

Union Pacific Railroad Company
Research & Mechanical Standards

REPORT OF TESTS

Locomotive 3992
Equipped with single stack, annular
ported exhaust nozzle and Master
Mechanic's front end arrangement

Locomotive 3996
Equipped with double stack, multiple jet
exhaust nozzles and modified Master
Mechanic's front end arrangement

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Union Pacific Railroad Company
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SUMMARY OF TEST RESULTS
Between Laramie and Green River

	Westbound		Eastbound		Westbound and Eastbound Combined	
	3992	3996	3992	3996	3992	3996
Locomotive number	3992	3996	3992	3996	3992	3996
Number of trips	6	6	6	6	12	12
Ave. number of stops per trip	7.3	8	7.3	5.2	7.3	6.6
Ave. running time	6'51"	6'25"	7'39"	6'42"	7'15"	6'39"
Ave. speed MPH	36.6	39.1	32.8	37.5	34.7	38.3
Ave. tons per trip	3004	3085	3570	3575	3287	3330
Ave. MGTM per trip	753.90	774.42	896.00	897.32	824.95	835.87
Ave. coal pounds per trip	63,569	62,168	90,616	83,301	77,093	72,735
Ave. coal per MGTM	84.3	80.3	101.1	92.8	92.7	86.6
Per cent increase in fuel consump- tion	5.0		8.9		7.0	
Max. indicated horsepower	4423	4825	4480	4844	4480	4844

Draft in inches of water at
front flue sheet for exhaust
stand pressure of:

	Ave. from curves Figure No. 12	Loco. Number 3992	3996
4 PSI gauge	5.1	9.3	
6 "	6.5	11.9	
8 " "	7.4	14.1	
10 " "	8.3	16.0	
11 " "	8.7	16.8	

Temperature °F of Steam to Cylinders

For exhaust stand pressure of:	From Curve Figure No. 3	3992	3996
8 PSI gauge	650.5	721.2	
9 " "	660.5	731.0	
10 " "	670.0	739.6	
11 " "	678.8	747.2	

The results of this test show the desirability of using the double stack, multiple jet exhaust nozzles and modified Master Mechanic's front end arrangement for drafting 3900 class locomotives.

Locomotive 3996, which is equipped with the double stack arrangement, was used for comparison with locomotive 3992 which is equipped with a single stack, annular ported exhaust nozzle and Master Mechanic's front end arrangement.

The front end arrangement on locomotive 3996 includes a 45-degree deflector plate extending forward and upward from the bottom of an 21-inch strip of netting across the back plate. With this deflector plate the front end has proven to be a very effective spark arrester and can be considered satisfactory in this respect.

The above summary shows some of the more important results of this test and indicates higher front end efficiency and better overall efficiency for locomotive 3996.

Averages are based on complete trips between Laramie and Green River where locomotive operation varies from drifting to maximum capacity.

Indicated horsepower is taken from Table VII, temperature of steam to cylinders is from Figure No. 3 and draft in inches of water from Figure No. 12.

Locomotives:

The important locomotive dimensions are shown in the following tabulation:

General classification	4-6-6-4
Service	Freight
Starting, tractive force	97,350
Weight locomotive in working order, pounds	633,500
Weight locomotive light, pounds	581,400
Weight tender light, pounds	172,300
Weight tender loaded, pounds	436,500
Weight locomotive and tender loaded, pounds	1,070,000
Tender water capacity, gallons	25,000
Tender coal capacity, pounds	56,000
Expansion of steam	Single
Number of cylinders	4
Cylinder diameter, inches	21
Cylinder stroke, inches	32
Valve gear	Walschaerts

Valves:

Diameter, inches	12
Full gear travel, inches	7
Lap, inches	1-3/8
Lead, inches	1/4
Exhaust clearance, inches	1/8

Boiler:

Working pressure, pounds per square inch gauge	280
Length tubes and flues, feet inches	20'0"
Number of 2-1/4 inch diameter tubes	45
Number of 4 inch diameter flues	177

Firebox:

Length, inches	187-1/32
Width, inches	108-3/16
Grate area, square feet	132
Number of Security Circulators	5
Per cent air opening grates	12

Heating Surface, square feet:

Firebox and combustion chamber	519
Circulators	83
Boiler tubes	527
Boiler flues	3688
Total evaporative heating surface	4817
Superheater heating surface	2085
Total heating surface	6902

Territory and Trains:

Test runs were made in both directions between Laramie and Green River in regular freight service. Trains hauled were representative of the regular freight movement.

Data:

All data necessary for the determination of boiler, cylinder and exhaust steam injector performance were taken.

Coal consumption was determined by counting the revolutions made by the stoker conveyor screw. This was done

by means of an odometer operated by a device driven by the conveyor screw. The amount of coal delivered per revolution was determined by emptying a tank which had been filled to the specified capacity of 56,000 lbs. of coal and counting the revolutions required. A number of checks were made and an average coal factor determined which could be applied to all Standard MB stokers. This factor of 8 pounds per revolution checks very closely with data from the Standard Stoker Company.

This method of measuring coal is considered more accurate than the method formerly used of measuring coal space volume, where small errors in measurement may cause errors of several hundred pounds in determining the weight of coal used.

Tank water consumption was determined by measuring the water in the tank at the start of a run, before and after taking water and at the end of a run.

A continuous record was kept of the time the exhaust steam injector was operating on exhaust steam, on live steam and when shut off. A venturi meter was applied to the water intake line of the exhaust steam injector. With this device the rate at which tank water was being fed to the boiler could be determined at any time, and the amount of tank water delivered on live steam operation was calculated from the injector time log. For accurate timing of the injector operation an automatic signal was devised which indicated when the injector was started, when it changed from live steam operation to exhaust steam operation, from exhaust steam operation to live steam operation and when the injector was shut off.

A record was kept of the train movement, tonnage and number of cars.

The following pressures were observed and recorded:

1. Boiler
2. Valve chamber
3. Exhaust nozzle stand
4. Exhaust steam in injector
5. Live steam to injector

The following temperatures were observed and recorded:

1. Tank water
2. Delivery water
3. Steam to right cylinders

4. Steam to left cylinders
5. Exhaust steam from right back cylinder
6. Exhaust steam from left back cylinder
7. Exhaust steam from front engine
8. Smoke box gases right side
9. Smoke box gases left side

Draft was measured near the top and bottom of the smoke box, approximately one foot ahead of the front flue sheet.

A speed recorder was used to indicate and record the speed and to correlate temperature and pressure readings with the speed. Correlation of all readings with speed was accomplished by marking the speed recorder tape before and after taking each set of readings. By this procedure it is possible to calculate indicated horsepower for each reading and make an accurate comparison with theoretical horsepower-speed curves. These records may also be used in conjunction with the condensed profile to show the speed and required back pressure at any desired point with a given train.

COMPILED DATA AND GRAPHICAL PRESENTATION:

The data taken during the tests and the calculated results are shown in charts and tables compiled under the following headings:

Charts of speed recorder tapes for comparable Westbound and Eastbound runs

Table I	General Performance
Table II	Fuel - Water - Evaporation
Table III	Average Pressures and Temperatures
Table IV	Evaporation and Temperature Rise due to Exhaust Steam Condensed by Exhaust Steam Injector
Table V	Elesco Exhaust Steam Injector Performance
Table VI	Fuel Saved by Operation of Elesco Exhaust Steam Injector

Table VII Water Rates and Indicated Horsepower

The following curves are included:

- Figure 1 Relation between Firing Rate and Boiler Heat Absorption Rate
- Figure 2 Relation between Evaporation and Firing Rate and Relation between Evaporation Ratio and Firing Rate
- Figure 3 Relation between Exhaust Stand Pressure and Temperature of Steam to Engines and Relation between Exhaust Stand Pressure and Temperature of Smoke Box Gases
- Figure 4 Relation between Firing Rate and Pounds of Coal Saved and Relation between Firing Rate and Percent Coal Saved by Exhaust Steam Injector
- Figure 5 Relation between Firing Rate and Gross Ton Miles per Train Hour
- Figure 6 Relation between Gross Thousand Ton Miles and Pounds of Coal per Gross Thousand Ton Miles
- Figure 7 Relation between Exhaust Stand Pressure and Steam to Engines
- Figure 8 Relation between Exhaust Stand Pressure and Indicated Horsepower
- Figure 9 Relation between Steam to Engines and Indicated Horsepower
- Figure 10 Relation between Indicated Horsepower and Pounds of Steam per Indicated Horsepower Hour
- Figure 11 Relation between Indicated Horsepower and Speed
- Figure 12 Relation between Exhaust Stand Pressure and Draft

GENERAL PERFORMANCE:

At the time of the test the locomotives had comparable flue miles, machinery and appurtenances were in generally good condition, and valves were set as nearly as possible the same on both locomotives. The essential difference in the locomotives was, therefore, in the front end arrangement and admission of overfire air in the firebox.

Locomotive 3992 was equipped with a single stack annular ported exhaust nozzle and Master Mechanic's front end arrangement.

Locomotive 3996 was equipped with double stacks, multiple jet exhaust nozzles and modified Master Mechanic's front end arrangement. Overfire air was admitted into the firebox through thirty-two 2-1/4 inch tubes.

The general performance of locomotives 3992 and 3996 is shown clearly on the charts, on which are presented the speed recorder tapes arranged with condensed profiles of territory over which maximum performance is generally required. From the time checks on the recorder tapes it is possible to accurately correlate data such as speed, gradient, exhaust stand pressure and indicated horsepower.

Data were taken only while exhaust steam injector was operating on exhaust steam. Tables I to VII, therefore, show average performance which includes all operation from drifting movements to maximum capacity performance.

The better performance of locomotive 3996 is shown both by the speed recorder tapes and in Figures 5, 6, 7, 8, 9, 10 and 11.

Exhaust Steam Injector Performance:

Exhaust steam injector performance was satisfactory although delivery water temperatures were not as high as expected. The injector on locomotive 3992 showed somewhat better performance than the injector on locomotive 3996. This is accounted for by higher exhaust steam pressures and nearly equal exhaust steam temperatures. Injector performance is shown in Figure No. 4.

Boiler Performance:

Boiler performances are shown in Figure No. 1. The better heat absorption rate of the boiler of locomotive 3996 is due to better combustion of fuel and less stack loss.

This is due to the use of overfire air and a more efficient front end arrangement. At a given firing rate, the heat absorption rate of identical boilers should be the same, providing the fuel is utilized. The difference in unburned fuel loss is, therefore, responsible for the difference in boiler heat absorption rate at a given firing rate.

Front End Performance:

Figure 12 shows clearly the greater efficiency of the front end arrangement in locomotive 3996. It is interesting to note the small difference in draft from top to bottom of the flue sheets and especially in locomotive 3992 with a low table plate. The vertical distribution of draft is good as shown by draft readings and although readings were not taken on the horizontal center line of the boiler, it is reasonable to assume good distribution horizontally.

The draft at the front flue sheet in locomotive 3996 is greater than that in locomotive 3992 by 45.8% at 5 PSI exhaust stand pressure to 48.2% greater at 11 PSI exhaust stand pressure.

Discussion of Front End Arrangement:

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

	<u>Locomotive 3992</u>	<u>Locomotive 3996</u>
Type exhaust nozzle	Annular ported	Multiple jet
Exhaust nozzle area sq.inches	53.2	56.5
Vertical distance - nozzle tip to seat on exhaust base, inches	26-1/2	16-3/4
Vertical distance - nozzle tip to bottom of stack extension, inches	15-1/4	10-1/32
Total length of stack including extension, inches	51	66
Inside diameter stack at choke, inches	27	23-3/4
Inside diameter stack at top, inches	29	28-3/4
Type front end arrangement	Master Mechanic's	Modified Master Mechanics
Table plate	Solid plate	Solid plate

	<u>Locomotive 3992</u>	<u>Locomotive 3996</u>
Net gas area through tubes and flues, sq. inches		
At superheater return bend	1303	1303
At front flue sheet	1525	1525
Net area through front end arrangement, sq. inches	1479	2028
Area of stacks at top, sq. inches	661	1298
Area of stacks at choke, sq. inches	573	886
Ratio of stack choke area to nozzle area	10.8	15.7
Perimeter of exhaust steam jet at nozzle, inches	69.7	75.4

For a given locomotive and any given front end arrangement, which includes stack and exhaust nozzle, there is a definite upper limit of output of the locomotive at which the weight of air supplied will equal that required for the fuel burned. Below this limit the percentage of excess air will increase with decreasing locomotive output, above this limit there will be a deficiency of air. The position of the limits is determined by the characteristics of the engine boiler and of the front end arrangement.

With locomotives of the same design which have the same resistance to gas flow through the tubes, flues and firebox, the number of inches of water draft per pound of cylinder back pressure or exhaust stand pressure, when measured in the same relative position near the front flue sheet, may be used as the criterion of the performance of front end arrangements.

The entrainment ratio, which is the ratio of the weight of gases moved to the weight of steam required to move the gases, of a front end arrangement, increases with decreased back pressure, decreased front end resistance and increased ratio of stack area to nozzle area.

The multiple jet exhaust nozzle of 56.5 sq. inches area used on locomotive 3996 compared with the annular ported exhaust nozzle of locomotive 3992 has 6.2 per cent more area, and due to a better coefficient of discharge, will pass 10.5 per cent more steam for a given back pressure. This means that more flue gas can be moved at a given back pressure. Also, either the same power may be developed on less back pressure or more power may be developed on the same back pressure.

The net area through the front end arrangement is 37.1 per cent greater in locomotive 3996 than in locomotive 3992. It, therefore, offers less resistance and permits easier flow of gases and consequently less energy is needed to move the required amount of gases through the front end.

The larger ratio of stack to nozzle area of locomotive 3996 also helps increase the entrainment ratio of the front end.

Other front end dimensions although of lesser importance also serve to give the front end arrangement of locomotive 3996 a higher entrainment ratio than the front end arrangement of locomotive 3992.

Since the characteristics of engines and boilers of the two test locomotives are essentially the same, maximum output of the locomotives will be limited by the front end arrangement, and differences of maximum output will be attributable to differences in front end arrangements.

TABLE I

DATE 1948	LOADS	NUMBER OF CARS	NUMBER OF EMPTIES	GENERAL PERFORMANCE												TOTAL TANK WATER POUNDS	TOTAL COAL FIRED POUNDS	PER G.T.M. POUNDS WATER	AVERAGE SPEED M.P.H.				
				TONS	G.T.M.	DURATION OF TEST				TOTAL HOURS MIN.	DEAD HOURS MIN.	RUNNING HOURS MIN.											
						TOTAL HOURS MIN.	DEAD HOURS MIN.	RUNNING HOURS MIN.															
WESTBOUND - LARAMIE TO GREEN RIVER 251.0 MILES																							
LOCO. 3992																							
AUGUST 9	45 LARAMIE-RAWLINS 44 RAWLINS-GREEN RIVER		13	9	3011 LARAMIE-RAWLINS 2978 RAWLINS-GREEN RIVER	751.33	9	49	2	59	6	50	295613	53872	393.5	71.7	36.7						
11	49		13	11	3003	753.75	7	22	0	53	6	29	300603	52496	398.8	69.6	38.7						
17	54			23	3252	816.25	8	57	1	47	7	10	346308	62040	424.3	76.0	35.0						
20	1 LARAMIE-RAWLINS 0 RAWLINS-ROCK SPRINGS 0 ROCK SPRINGS-GREEN RIVER	114 LARAMIE-RAWLINS 101 RAWLINS-ROCK SPRINGS 51 ROCK SPRINGS-GREEN RIVER		7	2569 LARAMIE-RAWLINS 2269 RAWLINS-ROCK SPRINGS 1084 ROCK SPRINGS-GREEN RIVER	586.79	11	6	4	3	7	3	370803	74136	632.0	126.3	35.6						
22	78 LARAMIE-RAWLINS 72 RAWLINS-GREEN RIVER		6	8	3636 LARAMIE-RAWLINS 3576 RAWLINS-GREEN RIVER	911.74	9	5	1	52	7	13	377212	78744	413.7	86.4	34.8						
24	41		19	6	2803	703.55	7	10	0	51	6	19	315092	60128	449.0	85.5	39.7						
AVERAGE	44.4		29.3	7.3	3004	753.90	8	55	2	4	6	51	334272	63569	443.4	84.3	36.6						
LOCO. 3996																							
SEPT. 11	29 LARAMIE-RAWLINS 58 RAWLINS-ROCK SPRINGS 56 ROCK SPRINGS-GREEN RIVER		22	7	2305 LARAMIE-RAWLINS 2921 RAWLINS-ROCK SPRINGS 2844 ROCK SPRINGS-GREEN RIVER	660.07	14	5	8	15	5	50	302961	55232	459.0	83.7	43.0						
13	58		1	6	3187	799.94	6	34	0	50	5	44	295740	52888	369.7	66.1	43.8						
16	67		5	8	3685	924.94	8	52	2	1	6	51	365211	71624	394.8	77.4	36.6						
18	57		1	12	2911	705.56	9	45	3	4	6	41	354865	72400	503.0	102.6	37.6						
22	92 LARAMIE-ROCK SPRINGS 94 ROCK SPRINGS-GREEN RIVER		1	7	2634 LARAMIE-ROCK SPRINGS 4524 ROCK SPRINGS-GREEN RIVER	689.30	8	48	2	30	6	18	348676	64872	505.8	94.0	39.8						
24	71		24	8	3453	866.70	8	43	1	36	7	7	339049	55992	391.2	64.6	35.3						
AVERAGE	64.9		4.5	8	3085	774.42	9	28	3	3	6	25	334417	62168	431.8	80.3	39.1						
EASTBOUND - GREEN RIVER TO LARAMIE 251.0 MILES																							
LOCO. 3992																							
AUGUST 10	60		2	9	3500	878.50	11	21	3	27	7	54	416174	88504	473.7	100.7	31.8						
12	69 GREEN RIVER-RAWLINS 77 RAWLINS-LARAMIE		14	7	4194 GREEN RIVER-RAWLINS 2961 RAWLINS-LARAMIE	908.68	13	31	5	26	8	5	472480	89176	520.0	98.1	31.1						
18	78		1	9	3905	980.16	10	21	2	56	7	25	454887	91040	464.1	92.9	33.8						
21	72		2	8	3760	943.76	9	52	1	54	7	58	448929	97408	475.7	103.2	31.5						
23	69		1	6	3508	880.51	12	0	4	9	7	51	476590	97248	541.3	110.4	32.0						
25	60 GREEN RIVER-ROCK SPRINGS 59 ROCK SPRINGS-LARAMIE		1	5	3174 GREEN RIVER-ROCK SPRINGS 3122 ROCK SPRINGS-LARAMIE	784.40	10	1	3	19	6	42	393502	80320	501.7	102.4	37.5						
AVERAGE	68.6		2.5	7.3	3570	896.00	11	11	3	32	7	39	443760	90616	495.3	101.1	32.8						
LOCO. 3996																							
SEPT. 12	75		1	4	3743	939.49	8	10	1	20	6	50	398997	81992	424.7	87.3	36.7						
14	65		1	5	3376	847.38	7	53	1	50	6	3	366820	69624	432.9	82.2	41.5						
16	50		25	5	3949	991.20	9	17	1	59	7	18	459501	97984	463.6	98.9	34.4						
19	63		1	7	3003	753.75	7	44	1	28	6	16	382566	72624	507.6	96.4	40.1						
23	71		5	5	4247	1066.00	9	30	2	50	6	40	412945	87824	387.4	82.4	37.6						
25	44 GREEN RIVER-RAWLINS 47 RAWLINS-LARAMIE		29	5	3068 GREEN RIVER-RAWLINS 3205 RAWLINS-LARAMIE	786.07	10	26	3	23	7	3	454976	89760	578.8	114.2	35.6						
AVERAGE	61.6		10.3	5.2	3575	897.32	8	50	2	8	6	42	412801	83301	460.0	92.8	37.5						

TABLE II

DATE 1948	TANK WATER TOTAL POUNDS	EXHAUST STEAM INJECTOR CONDENSATE POUNDS	BLOW DOWN POUNDS	FUEL - WATER - EVAPORATION				POUNDS OF COAL FIRED PER HOUR RUNNING TIME	
				TOTAL POUNDS WATER EVAPORATED BY BOILER		COAL FIRED TOTAL POUNDS	POUNDS WATER EVAPORATED PER POUND OF COAL FIRED ACTUAL		
				ACTUAL	ADJUSTED FOR BLOW DOWN				
WESTBOUND LARAMIE TO GREEN RIVER - 251.0 MILES									
LOCO. 3992									
AUGUST 9	295613	14675	2070	308218	308791	53872	5.72	6.8333 7884	
11	300603	15622	13731	302494	306291	52496	5.76	6.4833 8097	
17	346308	18689	2645	362352	363071	62040	5.84	7.1667 8657	
20	370803	19460	12328	377935	381297	74136	5.10	7.0500 10516	
22	377212	21402	4393	394221	395411	78744	5.01	7.2167 10911	
24	315092	19923	1242	333773	334105	60128	5.55	6.3167 9519	
AVERAGE	334272	18295	6068	346499	348161	63569	5.45	6.8445 9288	
LOCO. 3996									
SEPT. 11	302961	12233	6808	308386	310313	55232	5.58	5.8333 9468	
13	295740	17070	4623	308187	309443	52888	5.83	5.7333 9225	
16	365211	18985	2553	381643	382353	71624	5.33	6.8500 10456	
18	354865	15201	4876	365190	366554	72400	5.04	6.6833 10833	
22	348676	19744	6348	362072	363822	64872	5.58	6.3000 10297	
24	339049	20944	5497	354496	355997	55992	6.33	7.1167 7868	
AVERAGE	334417	17363	5118	346662	348080	62168	5.58	6.4194 9684	
EASTBOUND GREEN RIVER TO LARAMIE - 251.0 MILES									
LOCO. 3992									
AUGUST 10	416174	15332	11730	419776	422912	88504	4.74	7.9000 11203	
12	472480	33518	27002	478996	485997	89176	5.37	8.0833 11032	
18	454887	32402	6877	480412	482204	91040	5.28	7.4167 12275	
21	448929	28144	4048	473025	474108	97408	4.86	7.9667 12227	
23	476590	35362	4002	507950	508992	97248	5.22	7.8333 12415	
25	393502	27258	4462	416298	417481	80320	5.18	6.7000 11988	
AVERAGE	443760	30190	9687	464263	465282	90616	5.12	7.6500 11845	
LOCO. 3996									
SEPT. 12	398997	23729	4324	418402	419579	81992	5.10	6.8333 11999	
14	366820	21644	5244	383220	384643	69624	5.50	6.0500 11508	
16	459501	32273	12236	479438	482684	97984	4.89	7.3000 13422	
19	382566	20951	2139	401378	401969	72624	5.53	6.2667 11589	
23	412945	31620	0	444565	444565	87824	5.06	6.6667 13174	
25	454976	29493	6302	478167	479860	89760	5.33	7.0500 12732	
AVERAGE	412801	26618	5041	434195	435550	83301	5.21	6.6945 12443	

TABLE III

AVERAGE PRESSURES AND TEMPERATURES

DATE 1948	PRESSURE - POUNDS PER SQUARE INCH GAUGE					TEMPERATURE - DEGREES FAHRENHEIT									
	BOILER	VALVE CHAMBER	EXHAUST STAND	EXHAUST IN INJECTOR	INJECTOR LIVE STEAM NOZZLE	TANK WATER	DELIVERY WATER	STEAM TO CYLINDERS RIGHT	STEAM TO CYLINDERS LEFT	EXHAUST STEAM RIGHT BACK	EXHAUST STEAM LEFT BACK	EXHAUST STEAM FRONT ENGINE	SMOKE BOX GASES RIGHT	SMOKE BOX GASES LEFT	
WESTBOUND LARAMIE TO GREEN RIVER - 251.0 MILES															
LOCO. 3992															
AUGUST 9	271.3	231.3	10.1	8.4	259.3	64.8	246.6	671.4	674.9	294.3	293.5	265.7	661.1	663.3	
11	273.1	239.3	9.2	7.7	259.7	64.2	247.9	653.6	662.8	287.0	289.1	259.0	655.9	655.8	
17	273.1	235.5	11.0	9.3	259.6	68.0	244.7	661.3	671.3	298.6	297.2	273.4	664.5	675.0	
20	264.6	234.6	9.7	7.2	251.8	63.8	234.7	679.1	684.0	296.2	296.4	270.3	675.5	684.1	
22	267.2	231.1	10.1	8.0	252.6	63.7	235.2	664.7	680.9	301.7	304.0	285.4	675.5	681.7	
24	269.1	217.8	9.6	8.2	255.9	63.6	241.0	650.6	658.2	288.9	292.1	261.3	662.7	674.9	
AVERAGE	269.7	231.6	10.0	8.1	256.5	64.7	241.7	663.5	672.0	294.5	295.4	269.2	665.9	672.5	
LOCO. 3996															
SEPT. 11	276.9	200.8	6.8	5.1	261.6	65.7	213.2	719.6	721.0	322.1	321.8	303.3	698.9	711.9	
13	277.7	234.5	7.3	5.0	264.1	65.4	228.8	717.9	713.2	324.5	304.3	287.2	708.9	701.1	
16	276.9	248.8	7.9	5.9	267.0	62.9	224.8	681.0	705.6	300.9	292.6	275.1	687.9	719.0	
18	289.9	243.9	7.6	4.8	260.2	66.0	220.9	683.5	702.3	292.1	278.9	263.2	680.1	703.2	
22	278.3	249.6	7.6	5.2	268.0	61.7	237.7	704.4	719.3	306.8	290.2	278.4	715.9	727.6	
24	277.1	253.7	6.8	4.8	267.3	59.3	239.1	707.9	708.4	313.9	289.3	273.5	696.2	704.8	
AVERAGE	276.1	238.6	7.3	5.1	264.7	63.5	227.4	702.2	711.6	310.1	296.2	280.1	698.0	711.3	
EASTBOUND GREEN RIVER TO LARAMIE - 251.0 MILES															
LOCO. 3992															
AUGUST 10	266.5	246.8	12.5	10.9	252.2	66.4	240.8	672.7	682.5	305.3	307.2	291.8	673.9	682.5	
12	265.5	246.0	10.0	9.2	252.6	65.7	251.6	682.7	686.6	304.4	308.2	285.0	686.4	690.0	
18	268.4	251.7	11.9	11.0	255.6	64.3	248.3	679.4	683.3	310.7	314.6	295.5	679.7	700.9	
21	269.6	246.9	10.3	8.9	255.8	63.5	241.3	679.3	683.6	307.8	313.6	288.9	679.0	698.3	
23	271.2	233.7	10.1	9.2	258.7	62.7	251.6	665.8	665.0	307.2	314.6	292.5	667.6	686.5	
25	269.3	233.9	10.6	9.4	256.7	59.7	246.3	687.8	686.7	315.7	317.8	294.6	686.6	690.4	
AVERAGE	268.4	243.2	10.9	9.8	255.3	63.7	246.7	678.0	681.3	308.5	312.7	291.4	678.9	691.4	
LOCO. 3996															
SEPT. 12	278.7	265.1	7.3	5.5	265.5	63.3	225.2	726.2	720.4	329.9	304.9	294.3	724.3	715.0	
14	278.5	256.9	7.8	5.9	266.4	65.5	227.2	724.3	708.9	312.2	291.6	284.6	713.7	701.5	
16	279.0	263.7	7.5	6.1	270.3	61.8	225.3	727.4	716.1	328.0	309.0	298.6	713.6	728.2	
19	277.6	258.3	8.1	5.9	268.1	61.9	229.4	716.1	698.5	312.4	285.2	281.5	728.6	703.6	
23	277.4	254.8	8.0	6.7	267.7	61.4	232.1	736.8	725.0	332.8	313.1	307.6	732.9	744.8	
25	275.4	261.8	8.3	6.4	265.1	60.8	238.4	725.1	715.7	329.5	304.7	295.3	716.8	728.5	
AVERAGE	277.8	260.1	7.8	6.1	267.2	62.5	229.6	726.0	714.1	324.1	301.3	293.7	721.7	720.3	

TABLE IV

EVAPORATION AND TEMPERATURE RISE DUE TO EXHAUST STEAM CONDENSED BY EXHAUST STEAM INJECTOR

DATE 1948	RUNNING TIME HOURS	POUNDS OF TANK WATER FED TO BOILER			CONDENSATE RETURN POUNDS	TOTAL POUNDS OF WATER EVAPORATED BY BOILER ACTUAL	TEMP. RISE DUE TO EXHAUST STEAM DEGREES F.	PERCENT RETURN	MILLIONS OF BTUS ABSORBED BY EVAPORATIVE HEATING SURFACE	
		EXHAUST STEAM OPERATION	LIVE STEAM OPERATION	RIGHT INJECTOR						
WESTBOUND LARAMIE TO GREEN RIVER - 251.0 MILES										
Loco. 3992										
AUGUST 9	6.8333	193040	102573	0	295613	14675	308218	47.3	4.73	344.04
11	6.4833	206275	94328	0	300603	15622	302494	49.1	4.94	340.90
17	7.1667	246569	99739	0	346308	18689	362352	52.0	5.12	402.25
20	7.0500	264782	105058	963	370803	19460	377935	51.0	4.99	423.71
22	7.2167	284580	92632	0	377212	21402	394221	55.5	5.37	437.68
24	6.3167	247016	67049	1027	315092	19923	333773	61.8	5.95	367.78
AVERAGE	6.8445	240210	93563	332	334272	18295	346499	52.8	5.18	386.06
Loco. 3996										
SEPT. 11	5.8333	236196	66123	642	302961	12233	308386	38.9	3.88	348.12
13	5.7333	241854	53886	0	295740	17070	308187	57.4	5.46	341.52
16	6.8500	292227	72984	0	365211	18985	381643	50.7	4.94	413.78
18	6.6833	235315	119550	0	354865	15201	365190	41.0	4.11	410.28
22	6.3000	262146	86530	0	348676	19744	362072	55.5	5.36	403.59
24	7.1167	242323	96726	0	339049	20944	354496	61.2	5.82	393.71
AVERAGE	6.4194	251677	82633	107	334417	17363	346662	50.8	4.93	385.17
EASTBOUND GREEN RIVER TO LARAMIE - 251.0 MILES										
Loco. 3992										
AUGUST 10	7.9000	250433	165741	0	416174	15332	419776	33.9	3.55	465.41
12	8.0833	360319	111198	963	472480	33518	478996	70.1	6.62	529.88
18	7.4167	347088	106943	856	454887	32402	480412	70.9	6.65	526.04
21	7.9667	358151	90778	0	448929	28144	473025	61.9	5.90	521.90
23	7.8333	385261	82255	9074	476590	35362	507950	73.9	6.91	554.60
25	6.7000	312396	81106	0	393502	27258	416298	69.1	6.48	458.14
AVERAGE	7.6500	335608	106337	1816	443760	28669	462743	63.3	6.02	509.33
Loco. 3996										
SEPT. 12	6.8333	348205	50792	0	398997	23729	418402	59.3	5.61	463.17
14	6.0500	321246	46574	0	366820	21644	383220	58.3	5.57	425.71
16	7.3000	386317	64795	8389	459501	32273	479438	71.3	6.56	527.77
19	6.2667	308018	74548	0	382566	20951	401378	53.7	5.19	446.55
23	6.6667	339633	73312	0	412945	31620	444565	77.1	7.11	483.69
25	7.0500	357175	91937	5864	454976	29493	478167	64.9	6.09	528.90
AVERAGE	6.6945	343432	66993	2376	412801	26618	434195	64.1	6.02	479.30

TABLE V

ELESCO EXHAUST STEAM INJECTOR PERFORMANCE

DATE 1948	HOURS INJECTOR OPERATED		TANK WATER DELIVERED TO BOILER			RUNNING TIME HOURS	TEMP., DEGREES F. DELIVERED TO BOILER	ON EXHAUST STEAM WATER	POUNDS LIVE STEAM USED BY INJECTOR		POUNDS LIVE STEAM USED BY PUMP	POUNDS EXHAUST STEAM CONDENSED	TOTAL POUNDS WATER FED TO BOILER	COND. RETURN % TOTAL WATER FED TO BOILER	NET TEMP. RISE DUE TO EXHAUST STEAM COND.	% COND. RETURN EXHAUST STEAM COND.	TEMP. RISE DUE TO EX- HAUST STEAM COND. EXH. OPERATION	
	EXHAUST STEAM	LIVE STEAM	EXHAUST STEAM OPERATION	LIVE STEAM OPERATION	RIGHT INJECTOR TOTAL				POUNDS LIVE STEAM USED BY INJECTOR	POUNDS LIVE STEAM USED BY PUMP								
									POUNDS LIVE STEAM USED BY INJECTOR	POUNDS LIVE STEAM USED BY PUMP								
WESTBOUND LARAMIE TO GREEN RIVER - 251.0 MILES																		
LOCO. 3992																		
AUGUST 9	3.4464	1.9853	193040	102573	0	295613	6.8333	246.6	64.8	21323	1907	14675	310288	4.73	47.3	7.06	74.5	
11	3.7667	2.2797	206275	94928	0	300603	6.4833	247.9	64.2	23338	2071	15622	316225	4.94	49.1	7.37	77.6	
17	4.1769	1.9019	246569	99739	0	346308	7.1667	244.7	68.0	25868	2163	18689	364997	5.12	52.0	7.05	74.5	
20	4.3828	1.6617	264782	105058	963	370803	7.0500	234.7	63.8	26376	2200	19460	390263	4.99	51.0	6.85	72.4	
22	4.6336	1.6956	284580	92632	0	377212	7.2167	235.2	63.7	27968	2286	21402	398614	5.37	55.5	6.99	74.6	
24	4.0072	1.2278	247016	67049	1027	315092	6.3167	241.0	63.6	24851	1909	19923	335015	5.95	61.8	7.46	79.4	
AVERAGE	4.0789	1.7920	240210	93563	332	334272	6.8445	241.7	64.7	24954	2089	18295	352567	5.18	52.8	7.13	75.5	
LOCO. 3996																		
SEPT. 11	3.5517	1.1208	236196	66123	642	302961	5.8333	213.2	65.7	22109	1726	12233	315194	3.88	38.9	4.92	51.3	
13	3.5708	0.9222	241854	53886	0	295740	5.7333	228.8	65.4	22478	1668	17070	312810	5.46	57.4	6.59	70.9	
16	4.4675	1.2928	292227	72984	0	365211	6.8500	224.8	62.9	28413	2116	18985	384196	4.94	50.7	6.10	64.4	
18	3.4258	1.8411	235315	119550	0	354865	6.6833	220.9	66.0	21264	1964	15201	370066	4.11	41.0	6.07	63.7	
22	4.2403	1.5050	262146	86530	0	348676	6.3000	237.7	61.7	27062	2086	19744	368420	5.36	55.5	7.00	74.7	
24	3.6647	1.6392	242323	96726	0	339049	7.1167	239.1	59.3	23333	1953	20944	359993	5.82	61.2	7.96	86.3	
AVERAGE	3.8201	1.3869	251677	82633	107	334417	6.4194	227.4	63.5	24110	1919	17363	351780	4.93	50.8	6.44	68.6	
EASTBOUND GREEN RIVER TO LARAMIE - 251.0 MILES																		
LOCO. 3992																		
AUGUST 10	4.8219	2.7550	250433	165741	0	416174	7.9000	240.8	66.4	29062	2663	15332	431506	3.55	33.9	5.77	59.3	
12	5.8664	2.0131	360319	111198	963	472480	8.0833	251.6	65.7	35410	2850	33518	505998	6.62	70.1	8.51	92.2	
18	5.3975	1.7731	347088	106943	856	454887	7.4167	248.3	64.3	32946	2634	32402	487289	6.65	70.9	8.54	93.9	
21	5.9900	1.4267	358151	90778	0	448929	7.9667	241.3	63.5	36587	2691	28144	477073	5.90	61.9	7.29	78.0	
23	6.3797	1.3217	385261	82255	9074	476590	7.8333	251.6	62.7	39382	2796	35362	511952	6.91	73.9	8.41	91.3	
25	5.2586	1.3344	312396	81106	0	393502	6.7000	246.3	59.7	32225	2347	27258	420760	6.48	69.1	8.03	87.2	
AVERAGE	5.6190	1.7707	335662	106283	1816	443760	7.6500	246.7	63.7	34269	2664	28669	472430	6.02	63.3	7.76	83.7	
LOCO. 3996																		
SEPT. 12	5.1461	0.7969	348205	50792	0	398997	6.8333	225.2	63.3	32554	2219	23729	422726	5.61	59.3	6.38	68.3	
14	4.8000	0.7336	321246	46574	0	366820	6.0500	227.2	65.5	30461	2059	21644	388464	5.57	58.3	6.31	66.9	
16	4.7711	0.9831	386317	64795	8389	459501	7.3000	225.3	61.8	30697	2243	32273	491774	6.56	71.3	7.71	84.8	
19	4.8383	1.2408	308018	74548	0	382566	6.2667	229.4	61.9	30888	2229	20951	403517	5.19	53.7	6.37	67.5	
23	4.1550	1.1081	339633	73312	0	412945	6.6667	232.1	61.4	26488	2327	31620	444565	7.11	77.1	8.52	94.8	
25	5.4900	1.3444	357175	91937	5864	454976	7.0500	238.4	60.8	34680	2536	29493	484469	6.09	64.9	7.63	82.9	
AVERAGE	4.8667	1.0345	343432	66993	2376	412801	6.6945	229.6	62.5	30961	2269	26618	439253	6.02	64.0	7.15	77.5	

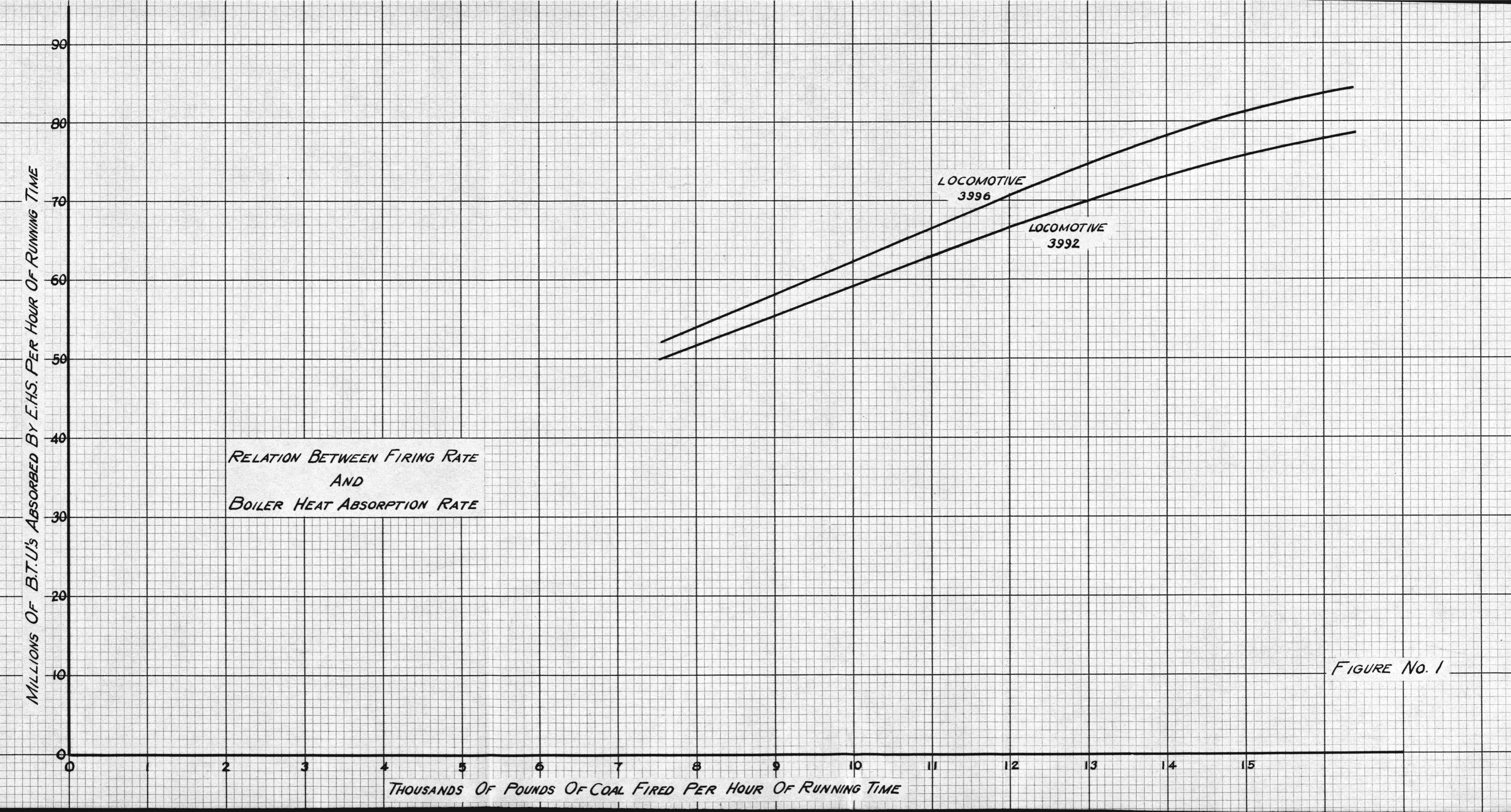
TABLE VI

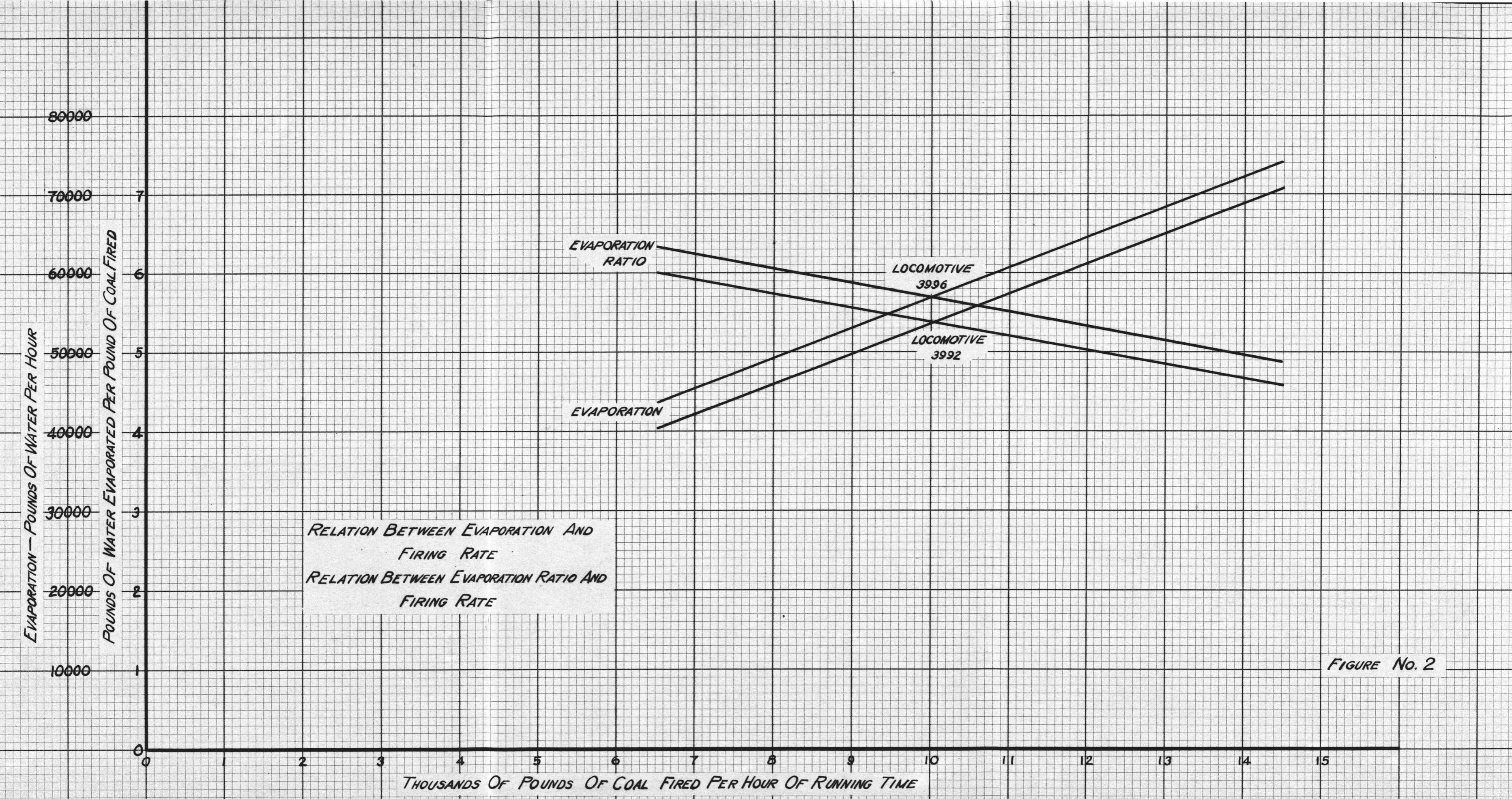
FUEL SAVED BY OPERATION OF ELESCO EXHAUST STEAM INJECTOR

DATE 1948	BOILER PRESSURE POUNDS PER SQ. IN. GAUGE	TANK WATER TEMPERATURE DEGREES F.	NET TEMP. RISE DUE TO EXHAUST STEAM CONDENSED DEGREES F.	WATER ACTUALLY EVAPORATED BY BOILER TOTAL POUNDS	RUNNING TIME HOURS	MILLIONS OF BTUS ABSORBED BY EVAP. HEATING SURFACE PER HR. IF FED BY LIVE STEAM INJECTOR	COAL PER HOUR FROM FIRING RATE HEAT ABSORPTION CURVE		COAL RATE DIFFERENCE POUNDS PER HOUR	POUNDS COAL SAVED PER TRIP BY EXHAUST STEAM INJECTOR								
							EXHAUST STEAM OPERATION	IF FED BY LIVE STEAM INJECTOR										
WESTBOUND LARAMIE TO GREEN RIVER - 251.0 MILES																		
LOCO. 3992																		
AUGUST 9	271.3	64.8	47.3	308218	6.8333	50.35	52.50	7618	8189	571								
11	273.1	64.2	49.1	302494	6.4833	52.58	54.98	8211	8859	648								
17	273.1	68.0	52.0	362352	7.1667	56.13	58.79	9170	9889	719								
20	264.6	63.8	51.0	377935	7.0500	60.10	62.37	10243	10857	614								
22	267.2	63.7	55.5	394221	7.2167	60.65	63.60	10392	11194	802								
24	269.1	63.6	61.8	333773	6.3167	58.22	61.50	9735	10622	887								
AVERAGE	269.7	64.7	52.8	346499	6.8445	56.34	58.96	9228	9935	707								
LOCO. 3996																		
SEPT. 11	276.9	65.7	38.9	308386	5.8333	59.68	61.78	9352	9852	500								
13	277.7	65.4	57.4	308187	5.7333	59.57	62.70	9326	10078	745								
16	276.9	62.9	50.7	381643	6.8500	60.41	64.87	9524	10588	1064								
18	269.9	66.0	41.0	365190	6.6833	61.39	63.65	9760	10298	538								
22	278.3	61.7	55.5	362072	6.3000	64.06	67.31	10395	11173	778								
24	277.1	59.3	61.2	354496	7.1167	55.32	58.42	8314	9052	738								
AVERAGE	276.1	63.5	50.8	346652	6.4194	60.07	63.12	9445	10172	727								
EASTBOUND GREEN RIVER TO LARAMIE - 251.0 MILES																		
LOCO. 3992																		
AUGUST 10	266.5	66.4	33.9	419776	7.9000	58.91	62.09	9922	10781	859								
12	265.5	65.7	70.1	478996	8.0833	65.55	69.94	11736	13000	1264								
18	268.4	64.3	70.9	480412	7.4167	70.93	75.59	13302	14735	1433								
21	269.6	63.5	61.9	473025	7.9667	65.51	69.22	11725	12788	1063								
23	271.2	62.7	73.9	507950	7.9333	70.80	75.64	13262	14751	1489								
25	269.3	59.7	69.1	416298	6.7000	68.38	72.72	12545	13852	1307								
AVERAGE	268.4	63.7	63.3	464263	7.6500	66.68	70.87	12082	13318	1236								
LOCO. 3996																		
SEPT. 12	278.7	63.3	59.3	418402	6.8333	67.78	71.45	11288	12197	909								
14	278.5	65.5	58.3	383220	6.0500	70.37	73.85	11920	12829	909								
16	279.0	61.8	71.3	479438	7.3000	72.30	77.10	12421	13703	1282								
19	277.6	61.9	53.7	401378	6.2667	71.26	74.72	12411	13086	675								
23	277.4	61.4	77.1	444565	6.6667	72.55	77.69	12487	13862	1375								
25	275.4	60.8	64.9	478167	7.0500	75.02	79.49	13141	14369	1228								
AVERAGE	277.8	62.5	64.1	434195	6.6945	71.55	75.72	12278	13341	1063								

TABLE VIII

DATE 1948	AVERAGE WATER RATES AND INDICATED HORSEPOWER												POUNDS INDICATED HORSEPOWER					
	EXHAUST STAND PRESSURE PSI		VALVE CHAMBER PRESSURE PSI		EXHAUST STAND SPECIFIC ENTROPY S		AFTER ADIABATIC EXPANSION FROM P ₁ TO P ₂				LBS. STEAM PER HOUR THROUGH EXHAUST NOZZLE		VELOCITY OF STEAM IN EXH. PIPE VEL. OF STEAM IN EXH. PIPE		CORRECTIONS FOR RAD. & VEL. OF STEAM INDICATED			
	GAUGE P ₁	DEGREES F. T ₁	GAUGE	DEGREES F.	V ₁	H ₁	P ₂ PSI ABSOLUTE	V ₂	H ₂	V ₂	W _y	W _c	H _p	V ₁	BTUS/LB.	STEAM PER HOUR		
WESTBOUND LARAMIE TO GREEN RIVER - 251.0 MILES																		
LOCO. 3992																		
AUGUST 9	10.1	284.5	231.3	673.1	1.7537	18.9	1183.0	13.4	29.0	1139.8	1477.1	59061	63817	1357.3	123.5	1.8845	14.8	4312
11	9.2	278.4	226.3	658.2	1.7544	19.5	1180.2	13.0	30.0	1140.0	1423.1	54751	59369	1349.8	117.0	1.9040	15.2	3911
17	11.0	290.9	235.5	666.3	1.7534	18.4	1185.8	13.9	28.1	1142.8	1473.7	61073	65983	1353.6	124.0	1.8354	15.3	4301
20	9.7	287.6	234.6	681.6	1.7577	19.3	1184.5	13.2	29.9	1137.5	1540.6	59625	64273	1361.5	127.5	1.8936	14.5	4423
22	10.1	297.1	231.1	672.8	1.7617	19.3	1189.0	13.4	29.2	1146.0	1473.9	58532	63195	1357.2	124.6	1.9056	15.3	4130
24	9.6	280.6	217.8	654.5	1.7537	19.2	1181.2	13.1	29.8	1139.5	1451.1	56320	61133	1348.4	119.8	1.9358	15.4	3970
AVERAGE	10.0	286.5	229.4	667.8	1.7558	19.1	1184.0	13.3	29.3	1140.9	1473.3	58227	62962	1354.6	122.7	1.8932	15.1	4175
LOCO. 3996																		
SEPT. 11	6.8	315.7	200.8	720.3	1.7911	23.1	1198.5	13.0	31.7	1164.7	1289.5	55549	58596	1383.2	141.9	2.1227	13.9	4185
13	7.3	305.4	234.5	715.5	1.7818	22.2	1193.5	13.0	31.1	1158.4	1333.6	58594	62976	1379.2	143.9	2.0147	13.9	4531
16	7.9	289.5	248.8	693.3	1.7685	21.1	1185.9	13.0	30.3	1149.4	1359.6	61292	65513	1366.9	143.0	1.9473	14.2	4614
18	7.6	278.0	243.9	692.9	1.7628	21.1	1180.4	13.0	30.0	1146.2	1316.4	59997	64107	1366.9	139.7	1.9626	13.8	4645
22	7.6	291.8	249.6	711.9	1.7716	21.5	1187.1	13.0	30.4	1151.5	1342.9	60320	65133	1377.6	143.2	1.9578	13.5	4825
24	6.8	292.2	253.7	708.2	1.7765	22.4	1187.4	13.0	30.8	1154.8	1285.6	57146	62385	1374.4	141.3	2.0148	13.8	4521
AVERAGE	7.3	295.4	238.6	707.0	1.7754	21.9	1188.8	13.0	30.7	1154.2	1321.3	58816	63118	1374.7	142.2	2.0033	13.9	4554
EASTBOUND GREEN RIVER TO LARAMIE - 251.0 MILES																		
LOCO. 3992																		
AUGUST 10	12.5	301.4	246.8	677.6	1.7531	17.5	1190.6	14.8	26.5	1147.0	1484.2	65750	70018	1353.5	127.4	1.7642	15.8	4434
12	10.0	299.2	246.0	684.7	1.7636	19.4	1190.0	13.3	29.3	1147.0	1473.9	58302	64050	1362.5	125.0	1.8864	14.9	4293
18	11.9	306.9	251.7	681.4	1.7593	18.1	1193.3	14.4	27.4	1150.5	1470.5	62744	68954	1370.4	125.5	1.7770	15.4	4480
21	10.3	303.4	246.9	681.5	1.7647	19.3	1191.9	13.5	29.5	1148.4	1482.3	58367	63232	1360.7	124.3	1.9033	15.3	4146
23	10.1	304.8	233.7	665.4	1.7666	19.5	1192.7	13.4	29.5	1150.2	1465.4	57700	63316	1353.2	124.2	1.9005	16.1	3945
25	10.6	309.4	233.9	687.3	1.7667	19.2	1194.8	13.7	29.0	1151.9	1472.2	59102	64572	1364.4	125.3	1.8750	15.2	4257
AVERAGE	10.9	304.2	243.2	679.7	1.7623	18.8	1192.2	13.9	28.5	1149.2	1474.8	60328	65690	1359.1	125.3	1.8511	15.5	4259
LOCO. 3996																		
SEPT. 12	7.3	309.7	265.1	723.3	1.7845	22.3	1195.6	13.0	31.3	1160.3	1337.3	58418	62638	1381.6	144.3	2.0258	13.8	4529
14	7.8	296.1	256.9	713.8	1.7732	21.4	1189.0	13.0	30.5	1152.6	1357.8	60790	65130	1377.1	143.7	1.9609	13.7	4764
16	7.5	311.9	263.7	721.8	1.7848	22.2	1196.6	13.0	31.3	1160.5	1352.4	59040	64268	1381.0	144.9	1.9882	13.9	4620
19	8.1	293.1	258.3	707.3	1.7697	21.0	1187.6	13.0	30.3	1150.2	1376.1	62077	66554	1373.7	144.0	1.9295	13.8	4816
23	8.0	317.8	254.8	730.9	1.7856	21.8	1199.3	13.0	31.4	1161.0	1387.1	60458	66427	1385.4	145.8	1.9428	13.8	4807
25	8.3	309.8	261.8	720.4	1.7791	21.3	1195.4	13.0	30.9	1156.6	1380.3	61955	67380	1380.3	145.7	1.9207	13.9	4844
AVERAGE	7.8	306.4	260.1	719.6	1.7795	21.7	1193.9	13.0	31.0	1156.9	1365.2	60456	65400	1379.9	144.7	1.9613	13.8	4730





RELATION BETWEEN EXHAUST STAND PRESSURE
AND TEMPERATURE OF STEAM TO ENGINES
AND

RELATION BETWEEN EXHAUST STAND PRESSURE
AND TEMPERATURE OF SMOKE BOX GASES

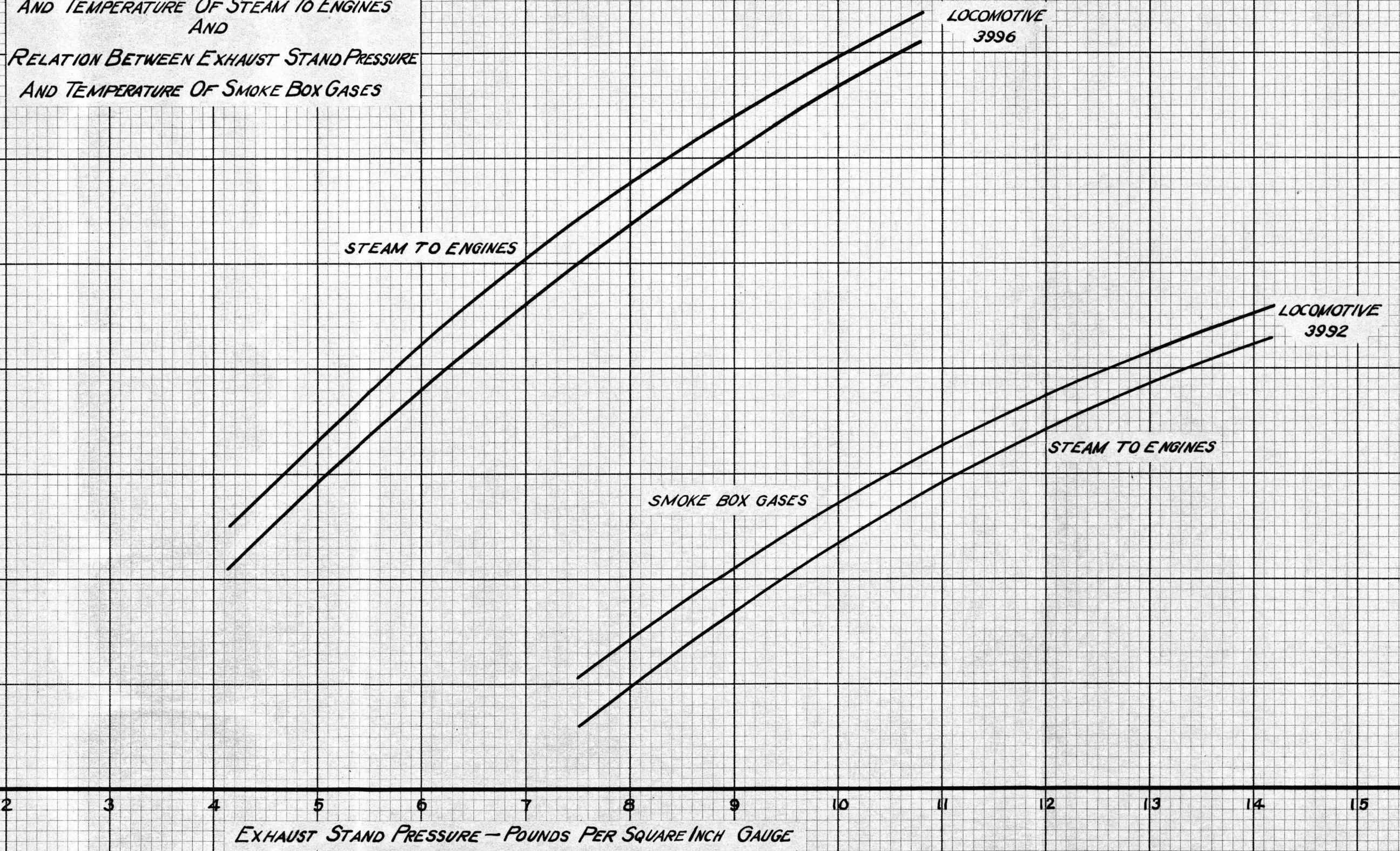
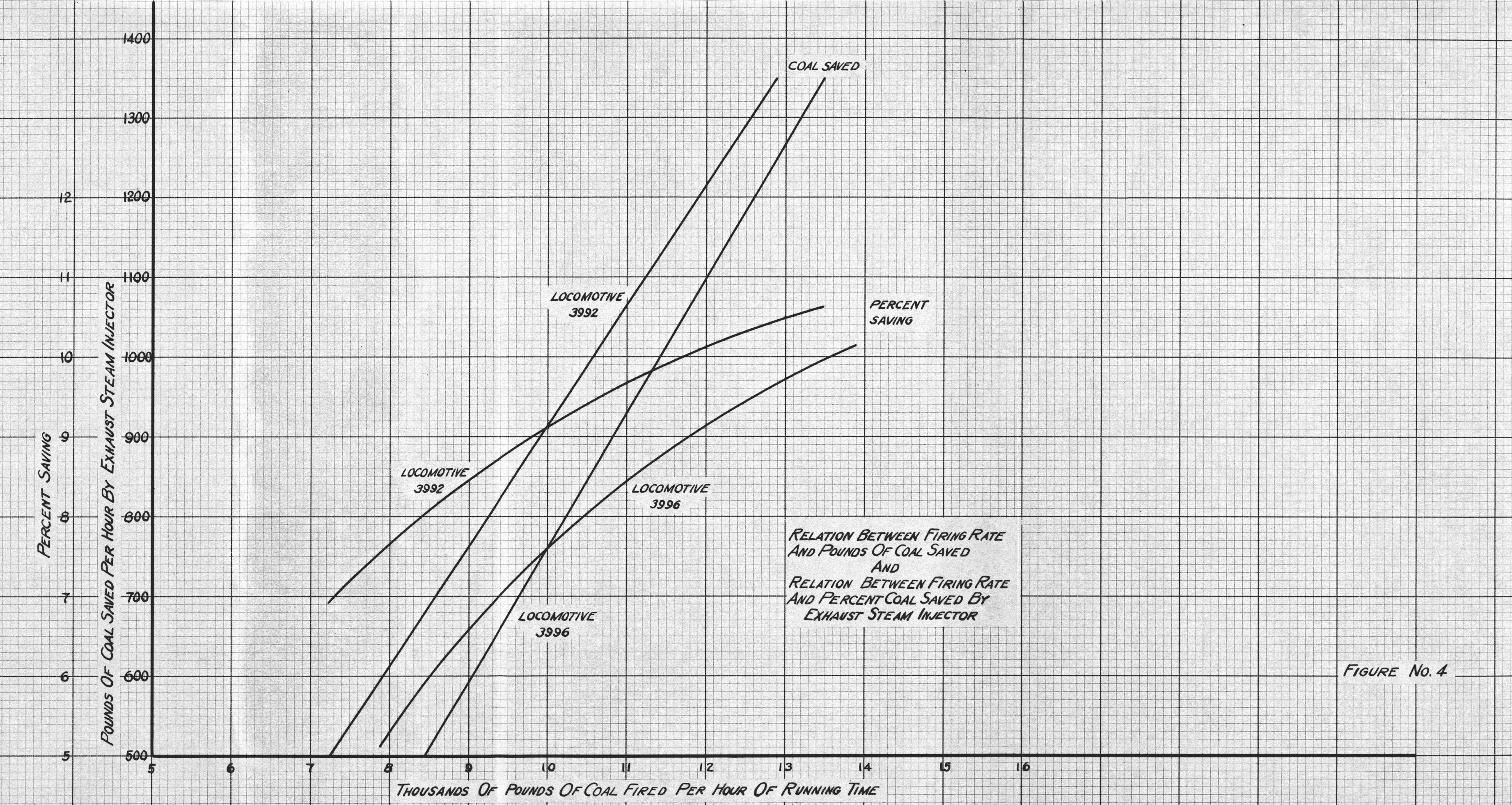
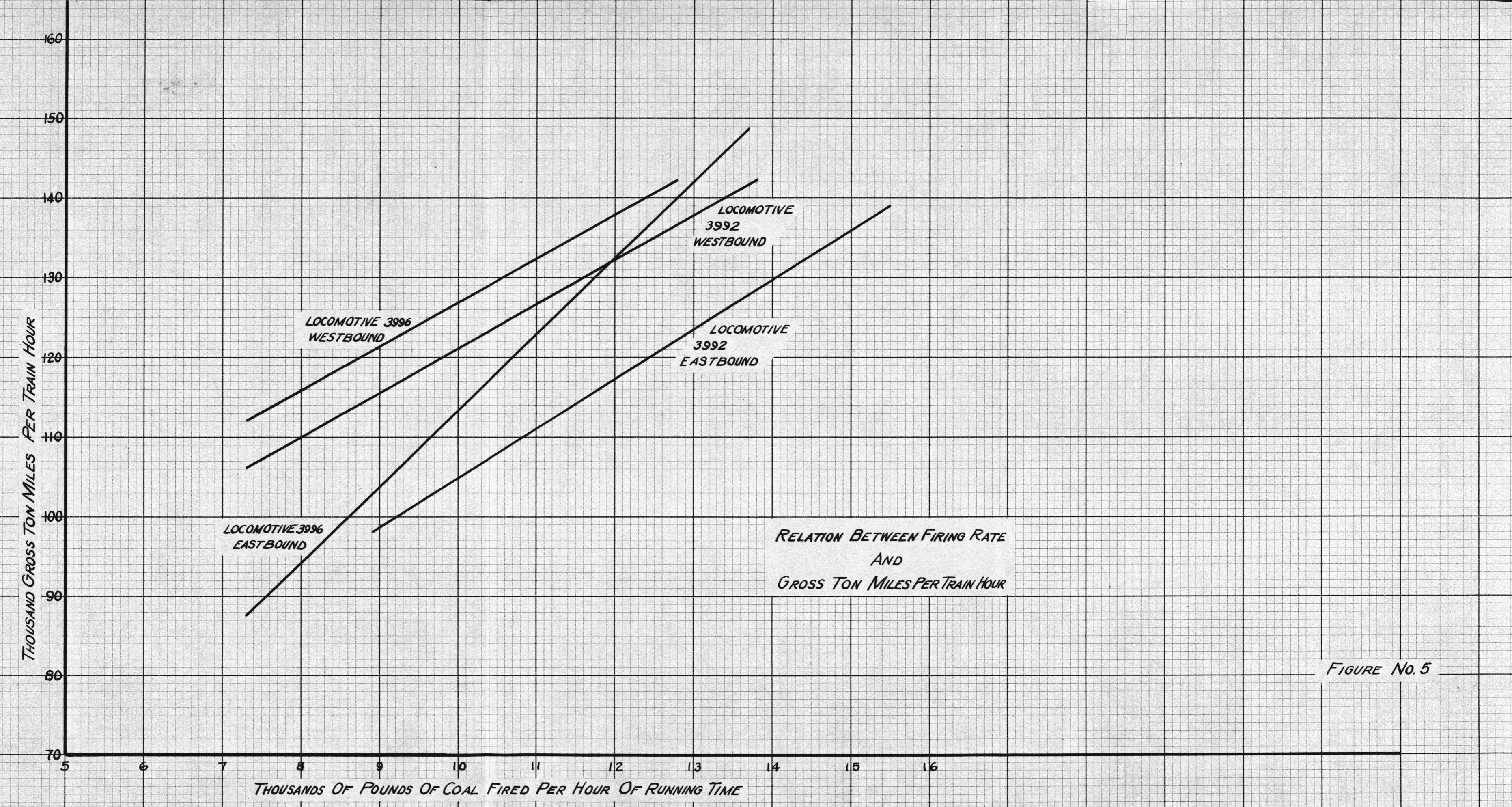
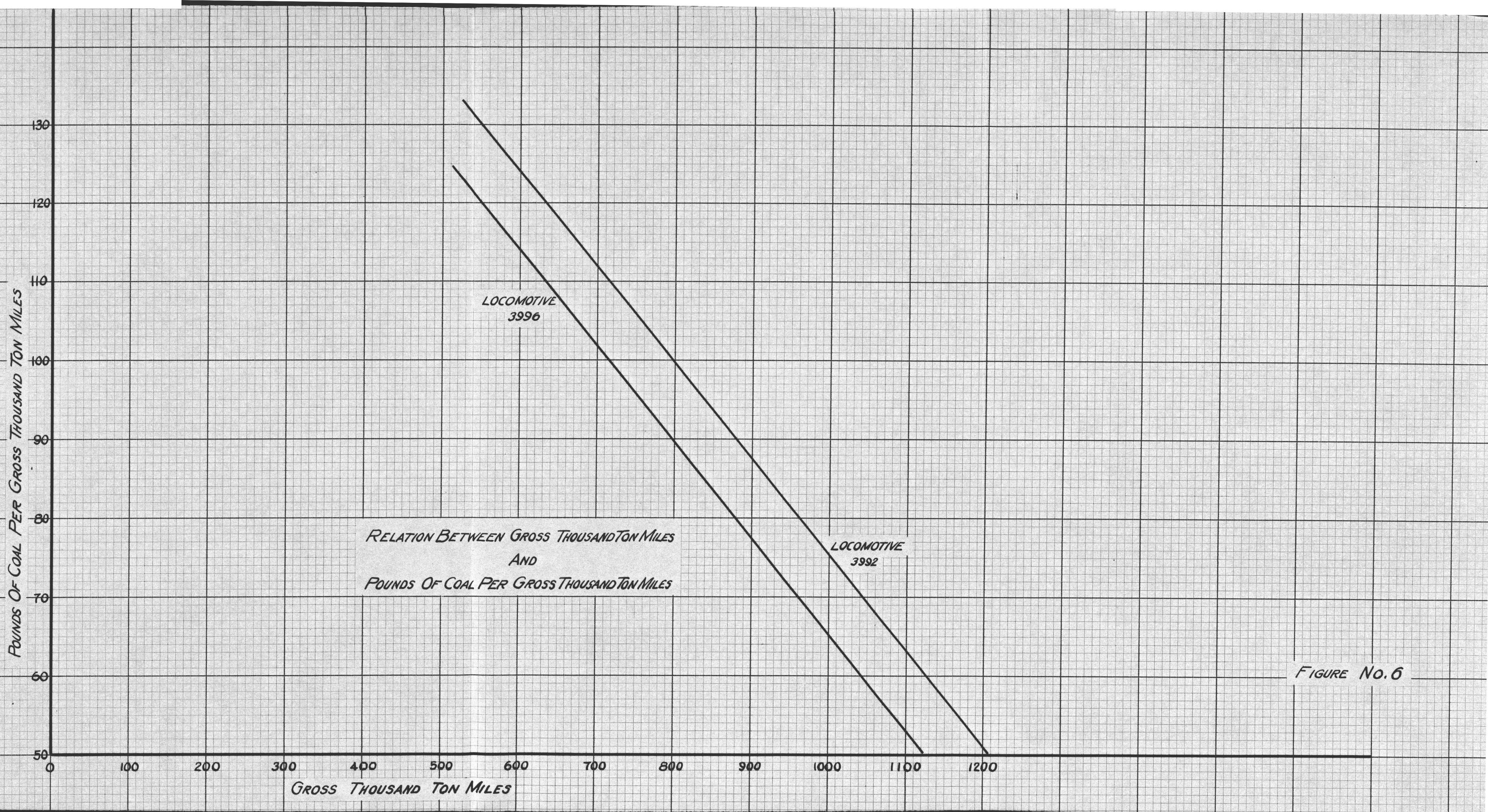
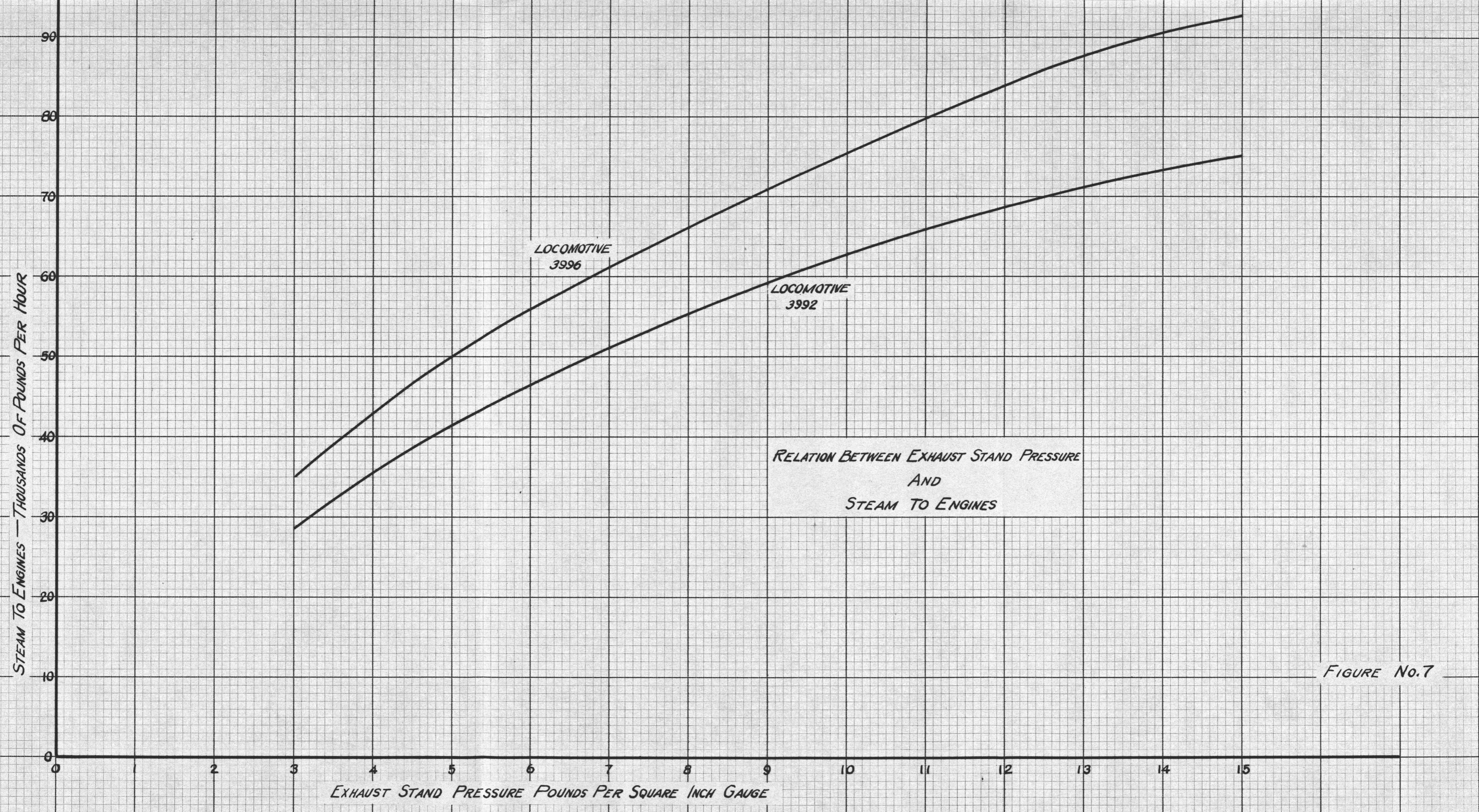


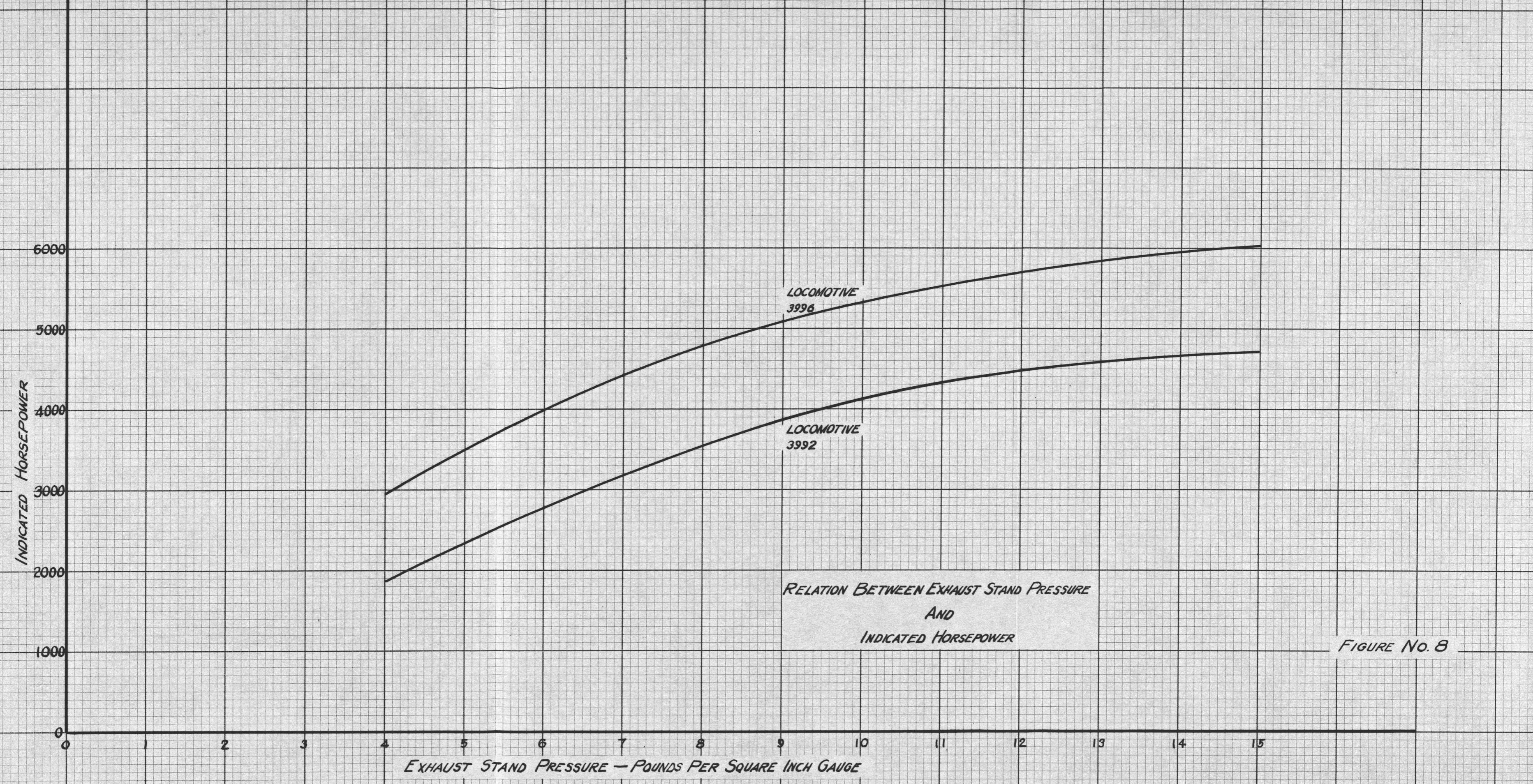
FIGURE NO. 3











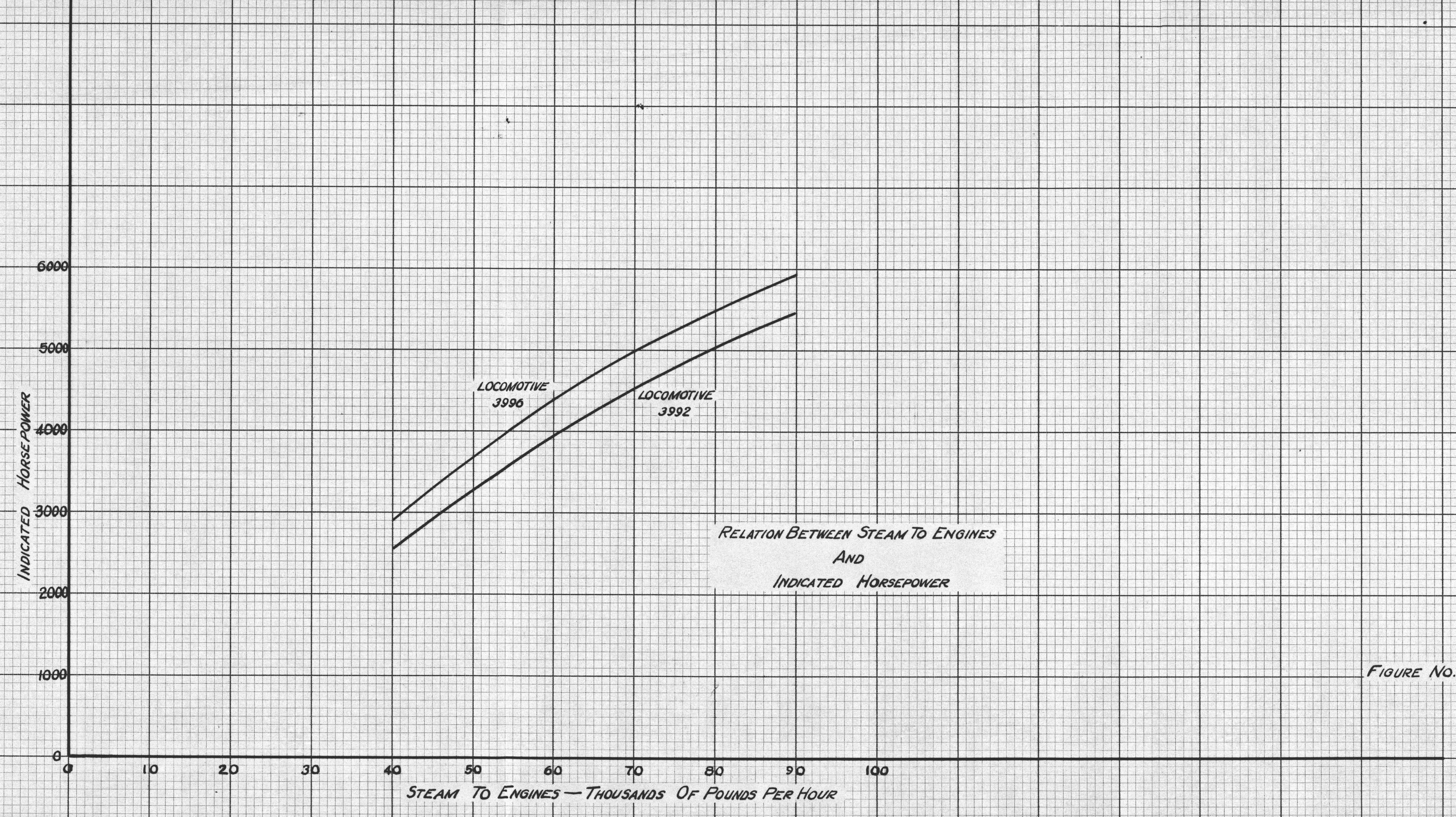


FIGURE NO. 9

Pounds Of Steam Per Indicated Horsepower Hour

17

16

15

14

13

12

11

10

*RELATION BETWEEN INDICATED HORSEPOWER
AND
POUNDS OF STEAM PER INDICATED HORSEPOWER*

INDICATED HORSEPOWER

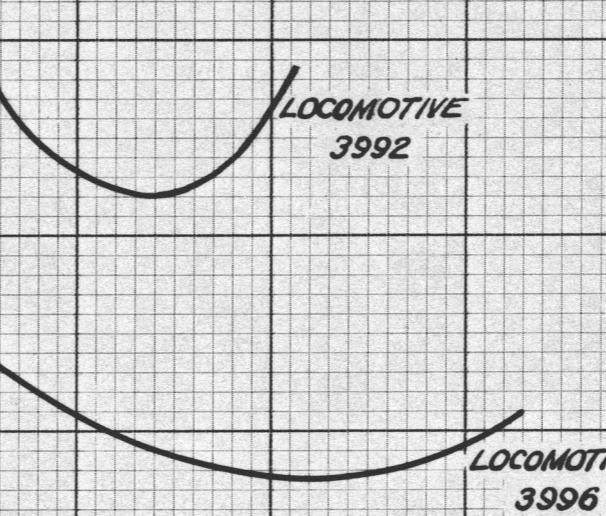


FIGURE NO. 10

