

Report of Tests of Locomotive 3911

With Labyrinth Front End, Multiple Stacks, Multiple Jet  
Exhaust Nozzles, Elesco Type "TP" Exhaust Steam  
Injector and Nathan Type 4000 Live Steam Injector

September - December, 1940

## Report of Tests Locomotive 3911

This report covers the performance of Locomotive 3911 with the Labyrinth Front End, Multiple Stacks, Multiple Jet Exhaust Nozzles, the Elesco Type "TP" Exhaust Steam Injector on the left side, and the Nathan Type 4000 Live Steam Injector on the right side of the locomotive.

With the exception of Locomotive 3911, all 3900 Class Locomotives are equipped with a single annular ported nozzle, a single stack, and a Master Mechanic's front end. Locomotive 3910-14 have Sellers Exhaust Steam Injectors with 9000 gallon tubes and Locomotive 3911 was first tested with this injector except that 11000 gallon tubes were applied.

As a result of tests of the Multiple Jet Exhaust Nozzle and Labyrinth Front End on Locomotives 815 and 7006, indications were that a considerable increase in power would be attained on 3900 Class Locomotives by a similar design especially with two stacks and two Multiple Jet Exhaust Nozzles.

Accordingly, the Labyrinth Front End, Multiple Stacks, and Multiple Jet Exhaust Nozzles were applied to Locomotive 3911 and tests started. The locomotive was first used in helper service to determine the correct nozzle size. The locomotive then steamed, but an analysis of the smoke box gases showed room for improvement in the combustion. Twenty-eight 2-1/4 inch diameter tubes were applied in the sides of the firebox for secondary air admission and this change resulted in very good combustion as shown not only by the gas analysis but also by the appearance of the fire and the gases leaving the stacks. All tests were then run with secondary air and at the conclusion of the tests, the holes were left open.

### Discussion of Standard Front End Arrangement and Arrangement on Locomotive 3911

The important front end dimensions are shown by the following tabulation:

	3900 Class Standard	Locomotive 3911
Type Nozzle	Annular Ported	Multiple Jet
Area Nozzle - Square Inches	45.35	56.55
Nozzle Tip to Bottom of Front End - Inches	30-3/16	25-3/32
Nozzle Tip to Bottom of Stack Flare - Inches	17	15-3/4
Total Length of Stack Including Flare - Inches	51-1/4	57-7/8
Inside Diameter of Stack at Choke - Inches	24	24-1/2
Inside Diameter of Stack at Top - Inches	26	29-1/2
Type Front End	Master Mechanic's	Labyrinth
Net gas Area through Tubes and Flues - Square Inches	1540	1540
Net Area Under Table Plate - Square Inches	1317	1635
Top Area Stacks - Square Inches	531	1367
Choke Area Stacks - Square Inches	452	943

The Multiple Jet Exhaust Nozzle compared with the Annular Ported Nozzle has 24.7 percent greater area and due to a better coefficient of discharge, will pass 29.8 percent more steam for the same back pressures. This means that either the same power may be developed on less back pressure or more power may be developed on the same back pressure. For all powers developed with the small nozzle the same power is developed with the larger nozzle on less steam and fuel. With the larger nozzle, powers are attained which can not be developed with the smaller nozzle. This is due to the fact that the smaller nozzle cannot pass the required amount of steam for high powers without excessive back pressures and excessive back pressures in turn limit the power. However, when the locomotive with a larger nozzle is working at its highest powers, the steam requirements

are greater than the locomotive could utilize with a smaller nozzle and more coal is burned. 9000 gallon injector tubes are of ample size to supply the boiler on 3900 class locomotives with annular ported nozzles. On Locomotive 3911, 11000 gallon tubes barely supplied the boiler when developing maximum power.

The excellent steam discharge properties of the two Multiple Jet Exhaust Nozzles are shown by Figure No. 5, which shows the relation between exhaust stand pressure and flow through the exhaust nozzle.

The Labyrinth Front End compared with the Master Mechanic's shows less restriction in the front end and a more even draft over the fire. These are very desirable characteristics. The Labyrinth Front End is for all practical purposes perfectly self cleaning, spark arresting is very satisfactory, and there is no netting to stop up or wear out.

The drafts obtained with the Multiple Stacks, Multiple Jet Exhaust Nozzles, and Labyrinth Front End are very good as shown by Figure No. 3 in this report.

#### Tests, Territory and Trains

Tests were first run with the Sellers Exhaust Steam Injector in helper service out of Cheyenne, and in freight service between Cheyenne and Laramie, Laramie and Green River, and Green River and Ogden. In September 1940, the Sellers Exhaust Steam Injector was removed and replaced with an Elesco Type "Tp" Exhaust Steam Injector. This report is confined to the performance of Locomotive 3911 with the Elesco Exhaust Steam Injector. The performance of the Elesco Exhaust Steam Injector is covered in detail in another report.

#### Locomotive

The important locomotive dimensions are shown by the following tabulation:

General Classification	- - - - -	4-6-6-4
Union Pacific Classification	- - - - -	CSA
Service	- - - - -	Freight
Starting Tractive Effort, Pounds	- - - -	97,400
Weight Locomotive, Pounds	- - - - -	566,000
Weight Locomotive and Tender, Pounds	- - - -	876,000
Tender Water Capacity, Gallons	- - - - -	18,106
Tender Coal Capacity, Pounds	- - - - -	44,000

Expansion of Steam	-----	Single
Number of Cylinders	-----	4
Cylinder Diameter, Inches	-----	22
Cylinder Stroke, Inches	-----	32
Valve Gear	-----	Walschaert

Valves

Diameter, Inches	-----	12
Full Gear Travel, Inches	-----	7-1/2
Lap, Inches	-----	1-3/8
Lead, Inches	-----	1/4
Exhaust Clearance, Inches	-----	1/8

Boiler

Working Pressure, Pounds per Square Inch	---	255
Length Between Flue Sheets, Feet-Inches	---	22-0
Number of 2-1/4 Inch Diameter Tubes	---	222
Number of 5-1/2 Inch Diameter Tubes	---	60
60 Unit Type A Superheater		

Firebox

Length, Inches	-----	213-1/16
Width, Inches	-----	108-1/4
Grate Area, Square Feet	-----	108.25
Number of Arch Tubes	-----	5
Gaines Wall in Firebox		

Heating Surface - Square Feet

Firebox and Combustion Chamber	-----	548
Arch Tubes	-----	77
Boiler Tubes	-----	2864
Boiler Flues	-----	1892
Total Evaporative Heating Surface	-----	5381
Superheater Heating Surface	-----	<u>1650</u>
Total Heating Surface	-----	7031

Data

All data necessary for the determination of boiler and cylinder performance were taken. The determination of boiler performance requires that the weight of exhaust steam condensed and the temperature rise due to exhaust steam be known. Therefore, all data necessary for the determination of injector performance was also taken.

Coal consumption was determined by measurements of the coal space at the start of a run, before and after taking coal, and at the end of a run. Tank water consumption was determined by measurements of the water in the tank at the start of a run, before and after taking water, and at the end of a run. All blow downs were timed to determine the weight of water blown off. A continuous record was kept of the time the injector was operating on exhaust steam, on line steam, or shut off. A venturi meter was applied to the suction line of the Elesco Exhaust Steam Injector. Thus, the rate at which tank water was being fed to the boiler was always known and furthermore, combining the rate with the time gave the weight of tank water delivered to the boiler on live steam operation.

A record was kept of the train movement.

The following pressures were taken: (1) Boiler, (2) Valve Chamber, (3) Exhaust Stands, (4) Exhaust in the Injector, and (5) Injector Live Steam Nozzle.

The following temperatures were taken with distant reading thermometers and mercury thermometers: (1) Tank Water, (2) Delivery Water to Boiler, and (3) Exhaust Steam to Injector.

The following temperatures were taken with a patentometer: (1) Steam to Cylinders Right Side, (2) Steam to Cylinders Left Side, (3) Exhaust Steam Back Engine Right Side, (4) Exhaust Steam Back Engine Left Side, (5) Exhaust Steam Front Engine, (6) Smoke Box Gases Leaving 2-1/4 Inch Tube, (7) Smoke Box Gases Leaving 5-1/2 Inch Flue, (8) Smoke Box Gases Entering Stack, and (9) Delivery Water to Boiler.

Drafts were taken in the front end.

#### Compiled Data and Graphical Presentation

The data taken during the tests and all calculated results are shown graphically in condensed form on sheets in this report under the following headings:

1. General Performance
2. Boiler Performance
3. Average Pressures and Temperatures
4. Water Rates and Indicated Horse Power

The following curves are presented:

Figure No. 1 - Relation Between Firing Rate and Evaporation Ratio and Relation Between Firing Rate and Evaporation.

Figure No. 2 - Relation Between Firing Rate and Boiler Heat Absorption Rate.

Figure No. 3 - Relation Between Exhaust Stand Pressure and Draft.

Figure No. 4 - Relation Between Exhaust Stand Pressure and Indicated Horse Power.

Figure No. 5 - Relation Between Exhaust Stand Pressure and Steam Through Exhaust Nozzle and Relation Between Exhaust Stand Pressure and Steam to Engines.

Figure No. 6 - Relation Between Steam to Engines and Indicated Horse Power.

Figure No. 7 - Relation Between Indicated Horse Power and Pounds of Steam Per Indicated Horse Power Hour.

Figure No. 8 - Relation Between Indicated Horse Power and Pounds of Coal per Indicated Horse Power Hour and Relation Between Indicated Horse Power and Pounds of Coal Fired per Hour.

#### Boiler Performance

Boiler performances are shown by Figure No. 1 and Figure No. 2. For identical firing rates, the efficiencies are about the same as for 800-819 class locomotives with secondary air admitted over the fire. However, the boiler on Locomotive 3911 could be and was forced to very high evaporative rates due to the efficient front end arrangement. The evaporation was limited mostly by the grate area. At high evaporative rates the fuel fired per square foot of grate per hour becomes excessive.

#### Cylinder Performance

Cylinder performances are shown by Figure Nos. 4, 6 and 7. As shown by Figure No. 7, there is nothing unusual in the water rates except that the rates do not go up abruptly at the higher powers. This is also shown by

Figure No. 4 which shows that the indicated horse power limit was not reached at 16 pounds per square inch exhaust stand pressure. Figure No. 6 shows that if the boiler could have made more steam, still more power could have been developed.

Conclusions:

The front end arrangement on Locomotive 3911 proved successful and efficient. The locomotive was a free steamer and the exhaust nozzle showed excellent flow characteristics, which enabled the cylinders to handle large quantities of steam without excessive back pressures.

The boiler efficiency was about the same as 800-819 class locomotives with secondary air admitted over the fire. Due to an efficient front end arrangement, the boiler could be forced to high evaporative rates. Calculations show the maximum evaporation which could be attained in conjunction with the Elesco Exhaust Steam Injector to be 97,998 pounds of water per hour, requiring 32,440 pounds of coal per hour. The capacity of the boiler is mostly limited by the grate area.

The cylinder performance is usual except that the water rates do not increase greatly at the higher powers. If more steam could be generated more power could be developed. Thus the grate area becomes the limiting factor for power.

Office of  
Vice President, R&MS,  
Omaha - April 1, 1941

## GENERAL PERFORMANCE - LOCOMOTIVE 3911

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DATE 1940	NUMBER OF CARS LOADS    EMPTY'S	NUMBER OF STOPS	NUMBER OF TONS	TON MILES NOT CORRECTED FOR HELPER G.M.T.M.	DURATION OF TEST						TOTAL POUNDS WATER ACTUALLY EVAPORATED BY BOILER	TOTAL POUNDS OF COAL FIRED	CORRECTED FOR HELPER POUNDS WATER    POUNDS COAL	AVERAGE SPEED M.P.H.	HELPER USED					
					TOTAL HOURS MINUTES		DEAD HOURS MINUTES		RUNNING HOURS MINUTES											
<b>OGDEN TO GREEN RIVER</b>																				
					<b>ELESKO EXHAUST STEAM INJECTOR WITH L-18 TUBES</b>									<b>175.6 MILES EASTBOUND</b>						
SEPT. 28	63-71-76	1-8	8	3362	590.423	7	38	1	45	5	53	377204	75358	745.7	149.0	29.8	NOTE 1			
OCT. 1-2	63	0	6	3100	544.360	6	0	1	8	4	52	330489	75296	718.8	163.8	36.0	" 1			
OCT. 16	65-68	4	12	3350	588.325	8	13	2	12	6	1	361786	78704	726.3	158.0	29.2	" 1			
OCT. 18	56	13-25	9	3320	582.960	6	50	2	2	4	48	307475	72071	997.2	235.8	36.6	" 2			
OCT. 22	63	11	6	3250	570.700	6	21	0	53	5	28	360707	78810	748.3	163.5	32.1	" 1			
OCT. 31	58	10	8	3182	558.748	6	37	1	54	4	43	279783	62283	945.2	210.4	37.2	" 2			
<b>OGDEN TO GREEN RIVER</b>																				
					<b>ELESKO EXHAUST STEAM INJECTOR WITH L-19 TUBES</b>									<b>175.6 MILES EASTBOUND</b>						
DEC. 2	62	0	8	2991	525.219	6	4	0	56	5	8	331049	70004	746.2	157.8	34.2	NOTE 1			
DEC. 4	70	1	6	3000	526.800	5	50	0	59	4	51	326200	70753	1238.4	268.6	36.2	" 2			
DEC. 6	50-51	19-25	7	3304	580.161	6	15	1	6	5	9	361716	76287	734.9	155.0	34.1	" 1			
<b>GREEN RIVER TO OGDEN</b>																				
					<b>ELESKO EXHAUST STEAM INJECTOR WITH L-18 TUBES</b>									<b>175.6 MILES WESTBOUND</b>						
OCT. 17	1	97	11	2700	474.120	6	59	0	57	6	2	271693	59984	573.0	126.5	29.1	NO HELPER			
OCT. 18-19	44-43-42	1	5	1769	310.670	5	8	0	49	4	19	217677	54163	701.3	174.3	40.7	NO HELPER			
<b>GREEN RIVER TO OGDEN</b>																				
					<b>ELESKO EXHAUST STEAM INJECTOR WITH L-19 TUBES</b>									<b>175.6 MILES WESTBOUND</b>						
DEC. 3	50	2	4	2300	403.880	5	30	0	42	4	48	242050	48425	599.3	119.9	36.6	NO HELPER			
DEC. 5	19	66	5	3100	544.360	5	49	0	36	5	13	285802	56429	525.0	103.7	33.7	NO HELPER			
DEC. 7	23-22-18-20	24	11	1731	304.071	6	31	1	54	4	37	231499	40893	761.3	134.5	40.2	NO HELPER			
<b>LARAMIE TO GREEN RIVER</b>																				
					<b>ELESKO EXHAUST STEAM INJECTOR WITH L-18 TUBES</b>									<b>251.0 MILES WESTBOUND</b>						
OCT. 24	46-30	0	6	1634	410.252	8	13	2	47	5	26	263707	51129	691.5	124.6	46.2	NO HELPER			
OCT. 28	52	0	5	1620	406.620	6	36	0	39	5	57	286935	54562	705.7	134.2	42.2	NO HELPER			
NOV. 6	42-39-37-35	16	6	2169	544.499	7	35	1	42	5	53	314666	61299	577.9	112.6	42.7	NO HELPER			
<b>LARAMIE TO GREEN RIVER</b>																				
					<b>NATHAN TYPE 4000 LIVE STEAM INJECTOR</b>									<b>251.0 MILES WESTBOUND</b>						
NOV. 2	36	0	5	1490	373.990	6	10	0	43	5	27	280224	58900	749.3	157.5	46.1	NO HELPER			
NOV. 4	46-43	3	8	1727	433.474	6	54	0	43	6	11	297277	63601	685.8	146.7	40.6	NO HELPER			
NOV. 8	49	7	4	2350	589.850	6	25	0	39	5	46	303959	66062	515.3	112.0	43.5	NO HELPER			
<b>GREEN RIVER TO LARAMIE</b>																				
					<b>ELESKO EXHAUST STEAM INJECTOR WITH L-18 TUBES</b>									<b>251.0 MILES EASTBOUND</b>						
OCT. 25	45-50-47	0	7	3256	817.154	9	4	1	33	7	31	409358	89278	501.0	109.3	33.4	NO HELPER			
NOV. 1	57-53	51-18	5	3306	829.905	8	15	1	17	6	58	459240	102297	553.4	123.3	36.0	NO HELPER			
NOV. 7	56-57	15	5	3263	819.107	8	6	0	59	7	7	464952	93584	567.6	114.3	35.3	NO HELPER			
<b>GREEN RIVER TO LARAMIE</b>																				
					<b>NATHAN TYPE 4000 LIVE STEAM INJECTOR</b>									<b>251.0 MILES EASTBOUND</b>						
NOV. 3	58	7	12	3165	794.312	9	24	1	48	7	36	456549	119109	574.8	150.0	33.0	NO HELPER			
NOV. 5	52	13	4	2900	727.900	8	5	0	55	7	10	436364	97461	599.5	133.9	35.0	NO HELPER			
NOV. 9	43	22	7	3200	803.200	8	36	1	15	7	21	464915	100003	578.8	124.5	34.1	NO HELPER			

## AVERAGE PRESSURES &amp; TEMPERATURES - LOCOMOTIVE 3911

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DATE 1940	PRESSURE - POUNDS PER SQUARE INCH GAUGE					TEMPERATURES										SMOKE BOX GASES		
	BOILER	VALVE CHAMBER	EXHAUST STANDS	EXHAUST IN INJECTOR	INJECTOR LIVE STEAM NOZZLE	TANK WATER	DELIVERY TO BOILER	STEAM TO CYLINDERS		EXHAUST BACK ENGINE		STEAM FRONT ENGINE	LEAVING 2-1/4" TUBES	LEAVING 5-1/2" FLUES	ENTERING SMOKE STACK			
								RIGHT SIDE	LEFT SIDE	RIGHT SIDE	LEFT SIDE							
<b>OGDEN TO GREEN RIVER</b>																		
SEPT. 28	249.1	211.1	11.8	8.1	229.0	59	223	694.2	674.0	336.0	312.0	338.9	658.0	644.8	637.2			
OCT. 1-2	248.4	209.3	12.5	8.3	227.9	56	220	691.2	676.7	328.8	304.3	325.7	645.6	630.1	626.0			
OCT. 16	248.2	206.5	11.0	7.2	228.2	56	212	690.6	670.2	335.6	309.1	338.4	654.7	626.8	634.4			
OCT. 18	247.5	183.2	12.2	7.7	227.7	55	220	-	-	-	-	-	-	-	-			
OCT. 22	247.7	205.4	12.0	8.9	227.7	54	208	689.8	688.0	339.0	329.1	357.5	668.8	643.8	643.3			
OCT. 31	245.2	187.6	10.2	7.1	225.6	51	207	679.8	675.0	326.1	310.8	338.3	637.3	633.1	615.4			
<b>OGDEN TO GREEN RIVER</b>																		
DEC. 2	248.3	-	11.4	6.3	229.9	51	217											
DEC. 4	246.1	198.4	10.7	6.6	228.6	51	222											
DEC. 6	245.7	200.9	12.1	8.3	227.7	51	231											
<b>GREEN RIVER TO OGDEN</b>																		
OCT. 17	244.1	212.4	10.6	8.0	232.2	55	208	688.3	668.8	333.0	305.9	330.9	653.8	630.5	632.0			
OCT. 18-19	248.5	212.3	13.1	10.0	228.6	55	209	-	-	-	-	-	-	-	-			
<b>GREEN RIVER TO OGDEN</b>																		
DEC. 3	252.1	-	10.0	6.0	232.7	52	228											
DEC. 5	250.2	217.1	12.3	6.6	232.4	52	227											
DEC. 7	245.6	213.4	8.7	5.8	225.3	51	228											
<b>LARAMIE TO GREEN RIVER</b>																		
OCT. 24	245.3	187.6	8.9	6.8	225.0	54	224	681.2	681.0	331.2	317.3	345.8	642.2	642.6	619.8			
OCT. 28	245.5	194.8	7.8	4.1	223.6	48	230	659.4	656.8	283.0	276.3	305.6	619.5	618.2	588.2			
NOV. 6	248.4	192.2	8.0	5.0	228.8	45	216	686.1	678.3	308.8	290.0	322.9	637.7	645.5	609.5			
<b>LARAMIE TO GREEN RIVER</b>																		
NOV. 2	245.2	175.2	11.3		THESE ITEMS DO NOT APPLY	48	THIS DATA NOT TAKEN	711.0	698.9	345.3	323.5	358.8	650.9	653.5	631.6			
NOV. 4	247.0	210.0	10.5			48	DATA NOT TAKEN	693.7	681.8	306.9	290.0	323.1	626.3	632.7	604.6			
NOV. 8	242.8	213.5	10.8			46	TAKEN	743.3	729.8	325.3	315.1	343.1	675.8	685.8	653.4			
<b>GREEN RIVER TO LARAMIE</b>																		
OCT. 25	247.7	211.1	10.1	7.2	ELESKO EXHAUST STEAM INJECTOR WITH L-18 TUBES	55	219	676.7	674.7	305.8	298.9	323.6	629.7	626.5	607.7			
NOV. 1	250.5	206.8	10.6	7.6		48	216	689.1	683.4	322.1	307.2	335.0	648.3	644.3	628.6			
NOV. 7	249.5	200.2	10.6	7.3		46	218	687.7	675.0	317.0	301.4	330.7	654.8	656.2	628.8			
<b>GREEN RIVER TO LARAMIE</b>																		
NOV. 3	248.4	213.6	12.0		NATHAN TYPE 4000 LIVE STEAM INJECTOR	48	THIS DATA NOT TAKEN	678.6	664.6	324.1	283.6	314.8	643.1	638.4	622.6			
NOV. 5	247.7	212.9	-			47	DATA NOT TAKEN	660.2	644.3	290.7	266.3	299.7	620.8	619.5	595.1			
NOV. 9	250.5	210.8	11.5			46	TAKEN	700.9	691.7	327.3	311.1	342.9	650.6	652.3	629.0			

## BOILER PERFORMANCE - LOCOMOTIVE 3911

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DATE 1940	TOTAL TANK WATER POUNDS	CONDENSATE FROM EXHAUST STEAM INJECTOR POUNDS	BLOW DOWN POUNDS	TOTAL POUNDS OF WATER EVAPORATED BY BOILER		POUNDS OF WATER EVAP PER POUND COAL FIRED		BOILER PRESSURE P.S.I.	TANK WATER TEMP °F	TEMPERATURE RISE DUE TO EXHAUST STEAM °F	RUNNING TIME HOURS	POUNDS OF COAL FIRED PER HOUR OF RUNNING TIME	MILLIONS OF BTU'S AC- TUALLY ABSORBED PER HOUR OF RUNNING TIME	
				ADJ. FOR ACTUAL	BLOW DOWN	TOTAL POUNDS OF COAL FIRED	ADJ. FOR ACTUAL							
<b>OGDEN TO GREEN RIVER</b>														
SEPT. 28	355122	20250	6168	377204	? 8774	75358	5.01	5.03	249.1	59	81.1	5.8903	12794	69.76
OCT. 1-2	311317	23696	4524	330489	331645	75296	4.39	4.40	248.4	56	77.3	4.8722	15454	74.25
OCT. 16	358192	22455	18861	361786	366871	78704	4.60	4.66	248.2	56	63.4	5.9833	13154	67.78
OCT. 18	294052	22775	9352	307475	309859	72701	4.23	4.20	247.5	55	78.7	4.8001	15146	70.43
OCT. 22	341212	24321	4826	360707	361947	76610	4.58	4.59	247.7	54	72.9	5.4667	14416	72.69
OCT. 31	269235	15867	5319	279783	281246	62283	4.49	4.52	245.2	51	59.5	4.8333	12886	64.81
<b>OGDEN TO GREEN RIVER</b>														
DEC. 2	320839	19688	9478	331049	333619	70004	4.73	4.77	248.3	51	62.7	5.1333	13637	72.19
DEC. 4	312019	24928	10747	326200	328961	70753	4.61	4.65	246.1	51	81.5	4.8500	14588	74.08
DEC. 6	345922	27111	11317	361716	364634	76287	4.74	4.78	245.7	51	80.5	5.1500	14813	77.44
<b>GREEN RIVER TO OGDEN</b>														
OCT. 17	268562	14502	11371	271693	274916	59984	4.53	4.58	244.1	55	54.4	6.0319	9944	50.81
OCT. 18-19	217247	10116	9486	217877	220634	54163	4.02	4.07	248.5	55	46.0	4.3167	12547	57.09
<b>GREEN RIVER TO OGDEN</b>														
DEC. 3	238017	13585	9552	242050	244847	48425	5.00	5.06	252.1	52	57.3	4.8000	10089	56.30
DEC. 5	271375	18640	4213	265802	266937	56429	5.06	5.08	250.2	52	70.1	5.2167	10817	60.69
DEC. 7	227232	13770	9503	231499	234210	40893	5.66	5.73	245.6	51	60.3	4.6167	8858	56.46
<b>LARAMIE TO GREEN RIVER</b>														
OCT. 24	270967	17149	4409	283707	284855	51129	5.55	5.57	245.3	54	63.2	5.2667	9708	60.25
OCT. 28	273319	19025	5409	286935	288390	54562	5.26	5.29	245.5	48	67.8	6.1167	8920	52.27
NOV. 6	301144	21934	8412	314666	316906	61299	5.13	5.17	248.4	45	72.9	5.8834	10419	59.64
<b>LARAMIE TO GREEN RIVER</b>														
<b>NATHAN TYPE 4000 LIVE STEAM INJECTOR</b>														
NOV. 2	300522	0	20298	280224	286486	58900	4.76	4.86	245.2	48	0	5.4500	10806	60.50
NOV. 4	311242	0	13965	297277	301596	63601	4.67	4.74	247.0	48	0	6.1833	10286	56.85
NOV. 8	315080	0	11121	303959	307394	66062	4.60	4.65	242.8	46	0	5.7667	11456	62.13
<b>GREEN RIVER TO LARAMIE</b>														
OCT. 25	341272	26999	28913	409358	417027	89278	4.59	4.67	247.7	55	66.0	7.5167	11877	61.23
NOV. 1	430521	33359	4640	459240	460454	102297	4.49	4.50	250.5	48	78.6	6.9667	14684	72.60
NOV. 7	440277	34590	9915	464952	467521	93584	4.97	5.00	249.5	46	79.2	7.1167	13150	72.16
<b>GREEN RIVER TO LARAMIE</b>														
<b>NATHAN TYPE 4000 LIVE STEAM INJECTOR</b>														
NOV. 3	459915	0	5049	454866	456430	119109	3.82	3.83	248.4	48	0	7.6000	15672	70.44
NOV. 5	440762	0	13194	427568	431663	97461	4.39	4.43	247.7	47	0	7.1667	13599	70.27
NOV. 9	464915	0	21801	443114	449904	100003	4.43	4.50	250.5	46	0	7.3500	13606	71.44

## WATER RATES AND INDICATED H.F. - LOCOMOTIVE 3911

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AFTER ADIABATIC EXPANSION FROM P <sub>1</sub> TO P <sub>2</sub>												CORRECTION FOR RADIATION AND VELOCITY OF STEAM IN EX- HAUST PIPES					
EXHAUST STAND PRESS P S I	VALVE CHAMBER PRESS P S I	EXHAUST STAND SPECIFIC ENTROPY	P <sub>2</sub> PRESS P S I	SPECIFIC VOLUME	ENTHALPY	JET VELOCITY FT. PER SEC.	POUNDS STEAM PER HOUR THROUGH EXHAUST NOZZLE	ENTHALPY IN EXHAUST PIPES - FT PER SECOND	VELOCITY OF STEAM IN EXHAUST PIPES	POUNDS STEAM PER HOUR INDICATED	H.P.						
P <sub>1</sub>	T <sub>1</sub>			V <sub>1</sub>	H <sub>1</sub>	V <sub>2</sub>	H <sub>2</sub>	V <sub>2</sub>	V <sub>1</sub>								
<b>WITH ELESCO TYPE "TP" EXHAUST STEAM INJECTOR</b>																	
4.9	305	230	655	1.7960	25.20	1193.9	13.0	32.09	1168.2	1168.1	49811	54150	1346.9	270.79	2.5	16.91	3202
6.2	299	230	688	1.7842	23.28	1190.8	13.0	31.28	1160.1	1272.7	55677	60632	1364.4	279.61	2.4	14.87	4077
7.8	289	215	677	1.7687	21.17	1185.6	13.0	30.25	1149.6	1373.9	62150	67184	1359.5	283.83	2.4	14.84	4527
7.9	309	225	650	1.7808	21.66	1195.1	13.0	31.05	1157.7	1400.1	61704	67078	1344.6	288.32	2.5	17.31	3875
8.0	308	225	679	1.7796	21.52	1194.7	13.0	30.97	1156.9	1422.1	62835	67516	1360.0	291.72	2.5	15.63	4320
8.1	350	227	708	1.8044	22.65	1214.6	13.0	32.68	1174.2	1454.7	60912	66425	1375.3	297.62	2.6	16.10	4126
8.2	315	224	685	1.7828	21.53	1198.0	13.0	31.18	1159.1	1427.2	62636	67302	1363.2	290.92	2.5	15.64	4303
8.3	326	218	702	1.7891	21.75	1203.1	13.0	31.61	1163.4	1441.6	62407	68055	1372.6	292.81	2.5	15.24	4466
10.1	331	216	702	1.7828	20.162	1205.3	13.4	30.50	1161.3	1515.0	67971	74122	1372.7	295.64	2.5	15.43	4804
10.4	340	208	708	1.7867	20.144	1209.4	13.6	30.41	1165.0	1522.0	68487	74315	1376.2	297.61	2.5	15.49	4798
10.5	311	215	698	1.7685	19.295	1195.6	13.6	29.24	1152.7	1495.8	70002	75959	1370.6	291.38	2.4	14.75	5150
10.8	340	224	699	1.7848	19.799	1209.3	13.8	29.93	1164.9	1521.9	69581	76476	1370.6	297.20	2.5	16.03	4771
11.1	347	218	699	1.7874	19.726	1212.7	14.0	29.75	1167.9	1528.9	70324	76498	1371.0	299.27	2.5	16.34	4682
11.4	315	222	695	1.7668	18.674	1197.3	14.2	28.17	1154.6	1492.6	72505	78958	1368.6	292.08	2.4	15.07	5239
11.4	324	226	705	1.7723	18.903	1201.6	14.2	28.51	1158.4	1501.3	72058	78579	1373.7	293.85	2.4	15.00	5239
11.4	344	216	711	1.7843	19.410	1211.2	14.2	29.26	1166.7	1523.8	71263	77327	1377.4	298.39	2.5	15.55	4973
11.7	344	216	710	1.7829	19.171	1211.1	14.3	29.02	1166.3	1528.7	72084	78218	1376.9	298.11	2.5	15.58	5020
12.1	321	206	697	1.7673	18.291	1200.1	14.6	27.62	1157.0	1499.5	74291	81653	1370.5	293.14	2.4	15.15	5390
12.2	331	219	706	1.7729	18.465	1204.9	14.6	27.95	1160.9	1514.9	74168	80680	1374.7	295.44	2.4	15.20	5308
12.4	343	215	693	1.7791	18.617	1210.5	14.7	28.18	1165.7	1528.7	74233	81589	1368.0	298.13	2.4	16.41	4972
12.6	347	216	711	1.7802	18.578	1212.4	14.8	28.10	1167.1	1537.2	74858	79844	1377.4	300.02	2.5	15.66	5099
12.6	326	200	689	1.7680	18.054	1202.4	14.8	27.37	1158.6	1511.4	75564	82289	1366.6	294.30	2.4	15.73	5231
12.7	342	216	703	1.7773	18.373	1210.0	14.9	27.77	1165.5	1523.6	75077	80077	1378.5	297.57	2.4	15.32	5227
13.0	358	213	697	1.7852	18.526	1217.6	15.1	27.97	1172.2	1539.0	75294	81905	1370.2	300.93	2.5	16.96	4829
13.6	352	212	684	1.7792	17.984	1214.6	15.4	27.22	1169.5	1533.8	77107	84386	1363.3	299.15	2.4	17.49	4431
13.8	322	209	695	1.7603	17.139	1200.2	15.5	26.00	1156.7	1506.0	79262	85730	1369.4	293.06	2.3	15.25	5622
13.9	318	216	682	1.7573	16.980	1198.2	15.6	25.70	1155.2	1497.6	79740	87092	1362.1	292.09	2.3	15.75	5530
14.0	333	217	708	1.7661	17.260	1205.4	15.7	26.05	1161.6	1511.7	79409	85889	1375.8	295.67	2.4	15.15	5669
14.2	334	218	681	1.7659	17.157	1205.9	15.8	25.91	1162.1	1511.6	79833	85150	1361.4	295.49	2.4	16.62	5123
15.1	333	212	690	1.7615	16.576	1205.2	16.3	25.07	1161.3	1513.3	82601	88928	1366.5	295.38	2.3	16.01	5555
15.1	371	218	710	1.7839	17.411	1223.5	16.3	26.34	1177.3	1552.4	80649	88383	1376.8	302.92	2.4	16.87	5239
1.4	336	60	658	1.8393	32.72	1209.1	13.0	35.32	1200.4	687.83	26649	28970	1358.6	188.10	2.5	17.31	1674
2.4	308	110	626	1.8150	29.47	1195.8	13.0	33.47	1182.0	862.70	35271	38484	1339.5	224.23	2.4	18.01	2137
3.3	331	100	639	1.8223	28.68	1206.5	13.0	34.02	1187.4	1011.7	40694	44267	1346.6	251.77	2.5	18.50	2393
3.3	262	136	631	1.7792	26.07	1173.8	13.0	30.94	1156.7	957.21	42335	45836	1340.3	238.09	2.3	15.50	2957
3.7	312	98	637	1.													

## WATER RATES AND INDICATED H.P. - LOCOMOTIVE 3911

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												CORRECTION FOR RADIATION AND VELOCITY OF STEAM IN EX- HAUST PIPES		POUNDS STEAM PER HOUR		VELOCITY OF STEAM	
EXHAUST STAND	VALVE	CHAMBER	PRESS	EXHAUST STAND	PRESS	SPECIFIC	JET VELOCITY	THROUGH	ENTHALPY	IN EXHAUST	STEAM IN EX-	POUNDS STEAM	INDICATED				
PRESS PSI	TEMPERA- TURE OF GAUGE	PSI	TEMPERA- TURE OF GAUGE	ENTROPY	VOLUME	ENTHALPY	FT. PER SEC.	EXHAUST	TO	PIPES - FT	HAUST PIPES	PER INDICATED	H.P.				
P <sub>1</sub>	T <sub>1</sub>				V <sub>1</sub>	H <sub>1</sub>	P <sub>2</sub> ABSOLUTE	V <sub>2</sub>	H <sub>2</sub>	V <sub>2</sub>	W <sub>y</sub>	W <sub>c</sub>	H <sub>p</sub>	V <sub>1</sub>			
<b>WITH LIVE STEAM INJECTOR</b>																	
7.3	346	218	705	1.8064	23.34	1212.8	13.0	32.83	1175.7	1395.8	58179	58179	1374.2	296.26	2.7	16.04	3627
8.1	308	220	678	1.7791	21.42	1194.7	13.9	30.93	1156.6	1412.7	62500	62500	1359.6	288.81	2.5	15.67	3989
9.2	315	229	703	1.7776	20.548	1197.8	13.0	30.83	1155.6	1484.2	65877	65877	1373.2	292.01	2.5	14.72	4475
10.3	345	218	758	1.7902	20.364	1211.8	13.5	30.82	1167.0	1528.7	67874	67874	1402.2	298.18	2.6	13.55	5009
13.2	350	200	728	1.7797	18.199	1213.8	15.2	27.51	1168.8	1532.1	76210	76210	1387.2	299.19	2.5	14.89	5118
13.2	345	220	730	1.7768	18.081	1211.4	15.2	27.33	1166.7	1527.0	76456	76456	1387.3	298.21	2.5	14.68	5208
13.6	375	190	760	1.7925	18.502	1225.6	15.4	28.03	1179.0	1559.0	76109	76109	1404.4	303.79	2.5	14.44	5271
14.2	313	213	700	1.7529	16.677	1195.8	15.8	25.21	1153.1	1492.5	81013	81013	1371.8	291.46	2.4	14.66	5526
15.0	366	200	720	1.7814	17.362	1221.1	16.2	26.31	1174.9	1552.3	80736	80736	1383.9	302.40	2.5	15.97	5055
15.3	316	215	693	1.7502	16.086	1197.0	16.4	24.36	1153.9	1499.3	84222	84222	1368.0	292.26	2.3	15.09	5581
15.3	354	215	723	1.7733	16.919	1215.2	16.4	25.61	1170.1	1533.8	81954	81954	1383.9	299.13	2.4	15.30	5356
15.4	364	210	718	1.7787	17.096	1220.0	16.5	25.79	1174.5	1540.8	81754	81754	1381.4	301.52	2.5	16.02	5103
16.1	375	200	723	1.7822	16.890	1225.2	16.9	25.51	1178.8	1555.8	83456	83456	1384.6	304.09	2.5	16.22	5145
3.5	395	55	655	1.8575	30.70	1236.5	13.0	36.76	1214.8	1077.6	40114	40114	1357.4	265.67	2.7	21.53	1863
4.0	328	125	630	1.8158	27.36	1205.0	13.0	33.52	1182.5	1095.6	44726	44726	1340.5	263.98	2.6	19.15	2336
5.4	375	85	700	1.8342	26.84	1226.8	13.0	34.93	1196.5	1266.6	49620	49620	1378.3	287.30	2.7	17.10	2902
12.0	366	160	710	1.7943	19.470	1221.5	14.5	29.45	1175.5	1539.0	71510	71510	1379.7	300.37	2.5	16.35	4374

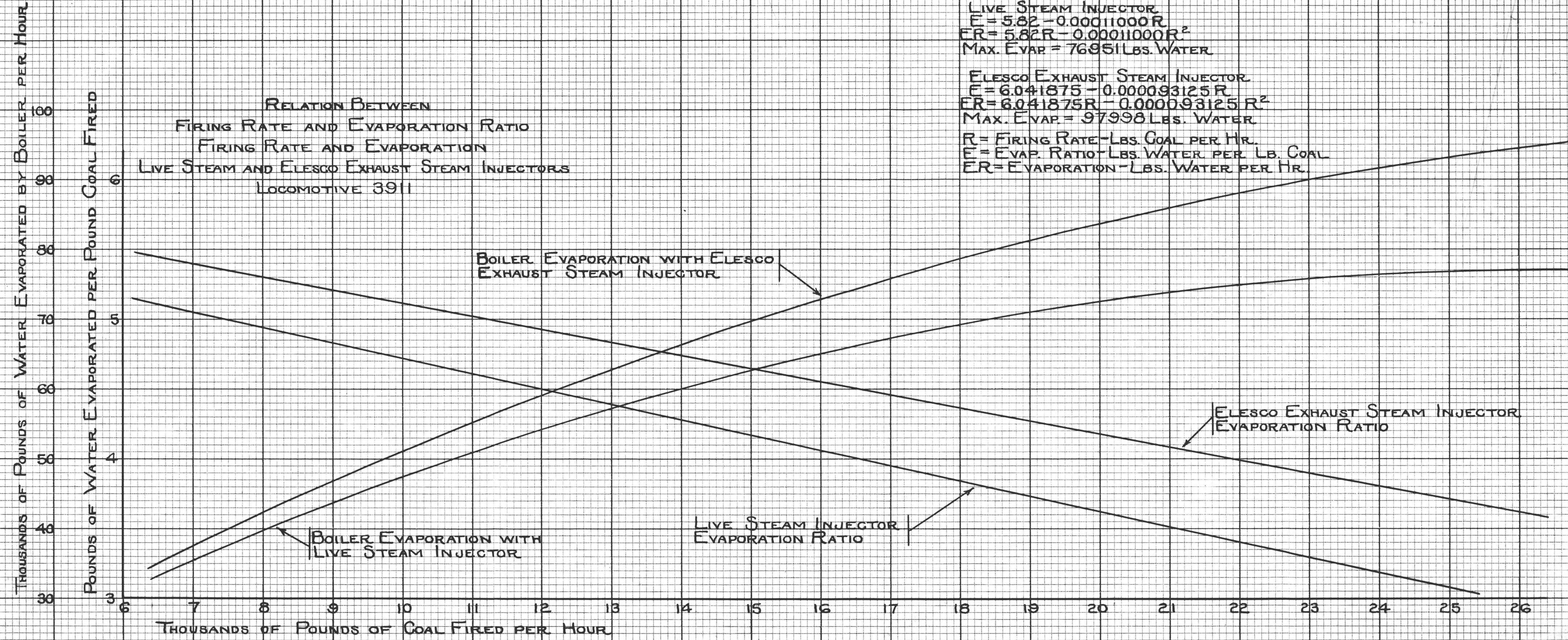


FIGURE NO. I

RELATION BETWEEN FIRING RATE  
AND  
BOILER HEAT ABSORPTION RATE

LOCOMOTIVE 3911

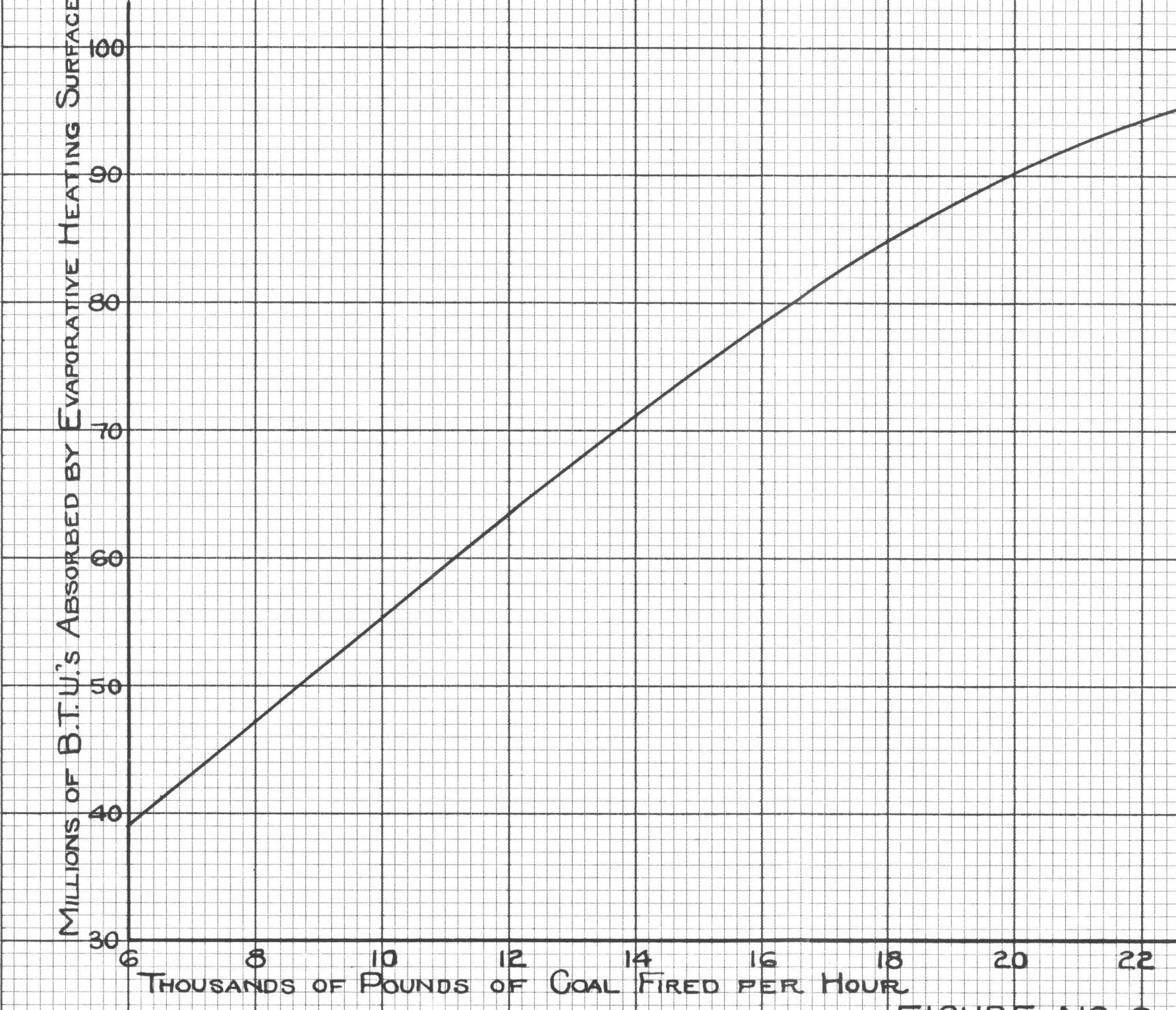


FIGURE NO. 2

RELATION BETWEEN EXHAUST STAND PRESSURE AND DRAFT  
LOCOMOTIVE 3911

MULTIPLE STACKS AND MULTIPLE JET NOZZLES

20

NOZZLE AREA 56.55 Sq. IN.

NOZZLE TIP TO BOTTOM STACK FLARE  $15\frac{3}{4}$  IN.

TOTAL LENGTH STACK INCLUDING FLARE  $57\frac{7}{8}$  IN.

STACK CHOKE DIAMETER  $24\frac{1}{2}$  IN.

STACK TOP DIAMETER  $29\frac{1}{2}$  IN.

LABYRINTH FRONT END.

15

ENTRANCE TO STACK

10

DRAFT - INCHES OF WATER.

5

0

FRONT FLUE SHEET



EXHAUST STAND PRESSURE - POUNDS PER SQUARE INCH GAUGE

RELATION BETWEEN EXHAUST STAND PRESSURE AND INDICATED HORSE POWER  
Locomotive 3911  
With ELESKO TYPE "TP" EXHAUST STEAM INJECTOR

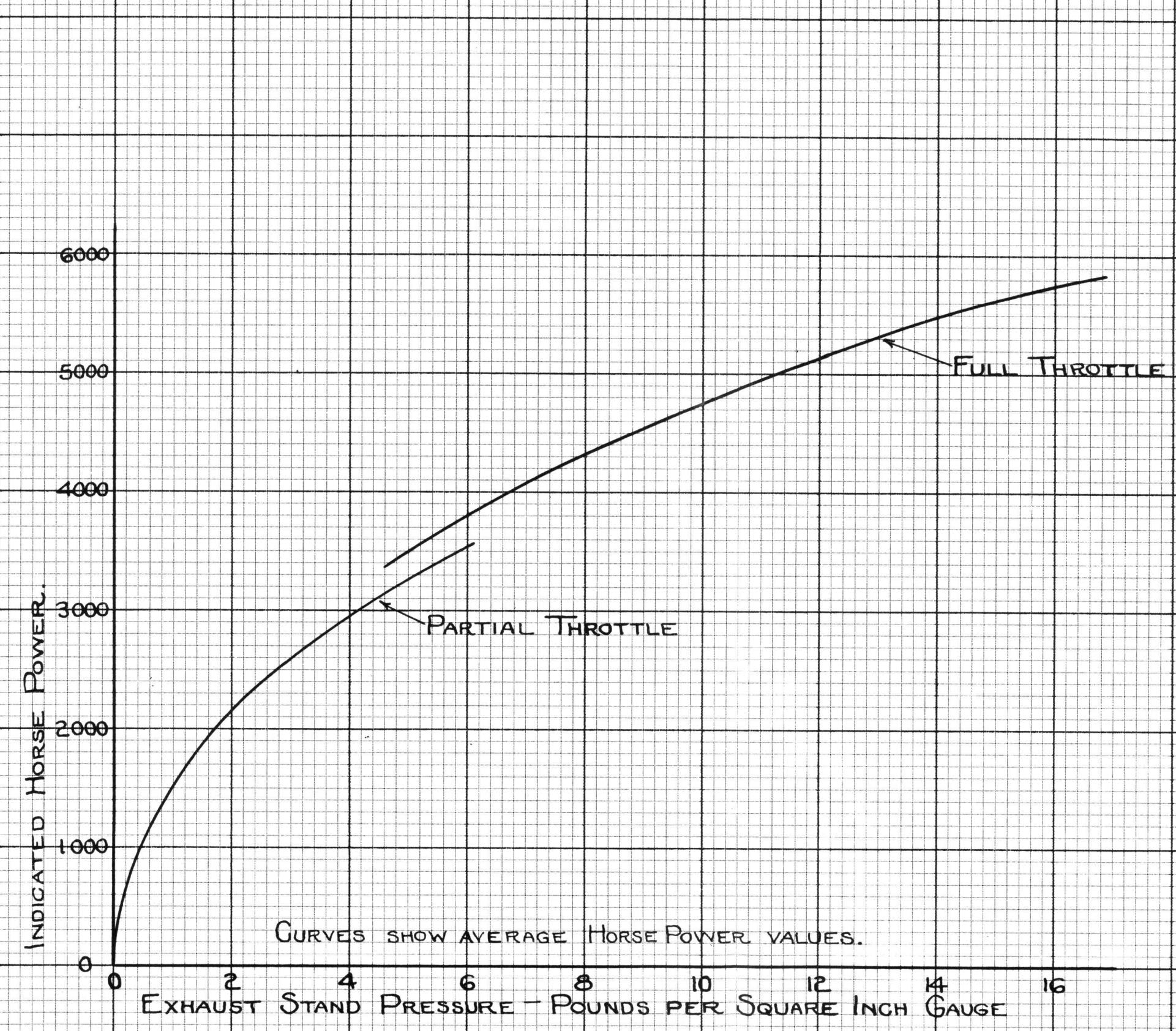


FIGURE NO. 4

RELATION BETWEEN  
EXHAUST STAND PRESSURE AND STEAM THROUGH THE EXHAUST NOZZLE  
AND  
EXHAUST STAND PRESSURE AND STEAM TO ENGINES

LOCOMOTIVE 3911  
WITH ELESCO TYPE "TP" EXHAUST STEAM INJECTOR

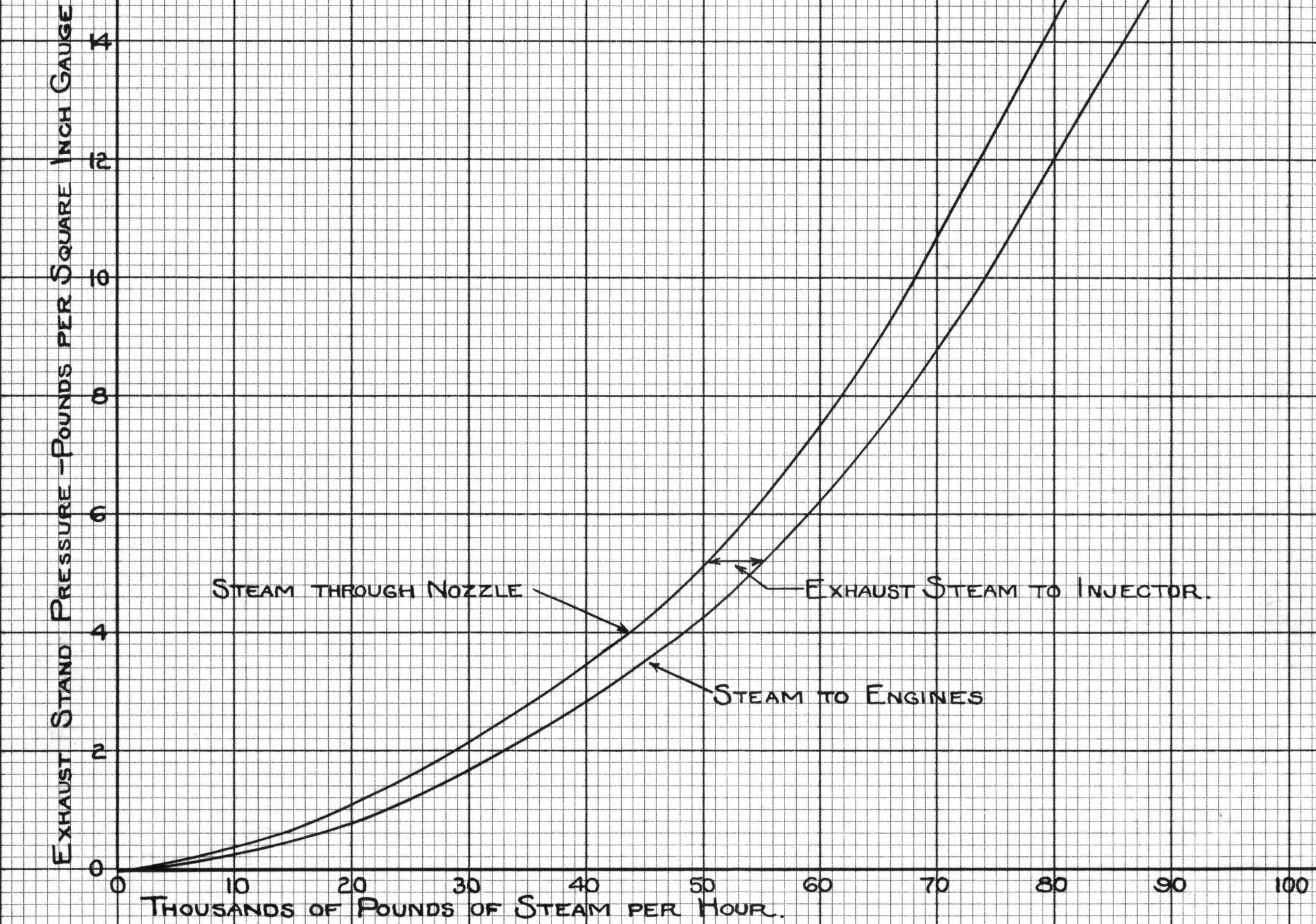


FIGURE NO. 5

L.R.B. 2-14-41

Two MULTIPLE JET EXHAUST Nozzles — TOTAL AREA 56.55 SQ. IN.

RELATION BETWEEN STEAM TO ENGINES AND INDICATED HORSE POWER  
LOCOMOTIVE 3911  
WITH ELESCO TYPE "TP" EXHAUST STEAM INJECTOR

ON INLETTING JACKETING CROWN  
A 2 IN. DIAMETER  
CROSS SECTION 10 X 10  
INCHES

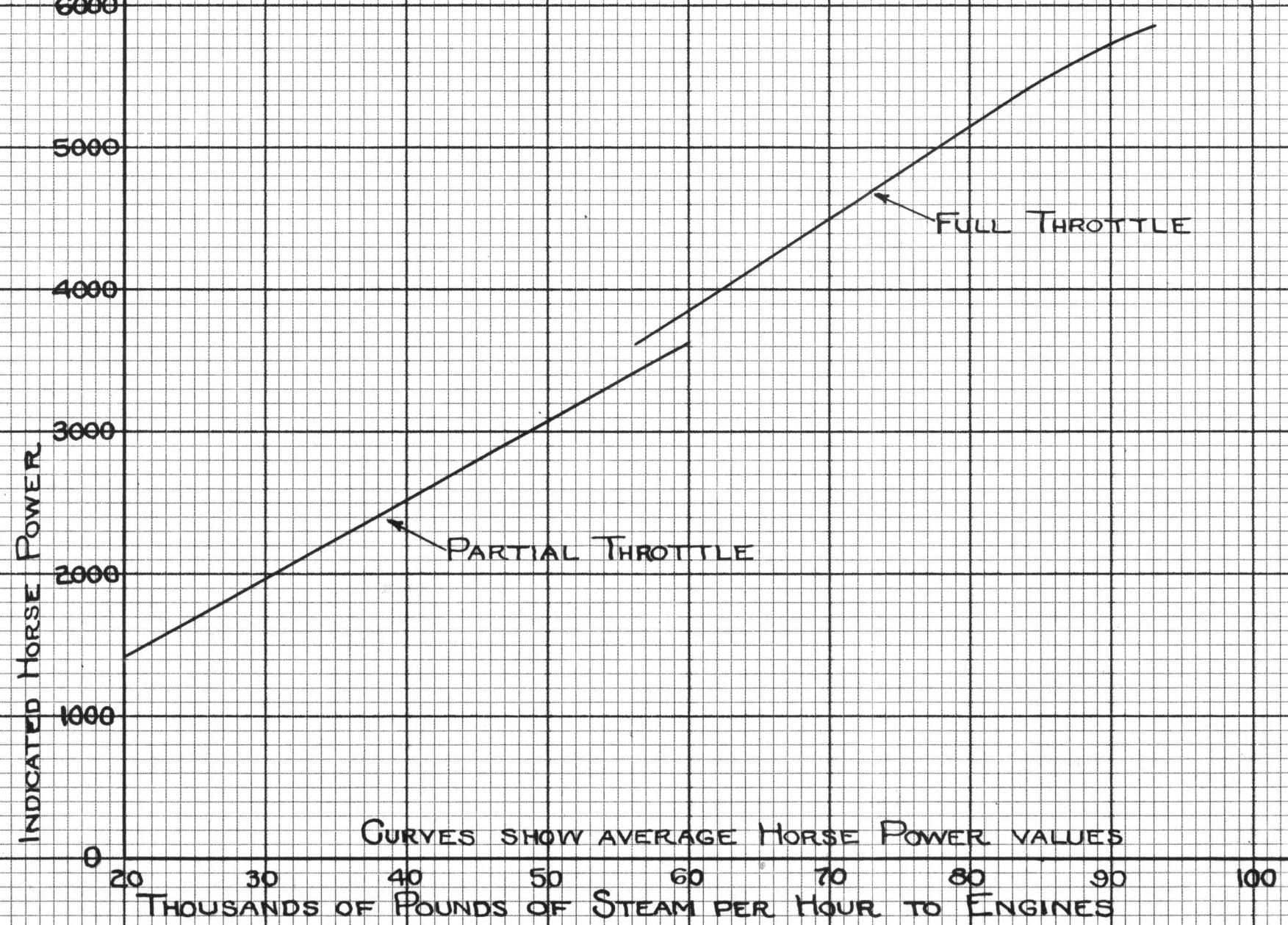
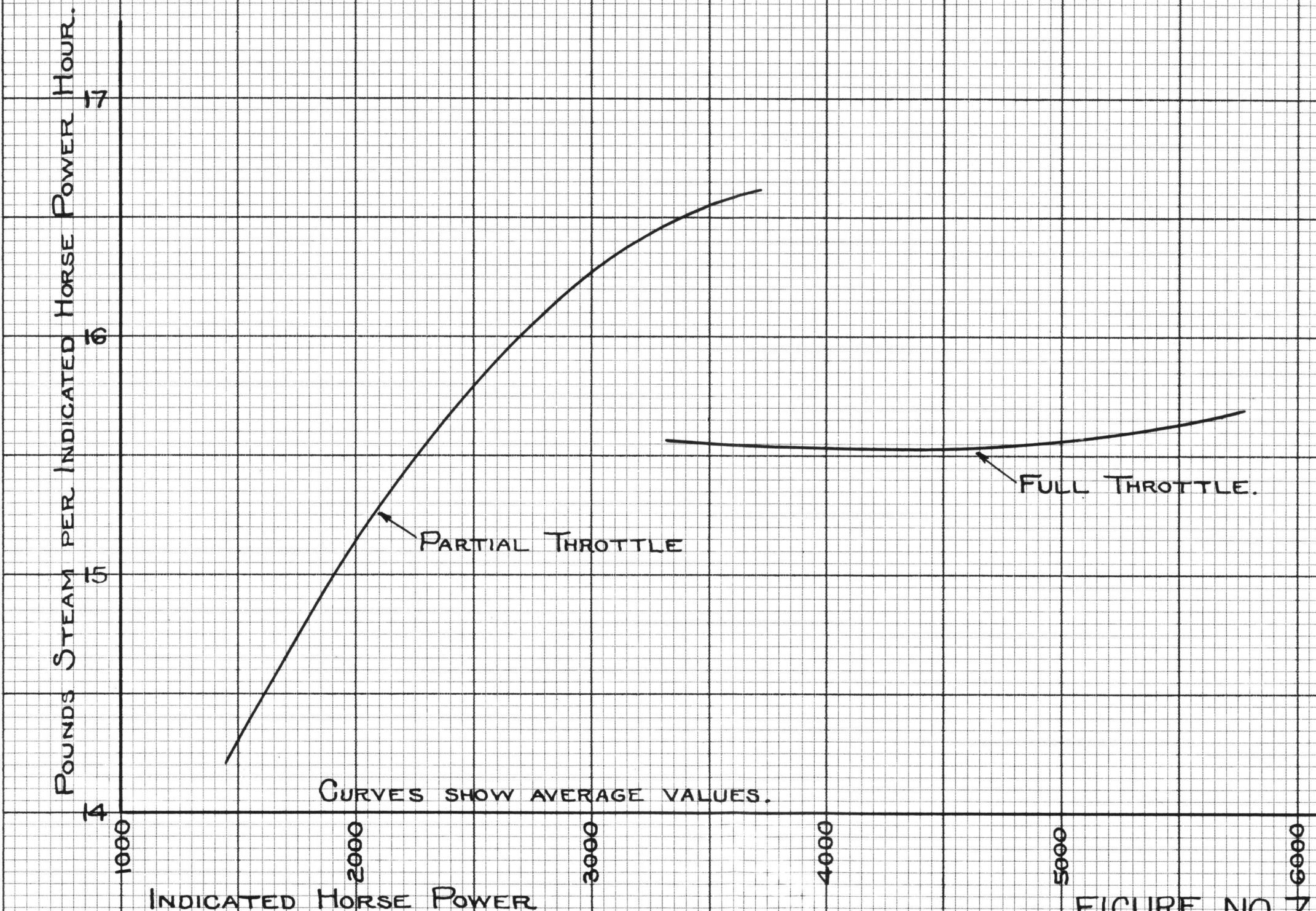


FIGURE NO. 6  
L.K.B. 2-14-41

RELATION BETWEEN WATER RATES AND INDICATED HORSE POWER  
LOCOMOTIVE 3911  
WITH ELESCO TYPE "TP" EXHAUST STEAM INJECTOR



RELATION BETWEEN  
INDICATED HORSE POWER AND POUNDS OF COAL PER INDICATED HORSE POWER HOUR  
INDICATED HORSE POWER AND POUNDS OF COAL FIRED PER HOUR  
LOCOMOTIVE 3911  
WITH ELESCO TYPE "TP" EXHAUST STEAM INJECTOR

