



SOUTHERN PACIFIC COMPANY

MAXIMUM EXHAUST NOZZLE PRESSURE DETERMINATION

**SACRAMENTO LOCOMOTIVE
STANDING TEST PLANT**

**San Francisco, Calif.
July 15, 1948.**

Report No. ST-2(a)

STEAM AND EXHAUST NOZZLE PRESSURE CALCULATIONS

Class _____ Passenger _____ or Freight _____

Feedwater heater type 4-2, capacity 8400 gals./hr. x 8 a = 67200 1 lbs/hr.

Length over tube sheets 14 ft. 0 in.

Tubes No. 25 2, size 2 1/4 in. OD, spacing 3 1/2 in.

Heating Surface 14.227 3 sq. ft. per tube

Evaporation 2775 4 lbs./hr./sq. ft. heating surface

Flues No. 10 5, size 1 1/2 in. OD, spacing 3 1/2 in.

Heating surface 4.905 6 sq. ft. per tube

Evaporation 563 7 lbs./hr./sq. ft. heating surface

Heating surface Firebox 2.8 8 sq. ft.

Tubes 2 x 3 = 9 sq. ft.

Flues 5 x 6 = 10 sq. ft.

Evaporation Firebox 8 x 80 = 640 lbs./hr.

Tubes 9 x 4 = 36 "

Flues 10 x 7 = 70 "

Calculated evaporation = 11 "

Feedwater heater adjustment b x c = 5276 "

Oil burning adjustment 11 x .05 = 55 "

Adjusted calculated evaporation = 5452 12 "

Boiler pressure _____ PSIG

Ratio of tubes to flues _____

Degree of superheat _____

Lbs. Steam per IHP Hr. 13

Maximum potential cylinder horsepower 14

Cylinder steam consumption 13 x 14 = _____ lbs./hr.

Required boiler evaporation (Curve A) = 15 "

Hot water rate = d lbs./hr.

Cold water rate e + (d - 1) = _____ "

Auxiliary steam consumption (Curve C) = _____ "

Steam to nozzle = _____ "

Nozzle _____ in. dia., _____ in. cross split, _____ sq. in. area (Curve D)

Exhaust nozzle pressure for maximum steam rate _____ PSIG (Curve E)
(or F)

Boiler capacity = (12 / 15) x 100 = _____ %

a 8.0 for type B&BL FWH, 7.9 for type S&SA FWH

b 1 or 11, whichever is smaller

c .08 for type B&BL FWH, .13 for type S&SA FWH

d 12 or 15, whichever is smaller

e Curve B - use 1 or d, whichever is smaller, in finding cold water e required to supply FWH. If 1 is larger than d, e is total cold water rate. For engines not equipped with FWH, cold water rate = hot water rate.

STEAM AND EXHAUST NOZZLE PRESSURE CALCULATIONS

Class _____ Passenger- _____ or Freight _____

Feedwater heater type 4 1/2 BL, capacity 8400 gals./hr. x 8 8 = 67200 1 lbs/hr.-

Length over tube sheets 24 ft. 0 in.

Tubes No. 25 2, size 2 1/4 in. OD, spacing 24 in.

Heating Surface 14.097 3 sq. ft. per tube

Evaporation 7.78 4 lbs./hr./sq. ft. heating surface

Flues No. 190 5, size 3 1/2 in. OD, spacing 3/4 in.

Heating surface 21.905 6 sq. ft. per tube

Evaporation 8.23 7 lbs./hr./sq. ft. heating surface

Heating surface Firebox 362 8 sq. ft.

Tubes 2.5 2 x 14.087 3 = 352.2 9 sq. ft.

Flues 190 5 x 21-905 6 = 24162 10 sq. ft.

Evaporation Firebox 362 8 x 80 = 28960 lbs./hr.

Tubes 352.2 9 x 7.78 4 = 2740

$$\text{Flues } \underline{4162 \ 10} \times \underline{8.23 \ 7} = \underline{34253}$$

Calculated evaporation = 6595.311

$$\begin{array}{r} \text{Feedwater heater adjustment } 5.935 \text{ [b]} \times 0.8 \text{ [c]} \\ 0.1 \text{ burning adjustment } 5.276 \text{ [2]} \times 0.5 \text{ [d]} \end{array} = \underline{5.276}$$

Adjusted calculated evaporation = $\frac{32.93}{1.12}$

Adjusted evaporated $\frac{119.52}{1.12}$

Boiler pressure _____ PSIG

Ratio of tubes to flues

Degree of superheat _____

Lbs. Steam per IHP Hr. 13

Maximum potential cylinder horsepower 14

Cylinder steam consumption 13 x 14

Required boiler evaporation (Curve A) = 15 "

Hot water rate = d lbs./hr.

Cold water rate _____ e + (_____ d - _____ l)

Auxiliary steam consumption (Curve C) = _____

Steam to nozzle =

Nozzle _____ in. dia., _____ in. cross split, _____ sq. in. area (Curve D)

Exhaust nozzle pressure for maximum steam rate PSIG (Curve E)

OF F

Boiler capacity = (12 / 15) x 100 = 80 %

Buffer capacity = $\frac{[A^-]}{[A] + [A^-]} \times 100 = \frac{1.2}{1.2 + 1.2} \times 100 = 50$

[illegible]

8.0 for type B&BL FWH, 7.9 for type S&S FWH

$\min\{p_1, p_2\}$ or p_3 , whichever is smaller.

e. .08 for type B&BL FWH, .13 for type S&SA FWH

12 or 15, whichever is smaller

Curve B - use $\frac{1}{2}$ or $\frac{d}{4}$, whichever is smaller, in finding cold water temperature to supply HWY. If $\frac{1}{2}$ is larger than $\frac{d}{4}$

water required to supply FWH. If 1 is larger than 0, 0 is total cold water rate. For engines not equipped with FWH

cold-water rate = hot water rate.

"A"

Length over Tube Sheet	Heating Surface - Square Feet				
	T u b e s		F l u e s		
	2"	2 $\frac{1}{4}$ "	3 $\frac{1}{2}$ "	5-3/8"	5 $\frac{1}{2}$ "
11' 0"	5.720				
11' 0-1/8"	5.726				
11' 5-7/8"	5.977				
11' 6"	5.982			16.066	
11' 6-1/4"	5.993				
11' 6-3/8"	5.999				
11' 10-1/8"	6.162				
12' 0"	6.244			16.769	
12' 5-1/2"	6.485				
12' 6"	6.506				
12' 8"	6.594			17.707	
13' 0"	6.768			18.176	
13' 1"	6.812			18.294	
13' 1-3/4"	6.845				
13' 4-3/4"	6.976			18.733	
13' 5-1/2"	7.009				
13' 6"	7.030	7.902			
13' 7"	7.074				
13' 10"		8.099			
14' 0"	7.292				
14' 6"	7.554	8.491		20.287	
14' 9"	7.685			20.639	
15' 0"	7.816			20.991	
15' 5-1/2"	8.057			21.636	
16' 0"	8.340			22.398	
18' 0"	9.388	10.553		25.212	25.798
19' 6"		11.436			27.958
20' 0"	10.436	11.731		28.027	28.678
20' 6"	10.698			28.730	
21' 0"		12.320			30.118
21' 5-1/2"		12.590			30.778
21' 6"		12.614	19.614		30.838
22' 0"		12.909	20.073		31.558
23' 6"		13.792			33.718
24' 0"		14.087	21.905		34.438

Table I

Evaporation--Lbs./Hr./Sq. Ft. Heating Surface

	Length	S p a c i n g			
		11/16"	3/4"	13/16"	7/8"
2" Tubes	11' 0"	11.32	11.62	11.90	12.13
	11' 0-1/8"	11.32	11.62	11.90	12.13
	11' 5-7/8"	11.10	11.40	11.67	11.90
	11' 6"	11.10	11.40	11.67	11.90
	11' 6-1/4"	11.09	11.39	11.66	11.89
	11' 6-3/8"	11.09	11.39	11.66	11.89
	11' 10-1/8"	10.95	11.25	11.52	11.75
	12' 0"	10.89	11.18	11.45	11.68
	12' 5-1/2"	10.70	10.99	11.25	11.48
	12' 6"	10.68	10.97	11.23	11.46
	12' 8"	10.61	10.90	11.16	11.39
	13' 0"	10.47	10.76	11.02	11.24
	13' 1"	10.44	10.73	10.98	11.20
	13' 1-3/4"	10.41	10.70	10.96	11.18
	13' 4-3/4"	10.31	10.60	10.85	11.07
	13' 5-1/2"	10.29	10.58	10.83	11.05
	13' 6"	10.27	10.56	10.81	11.03
	13' 7"	10.24	10.53	10.77	10.99
	14' 0"	10.08	10.36	10.60	10.82
	14' 6"	9.89	10.16	10.40	10.62
	14' 9"	9.79	10.06	10.30	10.52
	15' 0"	9.70	9.97	10.21	10.42
	15' 5-1/2"	9.54	9.80	10.04	10.25
	16' 0"	9.36	9.60	9.83	10.05
	18' 0"	8.71	8.95	9.15	9.35
	20' 0"	8.10	8.32	8.51	8.70
	20' 6"	7.96	8.17	8.35	8.55

2 1/4" Tubes	13' 6"	11.08	11.31	11.51
	13' 10"	10.95	11.17	11.37
	14' 6"	10.70	10.90	11.11
	18' 0"	9.46	9.66	9.85
	19' 6"	8.97	9.15	9.34
	20' 0"	8.83	9.00	9.18
	21' 0"	8.55	8.73	8.89
	21' 5-1/2"	8.43	8.60	8.76
	21' 6"	8.42	8.59	8.75
	22' 0"	8.28	8.45	8.61
	23' 6"	7.90	8.07	8.21
	24' 0"	7.78	7.95	8.08

Table II

Evaporation---Lbs./Hr./Sq. Ft. Heating Surface

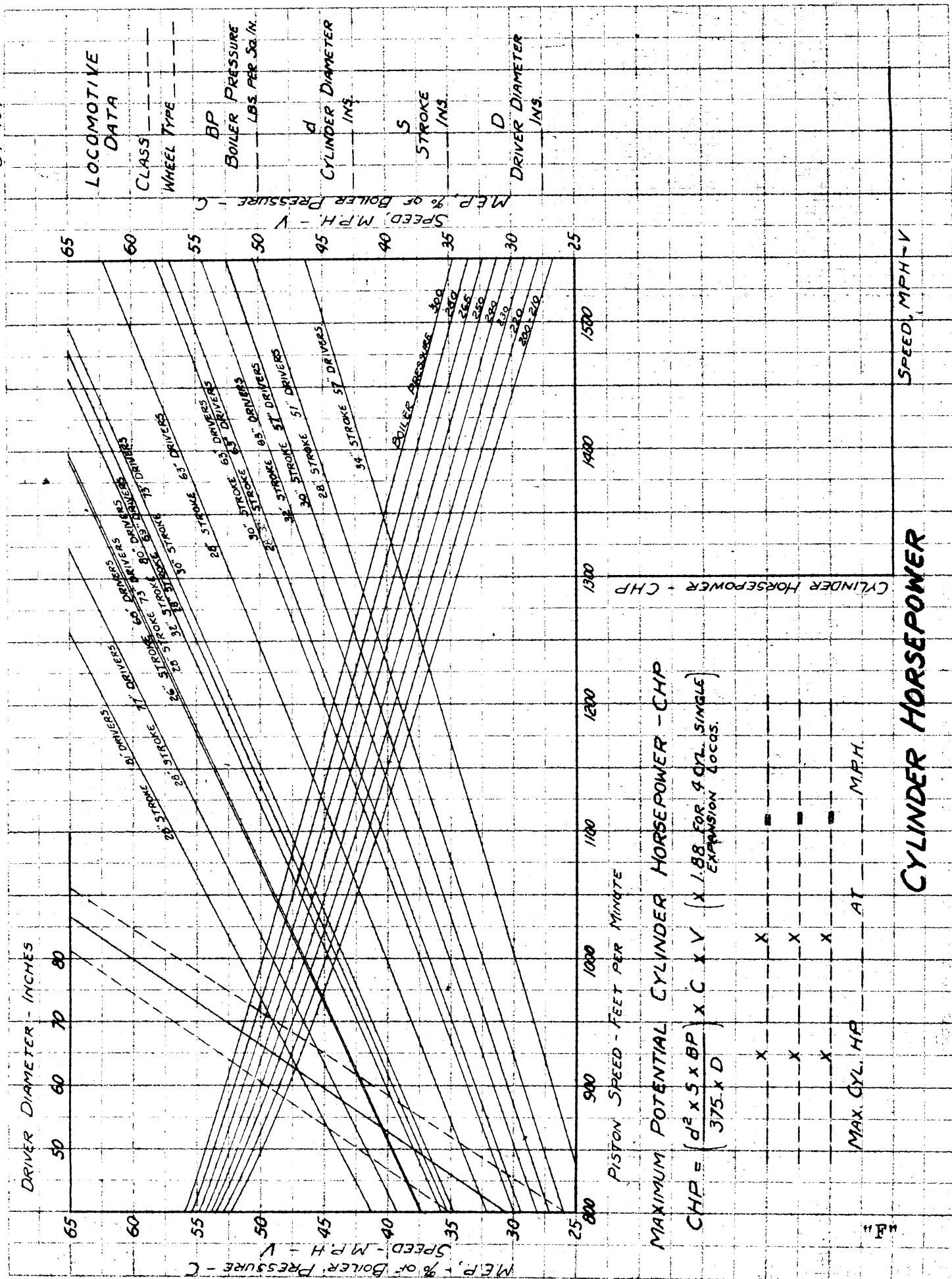
		S p a c i n g		
		<u>11/16"</u>	<u>3/4"</u>	<u>13/16"</u>
3-1/2" Flues	21' 6"	8.74		
	22' 0"	8.60		
	24' 0"		8.23	
5-3/8" and 5-1/2" Flues	11' 6"		13.09	13.16
	12' 0"		12.87	12.94
	12' 8"		12.58	12.65
	13' 0"		12.44	12.50
	13' 1"		12.41	12.47
	13' 4-3/4"		12.28	12.34
	14' 6"		11.84	11.91
	14' 9"		11.74	11.81
	15' 0"		11.65	11.72
	15' 5-1/2"		11.48	11.55
	16' 0"		11.28	11.35
	18' 0"		10.60	10.66
	19' 6"		10.14	10.20
	20' 0"		10.00	10.05
	20' 6"		9.86	9.91
	21' 0"		9.72	9.77
	21' 5-1/2"		9.59	9.64
	21' 6"		9.58	9.63
	22' 0"		9.44	9.50
	23' 6"		9.06	9.11
	24' 0"		8.94	8.99

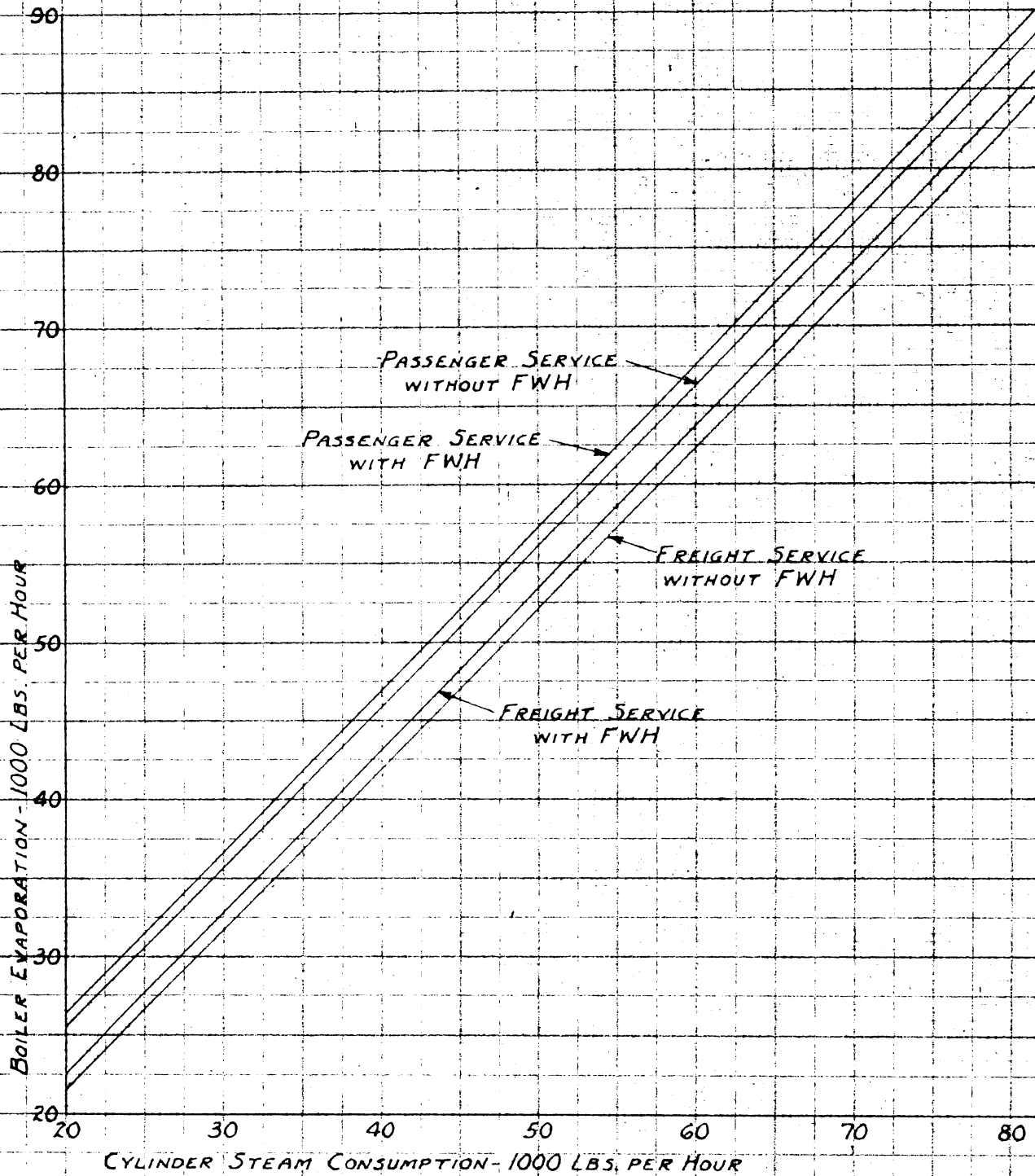
Table III

Type Superheater	Flue and Tube Size	Ratio of Tubes to Flues	Degree of Superheat
A	5-3/8" - 2" 5-1/2" - 2-1/4"	7 or over 6 or over	150
A	5-3/8" - 2" 5-1/2" - 2-1/4"	5 to 7 4 to 6	200
A	5-3/8" - 2" 5-1/2" - 2-1/4"	Under 5 Under 4	250
E	3-1/2" - 2-1/4"	- - - -	250

Steam		L b s. S t e a m P e r C H P H r .					
		(Superheat-°F.)					
PSIG	Temp. °F.	Sat.	150	200	250	300	350
190	384	28.30	21.25	19.90	18.90		
195	386	28.10	21.10	19.80	18.80		
200	388	28.00	21.00	19.70	18.70		
205	390	27.80	20.90	19.60	18.60		
210	392	27.75	20.80	19.50	18.50		
215	394	27.60	20.70	19.40	18.40		
220	396	27.50	20.65	19.30	18.30		
225	397	27.40	20.55	19.25	18.25		
230	399	27.30	20.50	19.10	18.20		
235	401	27.20	20.45	19.05	18.15		
250	406	26.90	20.20	18.85	17.95	17.10	16.30
260	409	26.80	20.10	18.80	17.85	17.00	16.15
280	416	26.55	19.95	18.70	17.75	16.80	15.95
300	422	26.30	19.70	18.60	17.675	16.75	15.90

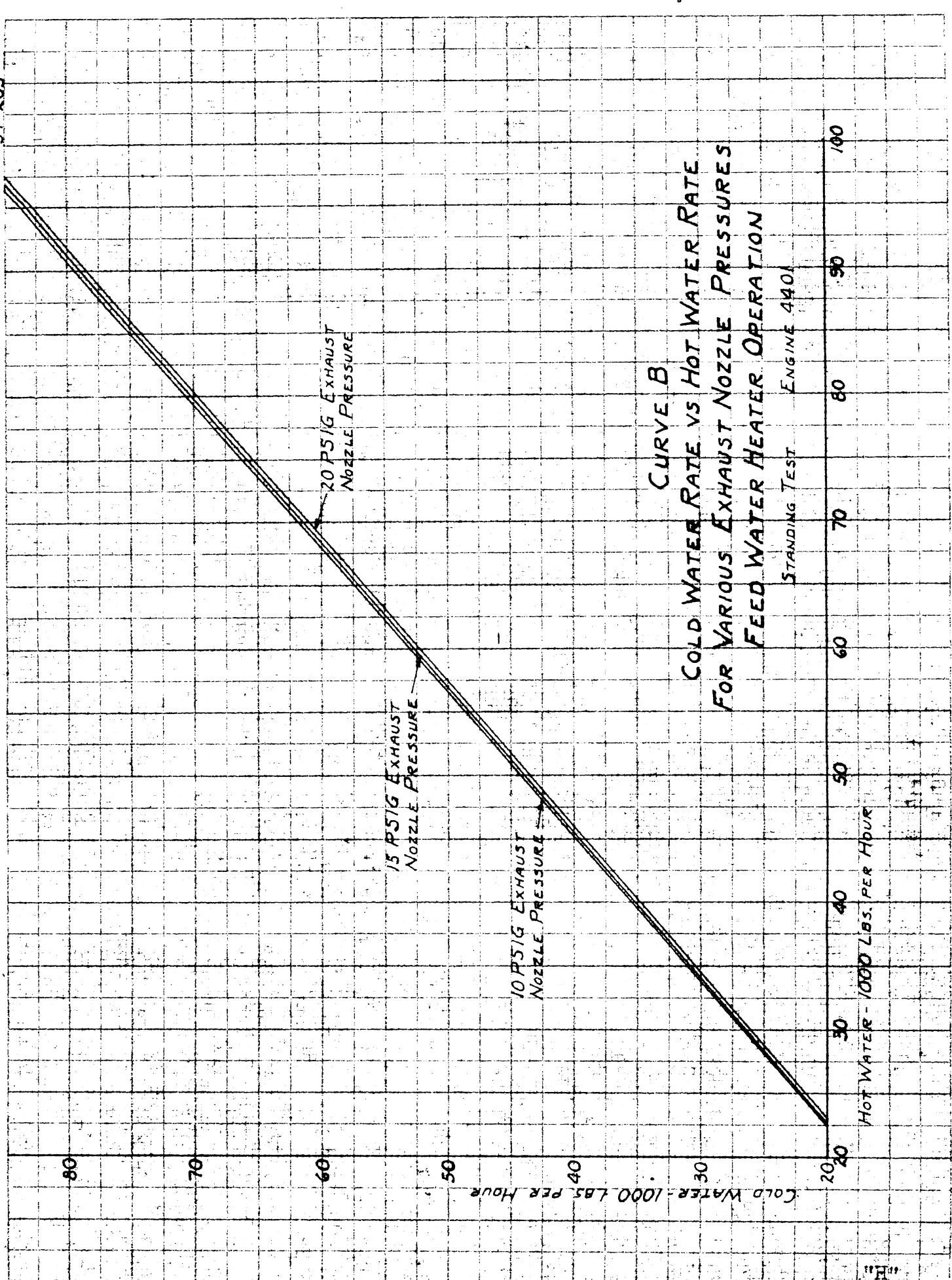
Table IV





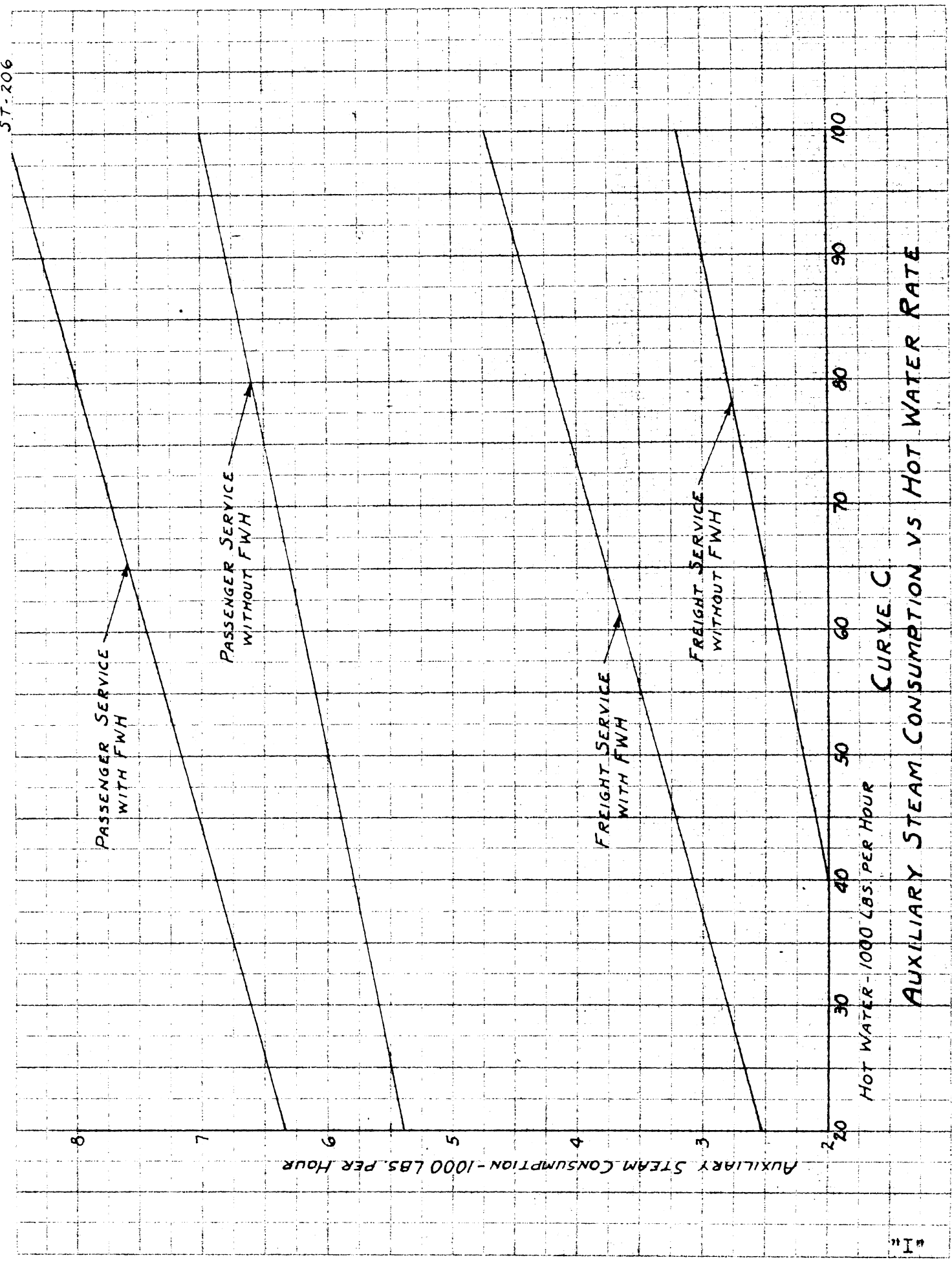
CURVE A
 BOILER EVAPORATION VS CYLINDER STEAM CONSUMPTION

ST-205

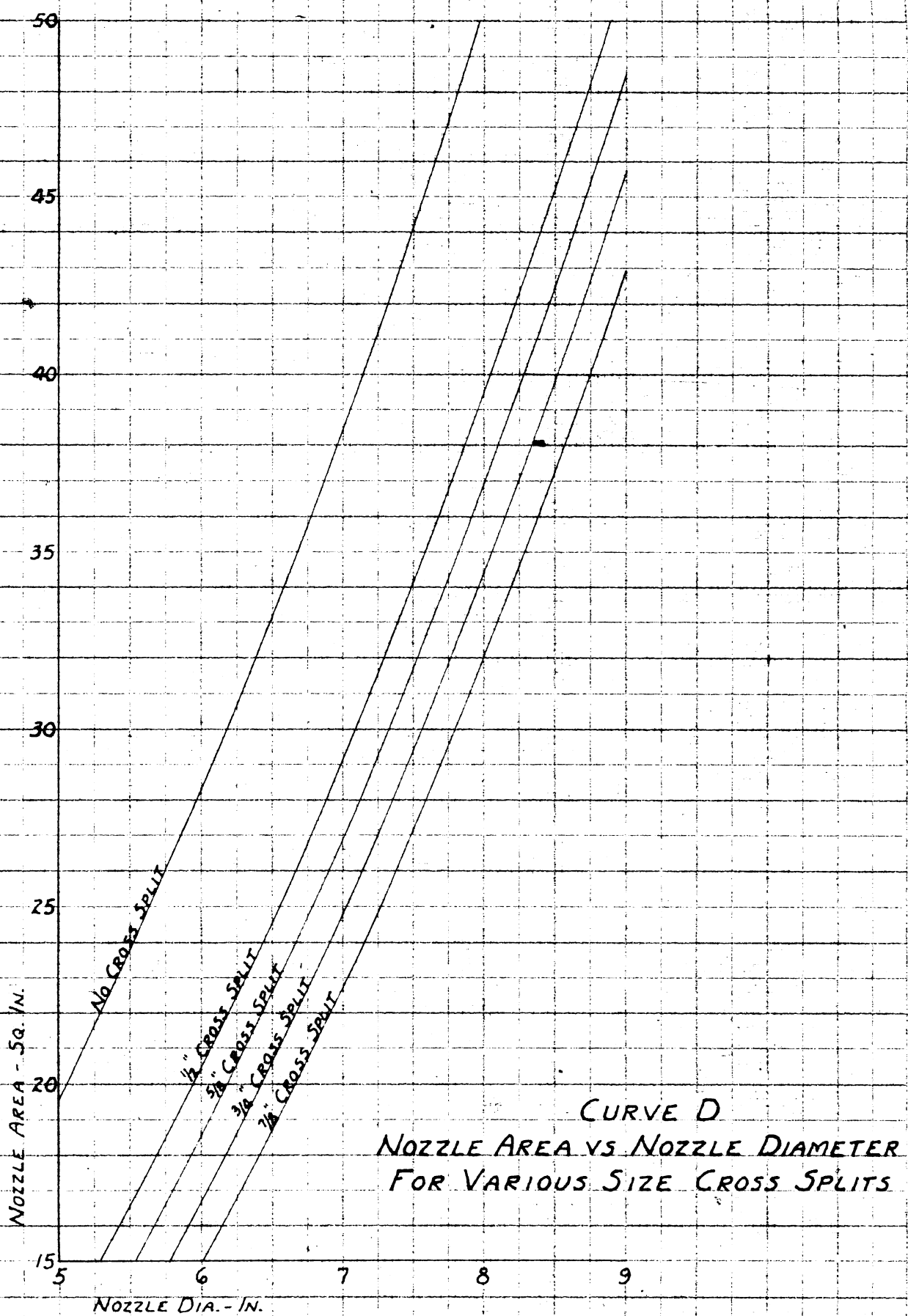


CURVE B
COLD WATER RATE VS HOT WATER RATE
FOR VARIOUS EXHAUST NOZZLE PRESSURES
FEED WATER HEATER OPERATION
STANDING TEST ENGINE 4401

H. H.



ST-207



CURVE D
NOZZLE AREA VS NOZZLE DIAMETER
FOR VARIOUS SIZE CROSS SPLITS

STEAM TO NOZZLE - 1000 LBS PER HOUR

80
70
60
50
40
30
20
10
0

NOZZLE AREA - Sq. IN.

0 10 20 30 40 50 60

20 PSIG
19 PSIG
18 PSIG
17 PSIG
16 PSIG
15 PSIG
14 PSIG
13 PSIG
12 PSIG
11 PSIG
10 PSIG
9 PSIG
8 PSIG
7 PSIG
6 PSIG
5 PSIG

CURVE E
CALCULATED STEAM FLOW VS NOZZLE AREA
FOR VARIOUS EXHAUST NOZZLE PRESSURES
ENGINES EQUIPPED WITH TYPE "A" SUPERHEATER



NOZZLE AREA - 50 IN.

CURVE F
STEAM FLOW VS NOZZLE AREA
FOR VARIOUS EXHAUST NOZZLE PRESSURES
ENGINES EQUIPPED WITH TYPE "E" SUPERHEATER