	564,420 LBS	70.55	1,440,900	10.34	2	102.2	4.26	

COAL ANALYSIS:- B. T. U. 14.556
 ASH 6.35%
 MOISTURE 3.29%
 EFFICIENCY OF BOILER, FURNACE AND GRATE 76.07%

DATA FOR MARCH - 1918
 ACTUAL WATER EVAPORATED IN LBS. PER LB. COAL. 8.95 LBS.
 COAL ANALYSIS - 12.967 B.T.U. 12% ASH. 4 TO 4 1/2% MOISTURE
 EFFICIENCY OF BOILER, FURNACE AND GRATE FOR MONTH - 74.76%
 ASSUMED

B.T.U. TRANSMISSION PER SQ. FT. OF SUPERHEAT SURFACE.



LESS STEAM AND SUPERHEAT ACTUALLY OBTAINED - NO. 1 CASE - TESTS - 6-21-1970 6-23-17

LESS STEAM AND SUPERHEAT ACTUALLY OBTAINED - NO. 2 CASE - TESTS - 2-23-18 702-26-18

LESS STEAM AND SUPERHEAT ACTUALLY OBTAINED - NO. 5 CASE - TESTS - 6-21-1970 6-23-17

LESS STEAM AND SUPERHEAT ACTUALLY OBTAINED - NO. 1 CASE - TESTS - 6-21-1970 6-23-17

LESS STEAM AND SUPERHEAT ACTUALLY OBTAINED - NO. 2 CASE - TESTS - 2-23-18 702-26-18

LESS STEAM AND SUPERHEAT ACTUALLY OBTAINED - NO. 5 CASE - TESTS - 6-21-1970 6-23-17

LESS STEAM AND SUPERHEAT ACTUALLY OBTAINED - NO. 1 CASE - TESTS - 6-21-1970 6-23-17

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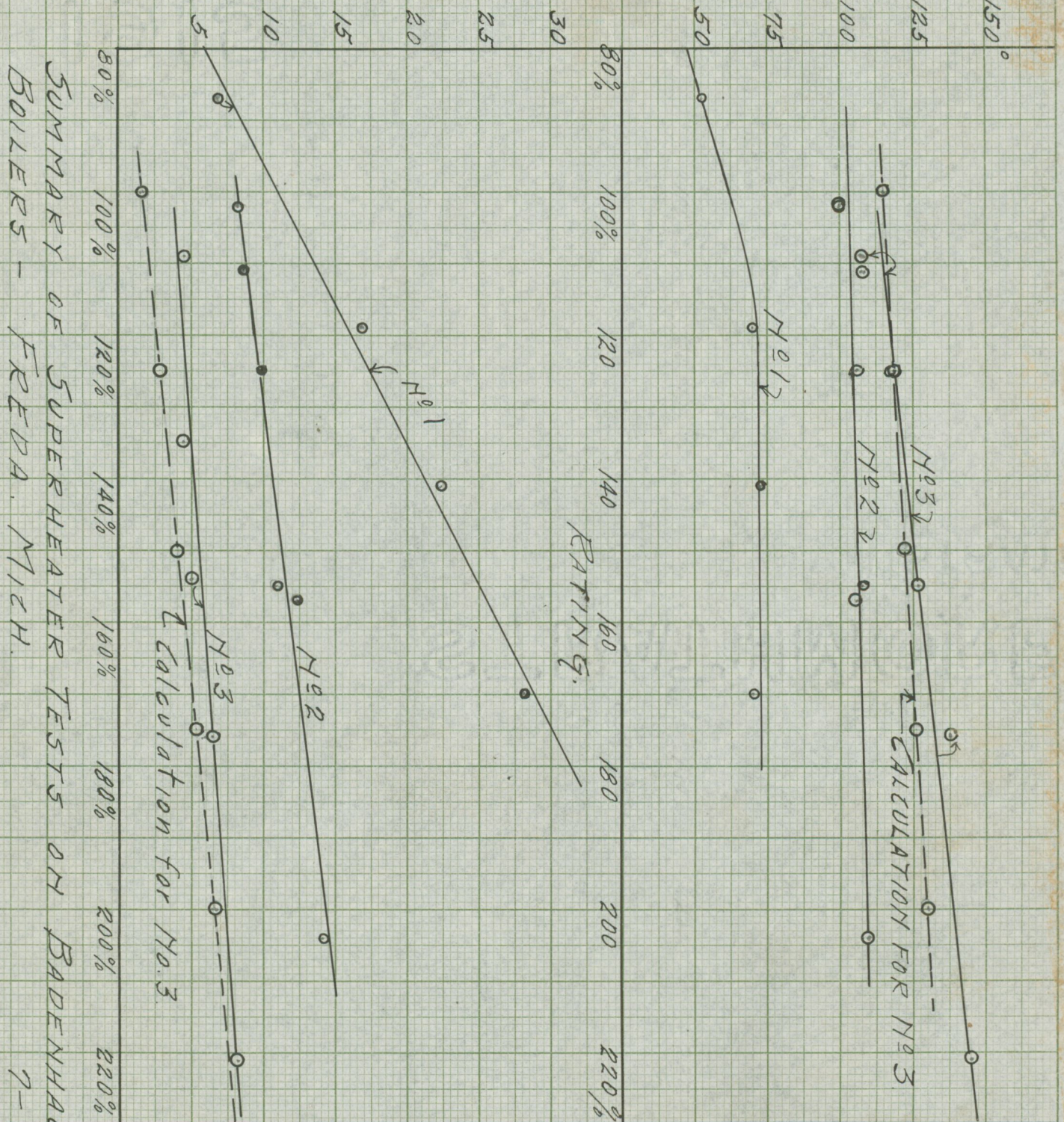
SUPERHEATERS ON BADENHAUSEN BOILERS - FREDR - MICH.

W. 29-18

M.E.H.

LBS. PRESSURE DROP THRU SUPERHEATER.

DEGREES SUPERHEAT.



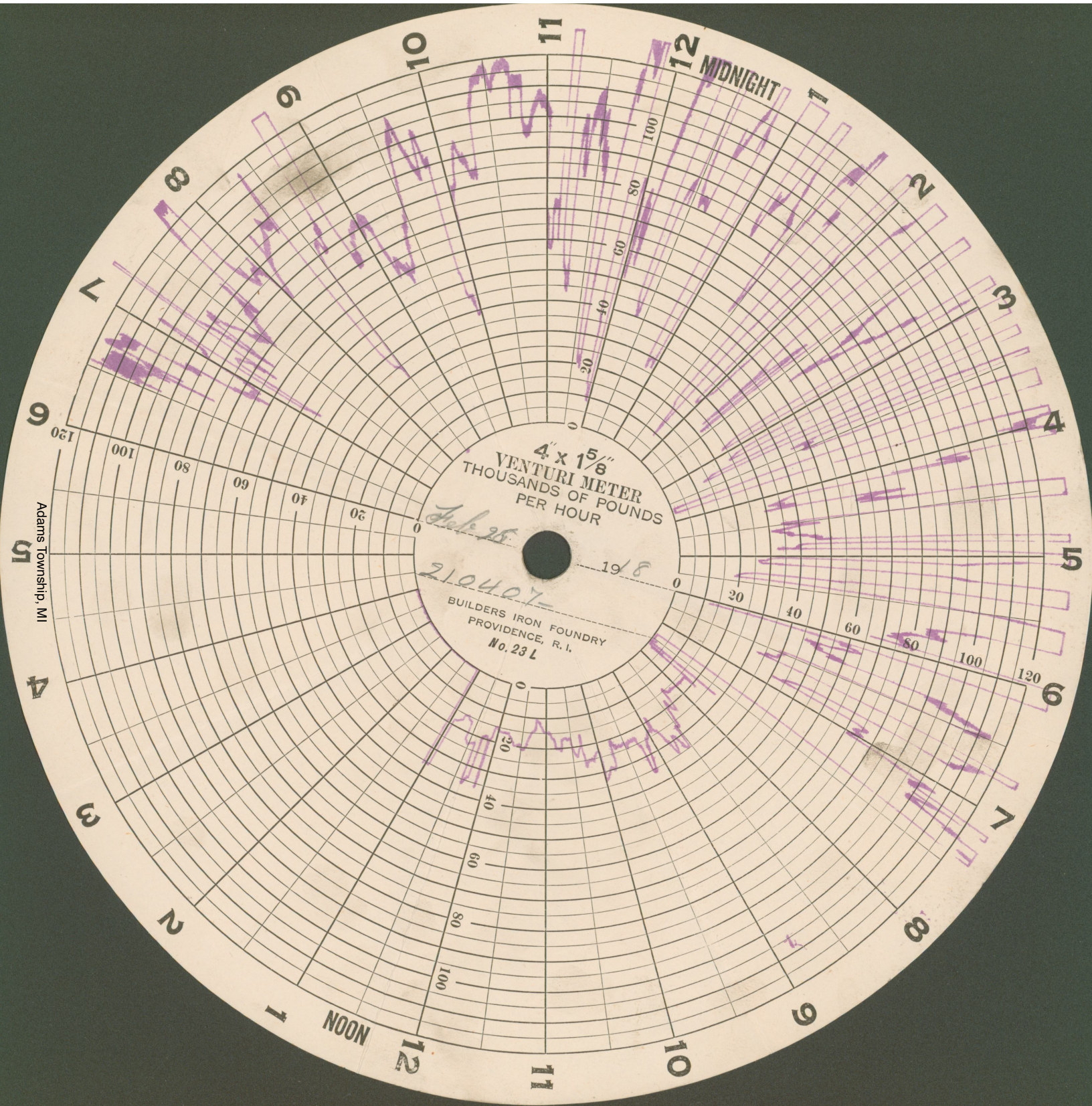
SUMMARY OF SUPERHEATER TESTS ON BADENHAUSEN BOILERS - FRED. MICH.

7-14-19
M.E.M.

CASE	NO. OF TUBES.			SIZE OF TUBES.			SQ. FT. SUPHTR SURFACE
	1ST. PASS	2ND. PASS.	3RD. PASS.	I.D.	O.D.	THICK-NESS	
NO. 1	4	4	4	1 7/8"	2 1/4"	3/16"	8'-6" 61.2
NO. 2	9	8	0	1 5/8"	2"	3/16"	11'-6" 102.2
NO. 3	12	14	0	"	"	"	Ave. 9'-3" 123.0
CALC.	"	"	"	"	"	"	"

240% RATING

FP 1762



4 x 1 1/8"
VENTURI METER
THOUSANDS OF POUNDS
PER HOUR

Feb 25
210407
1918

BUILDERS IRON FOUNDRY
PROVIDENCE, R. I.
No. 23 L

Adams Township, MI