SOUTHERN PACIFIC COMPANY
(PACIFIC LINES)

DYNAMOMETER TEST NO. 7

OF

LOCOMOTIVE NO. 3803

CLASS AC-9

Dated September 5, 1940

SOUTHERN PACIFIC COMPANY
Pacific System

DYNAMOMETER TEST NO. 7

Southern Pacific Locomotive No. 3803, Class AC-9, was put in test service on April 23, 1940, for the purpose of obtaining the operating characteristics of this class of locomotive and to determine if any improvement in combustion could be effected. In addition, the operating characteristics of the feedwater pump system, the injector, and the Valve Pilot, were obtained and improvements made where found advisable.

PHYSICAL DATA

Locomotive 3803 is one of 12 four cylinder articulated locomotives, type 2-8-8-4, Class AC-9. It was built by the Lima Locomotive Works and was put in service in November, 1939.

The locomotive has two 2 cylinder power units articulated under a common boiler. The cylinders and frame of each unit are cast integral, all cylinders using steam at 250 lbs. boiler pressure.

Walschaerts valve motion is used on both power units, the cut off being controlled by a single ALCO power reverse gear. The valves are 11" in diameter, inside admission.

The boiler is of conical, radial stayed, construction, with sloping back sheet, inside dry pipe equipped with a tangential steam drier, type "E" superheater, and an American front end multiple throttle in combination with the superheater header. The firebox is of radial stay design, equipped with grates and hoppers for coal firing and has seven American Arch Brick Company's Security

circulator tubes which also support the brick arch.

The locomotive is equipped with a Hancock Turbo Feedwater Heater and Pump, Type TA2, capacity 13,000 gallons per hour, and a Nathan Non-Lifting Automatic Simplex Injector, Special No. 17, Type 3871, Capacity 13,000 gallons per hour.

All auxiliaries use superheated steam except the turbo-generator, feedwater pump, steam turbine, coal pusher, hydrostatic lubricator, steam heat to the mechanical lubricators, cab heat, power reverse gear emergency steam control, and the injector.

The engine is equipped with a double stack, in tandem, with the front and back cylinders each having a separate exhaust, and the standard "Master Mechanic's" front end arrangement.

The locomotive is equipped with oil lubricated bearings on all axles on engine and tender, using spring pad lubricators developed on our lines. Mechanical lubricators feed oil to all driving box bearings, shoes and wedges. Felt pad inserts are used to lubricate the hub faces on all driving boxes and trailing trucks. Magnus self-cooling oil tube journal bearings, with Satco lining, are used in the engine truck, trailing truck, and tender boxes, the driving boxes having white metal lined crown brasses, and Satco hub faces.

The tender is rectangular, nominally rated at 28 tons of coal and 22,100 gallons of water, Class 22l-R-l, with a Standard type "MB" stoker engine mounted over the frame, and is carried on two 6-wheel Buckeye trucks. Actually, by calibration, it was found that the tender held 21,720 gallons of water and 31 tons of coal, level full.

CONDITION OF LOCOMOTIVE

Locomotive 3803 was originally placed in service in November 1939. At the time it was removed from regular service for test purposes, it had made approximately 25,000 miles and was in good mechanical condition.

During the time the test apparatus was being applied, the mechanical condition of the engine was checked and several minor repairs were made in order to put the engine in good condition. At the same time, the valve gear was checked by "rolling the wheels" and several minor changes were made in order to "square" the valves. The cut off was calibrated for "corner" or maximum stroke, and each five teeth on the reverse gear quadrant out of corner, to and including center, and at 35% and 60% in the back up motion. During the progress of the test it was necessary to replace piston rod packing of the left front and back and the right front cylinders.

DIMENSIONS AND PROPORTIONS

Tractive Power, MEP considered as 85% of boiler pressure	124,300 lbs.
Driving Wheels, No. pairs	8
" " Average Diameter	63.68"
Engine Truck Wheels, 1 pair, Diameter	36"
Trailing Truck Wheels, 2 pair, Diameter	45½"
Driving Wheel Base - Rigid, Front Engine	11'-4"
" " " " Back Engine	11'-4"
" " " Total, Both power units	44'-7"
Wheel Base of Engine	66'-3"
" " " " and Tender	112'-11 7/8"
Length of Engine and Tender, Overall	126'-2 1/8"
Weight on Drivers	531,200 lbs.
" " Engine Truck	48,300 lbs.
" " Trailing Truck	110,400 lbs.
Total Weight of Engine, Loaded	689,900 lbs.
Type of Tender, Class 221-R-1	Rectangular
Capacity of Tender, Water	21,780 gallons
" " " Coal	31 Tons
Weight of Tender, loaded	403,900 lbs.
Cylinder Diameter, front engine, right and left	24.03"
" " back engine " " "	24.028"
Piston Stroke, front and back power units	32"
Piston Rod Diameter	4 3/4"
Piston Valve Diameter	11"
Steam Lap	1-5/16"
Lead	3/16"

DIMENSIONS AND PROPORTIONS

Cylinder Steam Ports	24.1"X 2 3/8"
Valve Travel, forward motion, right and left, front unit	$6\frac{17}{32}$" and $6\frac{9}{16}$"
" " " " " " " back unit	$6\frac{9}{16}$" and $6\frac{9}{16}$"
" " back up " " " " front unit	$6\frac{3}{8}$" and $6\frac{3}{8}$"
" " " " " " " back unit	$6\frac{11}{16}$" and $6\frac{19}{32}$"
Exhaust Clearance	Line and Line
Valve Motion, Type	Walschaerts
Exhaust Nozzles, Nominal, Diameter and type split	7" diagonal split
Size of Split, diamond shape	$\frac{1}{2}$"
Extension Stack, distance above nozzles	15-1/4"
Boiler Pressure	250 lbs. per sq.in.
Tubes, Number and outside diameter	86 - 2-1/4"
Flues " " " "	260 - 3-1/2"
Superheater elements, number and outside diameter	131 - 1-3/16"
Length over tube sheets	22'-0"
Firebox length	205-5/8"
" width	102-1/4"
Total gas area of tubes and flues	6329 sq.ft.
Heating surface of firebox, less circulators	465 " "
" " " 7 circulators	124 " "
" " Total evaporating	6918 " "
" " Superheater elements	2831 " "
" " Combined	9749 " "
Grate, length	15'-1-1/4"
" width	7'-11-1/2"
" Area (less area of inside firing table)	110.5 sq.ft.

LIST OF AUXILIARIES AND SPECIALTIES

Feedwater Pump and Heater	Hancock TA-2
Injector	Nathan Simplex, Type 17 HW
Stoker	Standard Stoker Co. Type MB
Coal Pusher	" " " Type DA
Circulators (seven, 5" dia.)	American Brick Arch Co. Security type
Brick Arch	" " " "
Grates	Waugh Equip.Co's Firebars
Safety Valves, 3.	Consolidated -- 3½"
Tangential Steam Dryer	American Throttle Co.
Reverse Gear	ALCO type H
Air Compressors - 2	Westinghouse, 8½" cross compound
Turbo-generator	Sunbeam - type R-4
Signal Foam Meter	Electro-Chemical Corp. Model GES
Valve Pilot	Loco Valve Pilot Corp. Model VP-100
Superheater	Elesco Superheater Co. type "E"
Tank Level Indicator	Ashcroft-American, type 1189-T
Firedoor - air operated	Franklin R.R. Supply Co. Butterfly type No. 8A
Lubricators - Mechanical-4	Nathan - types DV-4 and DV-7
Drop Plugs -6	Nathan size No. 1

TEST DATA

The Dynamometer chart made a continuous record of drawbar pull, slack action, speed, steam chest pressure, back pressure, brake pipe and brake cylinder pressures, throttle and reverse lever positions, a duplicate of the Valve Pilot tape record, time and distance, and location.

On the locomotive, readings were taken at 10 minute intervals westward and at 5 minute intervals eastward, while the trains was in motion, of the following:

Cab - boiler pressure, back pressure, and cylinder pressure, of the back power unit; stoker engine and jet pressures, pressure of steam entering the feedwater pump steam turbine, feedwater pump suction and discharge temperatures and discharge pressure, speed and cutoff indication of the Valve Pilot, the temperature of the steam to back cylinders, and the throttle and reverse lever positions.

Front end and left running board - temperature and pressure of the steam to, and the exhaust from, the front cylinders, the pressure of the exhaust steam from the back cylinders to the feedwater heater, the vacuum in the smokebox in front of, and in back of, the diaphragm, the temperature of the smoke box gases and the temperature of the feedwater entering the boiler check valve. Readings were taken at 10 minute intervals, in each direction, of the carbon dioxide content of the smoke box gases.

At the beginning of the test, water meters were applied to the feedwater pump and the injector suction lines and these were read at the beginning and end of each run and at each stop of more than five minutes duration. As will be explained later, these meters

were subsequently removed.

The water section of the tender was calibrated and readings were taken, by means of a calibrated stick, at four points in the tender, at the beginning and end of each run and each time water was added to the tender. The temperature of the water in tne tender was taken at the beginning and end of each run and each time the water was gauged.

The coal section of the tender was calibrated with weighed coal for each 3" of height up to level full. An auxiliary coal container of 2 tons capacity was carried on top of the tender for use in emergency. The fuel consumption was measured by leveling the coal at the beginning and end of each run and at each time coal was added to the tender.

Engineers were requested to keep the throttle fully open, as much as possible, controlling speed with the reverse lever, and to regulate the cutoff according to the Valve Pilot, with or without corrections, as will be explained later.

TERRITORY

All test runs were made on the Rio Grande Division, between Tucumcari and Carrizozo, New Mexico. The uphill portion of the test was terminated, in each direction, at Corona. Odd numbered runs were westward, from Tucumcari to Corona, and even numbered runs were eastward, from Carrizozo to Corona.

The average distance of test runs from Tucumcari to Corona was 136.5 miles and from Carrizozo to Corona it was 51.3 miles. The

line is single tracked with a maximum of one per cent grade in each direction, the maximum curvature being four degrees. The track, part of the former EP&SW line from Carrizozo to Santa Rosa and leased from the CRI&P (Rock Island) from Santa Rosa to Tucumcari, is more or less uncompensated for curvature and many of the curves are excessively super elevated for freight train speeds. For a profile of the grades see page 29.

TRAINS

Locomotive 3803 was tested in freight service only. Trains of 101 cars were handled from Tucumcari to Corona, consisting of empty refrigerator cars and a few loads, the Dynamometer Car, and two cabooses, one caboose being permanently equipped with a brake pipe pressure recording instrument. The weight of these trains averaged 6040 Ms. During the first part of the test, when water conditions at Santa Rosa were not favorable, stops for water were made at Santa Rosa, where only a small amount of water was taken, at Pastura, and at Vaughn. Later, when the water treating plant at Santa Rosa was completed, a full tank of water was taken there and the stop at Pastura was eliminated. Coal was taken at Pintado, except in the few instances when train weights were extremely light, and at Vaughn.

From Carrizozo to Corona the trains consisted mostly of loads and an attempt was made to keep the tonnage as close to 7500 Ms as possible. However, due to the variation in the train load departing from El Paso, these trains averaged 6983 Ms. Ordinarily, water was taken at Ancho, but on several occasions when the train weight was

extremely light, water was not taken until arrival at Gallinas, and a few times, not until arrival at Vaughn. Coal was not taken until arriving at Vaughn.

FUEL

Coal burned was obtained from mines at Dawson, New Mexico, and varied considerably in the size of the lumps and the amount of "fines" or finely granulated coal, particularly the latter. Coal was fired by means of a Standard, type "MB" stoker, using the steam jet principle to distribute the coal over the grates. Normally, the grates were shaken only prior to taking water or coal and very little unburned coal was lost in the hoppers. The type of grates used, while allowing ample combustion air to enter, was very effective in retaining the coal and ash in the firebox and there was practically no loss of unburned coal through the grates.

Fuel samples were taken each time coal was added to the tender and composites of these samples were analyzed for heat and ash content, etc. The following is typical of the range of values for the coal used:

BTUs (actual) per lb.	11,220 to 12,629
BTUs dry " "	11,335 to 12,342
Fixed carbon %	41 to 50
Volatile %	38
Moisture %	0.06 to 1.28
Ash %	15 to 22
Wt. per cu.ft. lbs.	53.0 to 55.9

APPARATUS

The apparatus used on this test, excluding the Dynamometer Car, and the calibrated tender, consisted of bourdon tube pressure gauges, calibrated and frequently checked on a dead weight tester, calibrated mercury tube thermometers, and a thermo couple pyrometer. Draft in the smokebox was obtained in front and in back of the diaphragm plate, in inches of glycerine, later converted to inches of water. The carbon dioxide content of the smokebox gases was obtained by means of an absorption device calibrated to read directly in $\%CO_2$.

In the cab, regular cab connections were used for boiler pressure, cylinder and back pressures, cylinder steam temperature, stoker engine and jet pressures, feedwater pump discharge pressure and temperature, and Valve Pilot speed and cutoff indications. A gauge and a thermometer were applied in the cab to indicate the pressure of the steam to the feedwater steam turbine and the temperature of the feedwater pump suction water. The cutoff was obtained in the cab by means of an indicator directly connected to the crosshead of the power reverse gear. The cutoffs were recorded and put on the Dynamometer chart by means of a push button signal. As the normal pressure of the steam to the cylinders was 220 lbs. per sq.in. the throttle position was indicated in quarters or increments of 55 psi and was recorded and put on the Dynamometer chart by push button signal.

On the front end the pressure and temperature of the steam was obtained directly over the left steam chest. Exhaust steam pressure was obtained by connecting all four exhaust portions of the

valve chambers to a common pipe leading to the pressure gauge. The exhaust steam temperature was obtained just below the exhaust stand. Smokebox temperature was obtained by use of a four foot mercury tube pyrometer extending through the front of the smokebox. Smokebox vacuum was obtained from pipes extending through the side of the smokebox, on the horizontal center line of the boiler and extending in to the vertical center plane of the boiler, both in back and in front of the diaphragm plate. The smokebox gas samples were obtained by means of a vacuum pump connected to a pipe which extended into the smokebox and connected to a perforated sampler pipe located in back of the diaphragm and approximately 20" from the floor of the smokebox

On the left running board the temperature of the water from the feedwater pump was obtained at the boiler check by means of a glass tube mercury thermometer. The pressure and temperature of the exhaust steam to the feedwater heater was obtained about 12" from the heater.

Temperature of the water in the tender was obtained at several points in the tender by means of a glass tube mercury thermometer immersed in the water.

CHANGES MADE DURING TEST

Runs 1 to 12 inclusive were made with the engine standard in all respects, with 7" diameter exhaust nozzle tips on the front and back exhaust stand openings, hereafter to be designated as 7x7, the first dimension being that of the front nozzle tip. A 1/2" standard split was used in all cases, placed diagonally and in such a manner

that the diagonals of the square material used were vertical and horizontal. The main supply of water to the boiler was furnished by the feedwater pump.

Due to difficulty in supplying water to the boiler, due in part to the drag of the water meter, the 4" meter in the feedwater suction line was removed at the end of Run No. 4. The 3" meter was removed from the suction line of the injector at the end of Run No. 6

Runs 13 to 20 inclusive and Runs Nos. 24, 25, 31, and 32, were made with 7-1/4x 7" nozzle tips. This change was made in order to more nearly equalize the exhaust pressures of the front and back power units due to the fact that the exhaust steam supplied the feedwater heater is taken from the back unit only. At the end of Run #15 the feedwater pump hot well in the tender was modified in a manner which prevented the hot water, returned by the pump, from circulating in the main body of water in the tender and raising the temperature of that water to a point where neither the pump nor the injector would discharge into the boiler. At the same time the stoker engine exhaust was repiped in such a manner that the piping did not pass through the water in the tender. An automatic overflow control was placed on the injector, the purpose of which was to prevent loss of water through the overflow when the injector was in operation.

Runs Nos. 21, 22, 23, 26, 27, 28 and 29, and 30, were made with the injector supplying all the water to the boiler. The nozzle tips were 7-1/4x 7". No difficulty in supplying sufficient water to the boiler was encountered at any time.

Runs Nos. 33 to 38 inclusive were made with 7-1/2x 7-1/4" nozzle tips and with the feedwater pump in operation. The effective

diameter of the front nozzle was reduced to 7 3/8" as this was the minimum bore of the exhaust stand opening. At the end of Run No. 38 the stoker engine exhaust was changed back to its original piping through the water section in order to determine if this location excessively heated the water in the tender.

Runs Nos. 39 and 40 were made 7-1/4x 7" nozzle tips and with 580 sq.ins. of arch brick removed from between the two circulators nearest the back head of the firebox, the No. 6 and 7, with the opening centrally located on the center line of the firebox.

Runs Nos. 41 to 49 inclusive were made with the arch brick removed as described above and with 7x7" nozzle tips.

In the tabulation of average data it will be noted that certain runs are not included in arriving at an average. The deletion of these runs is caused by data which varies too greatly from the average due to the extreme variation of one or another of the principle variables, particularly the weight of the train and the average cutoff.

-AVERAGED DATA-

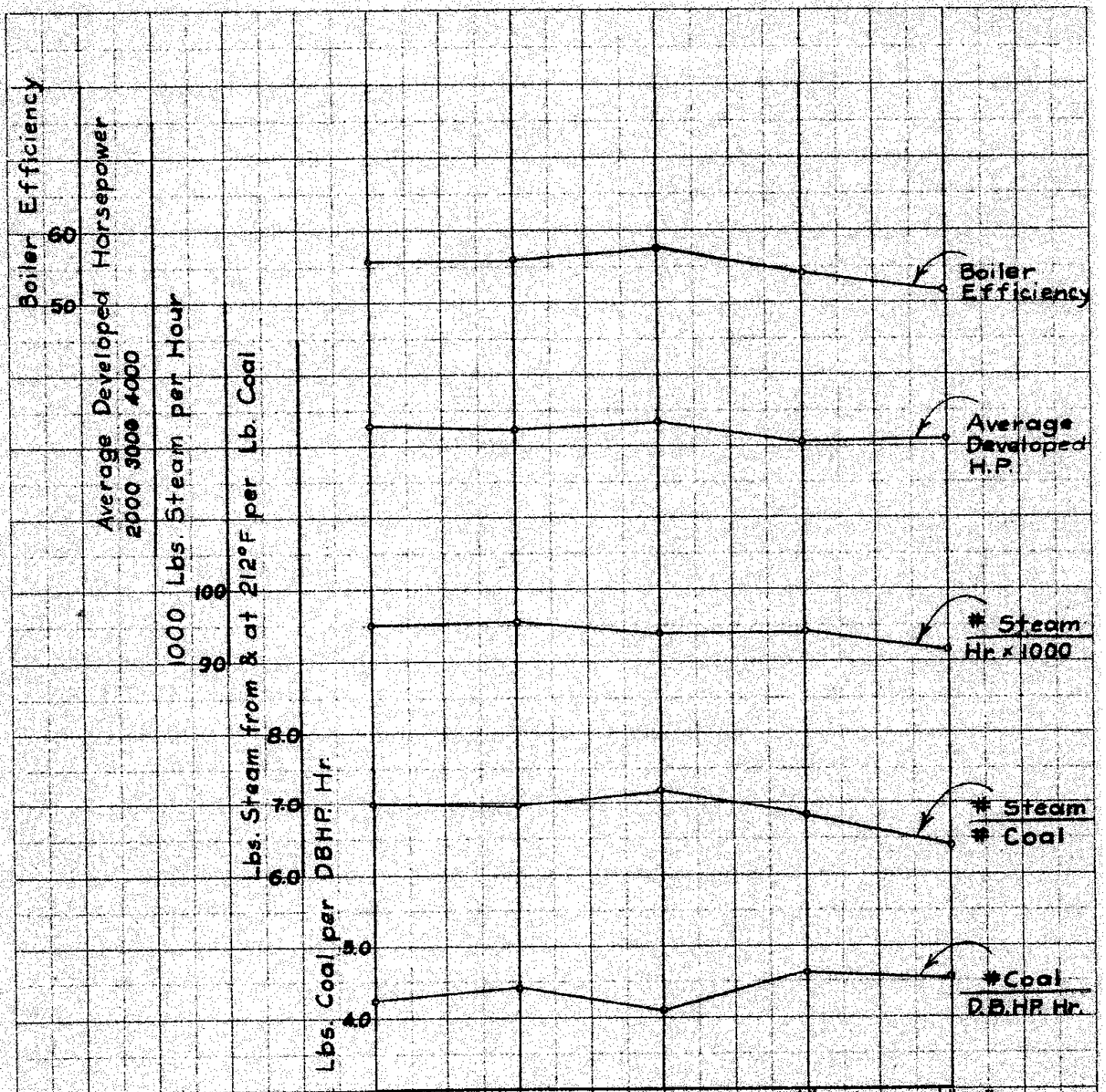
Tucumcari - Corona

	7-3/8" x 7-1/4" Nozzles	7"x7" Nozzles	7"x7' Nozz. 580 Sq.In. Arch Brick Removed	7-1/4"x7" Injector	7-1/4"x7" Nozzles
Test runs used	33,35,37	1,5,7,9 11	41,43,45 47,49	21,23,27 29	13,15,17, 25,31
Total time - hrs.mins.	6-54'	7-22'	6-59'	6-31'	7-40'
Standing time - hrs.mins.	1-44'	1-42'	1-27'	1-13'	1-42'
Running time - hrs.mins.	5-10'	5-40'	5-32'	5-18	5-58'
Number of Stops	6	7	6	5	8
Distance Run - Miles	136.6	136.7	136.6	136.3	136.7
Average Speed-M.P.H.	26.44	24.12	24.69	25.72	22.90
Pounds of water - Tender	354,786	359,512	380,549	353,032	363,172
Pounds of water-Condensate	49,300	44,965	50,100	--	47,349
Pounds of water - Total	404,086	404,477	430,649	353,032	410,521
Pounds of coal burned	66,667	67,759	70,509	67,707	70,679
Total No.cars in train	101	101	101	101	102
No.loads inc. dyn. car	8	7	12	4	8
No.empties inc.caboose	93	94	89	97	94
Wt.of train - Ms	6067	5983	6453	5614	6023
Wt.of train - tons	3004	2992	3227	2807	3012
1000 ton miles	410.35	409.00	440.81	382.59	411.74
Pounds coal/1000 ton miles	162.46	165.67	159.95	176.97	171.66
Drawbar pull - Lbs.	42089	42789	44046	38429	42555
DBHP Hrs. Adjusted	16664	16582	17102	15293	16813
Lbs. coal/DBHP Hr.	4.00	4.09	4.11	4.42	4.21
Average dev. H.P.	3223	3000	3093	2895	2861
Equiv.Evap.Lbs/DBHP Hr.	22.46	24.22	24.75	23.07	24.50
Lbs.coal/Sq.Ft.grate area	116.7	108.4	113.2	116.3	109.2
Lbs.water/Lb.coal(from 212°)	7.29	7.17	7.32	7.05	6.96
-Pressures-					
Boiler	244	246	244	245	244
Front Cylinders	166	180	176	172	166
Back "	172	193	184	178	174
Back Press-Front Cyl.	10.5	11.3	13.5	10.2	10.3
" " Back "	10.1	10.6	11.5	12.4	9.8
Stoker engine	36	37	41	39	40
" jets	152	146	142	150	145
F.W. to boiler - cab	257	256	257	-	256
Steam to F.W.H.turb.nozzles	160	146	152	-	147
Exh.steam to F.W.H.	10.0	7.6	10.3	-	8.8
-Temperatures °F-					
Front steam chest	654	640	660	654	636
Back " "	664	666	669	666	646
Smoke box gas	515	538	511	525	513
Exh.steam of front cyls.	310	322	315	311	304
" " to F.W.H.	317	327	318	-	302
F.W. at boiler check	214	209	213	-	208
Tender water temp.	75	77	82	73	75
Water at F.W. pump suct.	124	123	129	-	121
Degrees superheat-Back eng.	289.2	282.3	288.8	288.6	270.5
Average draft in smoke box back of dia.	14.3	14.4	15.9	15.0	13.7
Av.draft in smoke box front of dia.	9.9	9.2	11.1	10.4	9.2
Co2 Content of flue gas	9.9	-	9.0	11.1	10.3
Boiler efficiency	57.68	56.26	61.32	54.50	53.84

-AVERAGED DATA-

Carrizozo - Corona

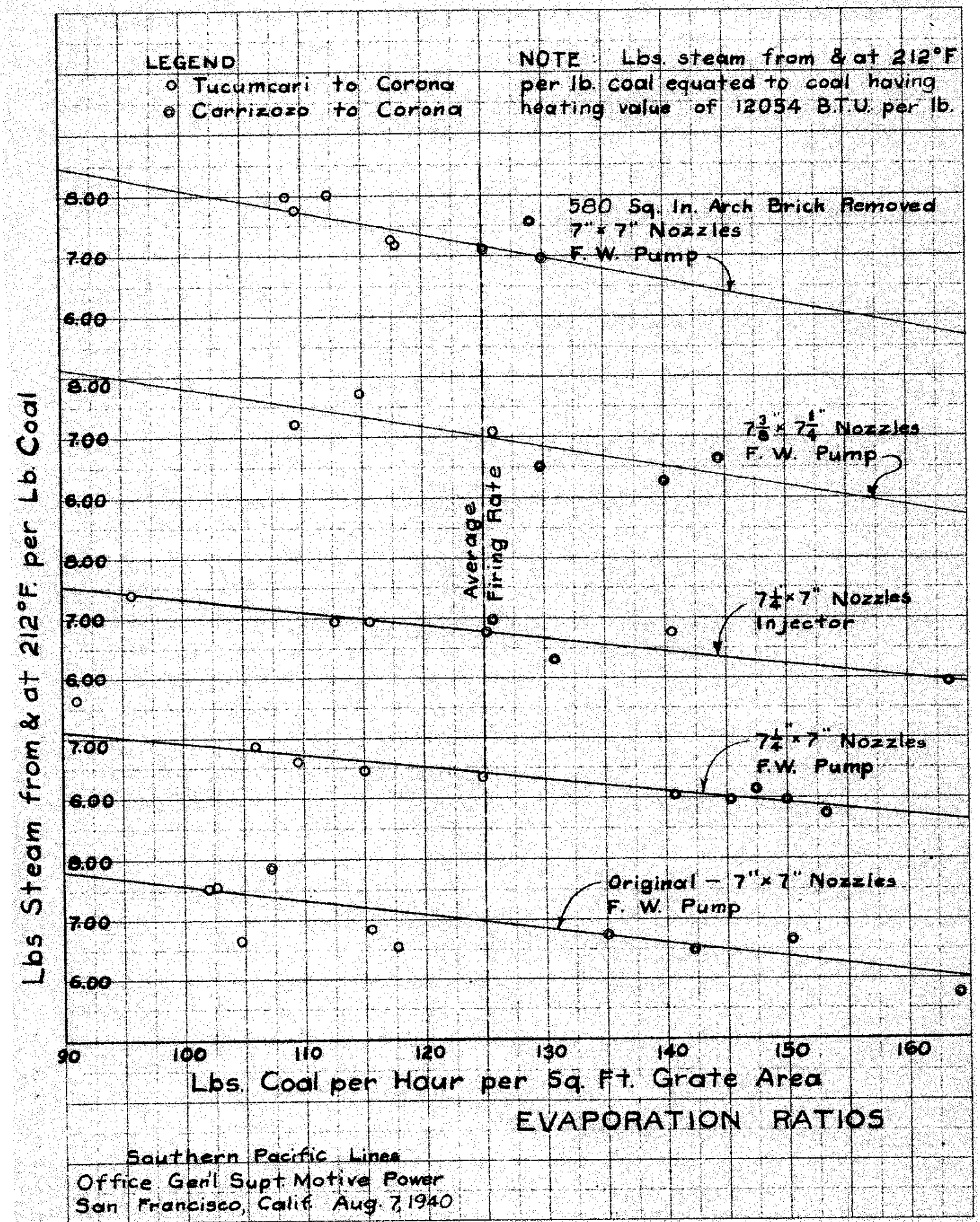
	7-3/8"x 7-1/4" Nozzles	7"x7" Nozzles	7"x7" 580 Sq.In. Arch Brick Removed	7-1/4"x7" Injector	7-1/4"x7 Nozzles
	---	---	---	---	---
Test runs used	34,36,38	2,6,8 10,12	42,ø44 ø46	22,26,28 30	16,18,20 24,32
Total time - hrs.mins.	2-47'	2-42'	2-17'	2-52'	2-39'
Standing time - hrs.mins.	18'	19'	21'	19'	24'
Running time - hrs.mins.	2-29'	2-23'	1-56'	2-33'	2-15'
Number of stops	1	2	2	1	1
Distance run - Miles	51.2	49.4	51.4	51.2	51.2
Average speed - M.P.H.	20.62	20.73	26.59	20.08	22.76
Pounds of water - Tender	179471	179127	135366	181445	165502
Pounds of water - Condensate	23984	23532	18133	--	23584
Pounds of water - Total	203455	202659	153499	181445	189086
Pounds of coal burned	37876	36497	27190	38396	36452
Total No. cars in train	94	86	70	91	83
No. loads inc. dyn. car	84	78	53	80	72
No. empties inc. caboose	10	8	17	11	11
Wt. of train - Ms	7665	7754	5575	7800	7023
Wt. of train - tons	3833	3877	2788	3900	3572
1000 ton miles	196.25	191.52	143.30	199.68	179.81
Pounds coal/1000 ton miles	193.00	190.56	189.74	192.29	202.73
Drawbar pull - Lbs.	56257	54793	42123	53553	50232
DBHP Hrs. Adjusted	8354	7886	6442	7971	7527
Lbs. coal/DBHP Hr.	4.40	4.62	4.23	4.81	4.86
Average dev. H.P.	3362	3330	3353	3124	3356
Equiv. Evap. Lbs./DBHP Hr.	24.48	25.97	23.87	22.75	25.16
Lbs.coal/Sq.Ft.grate area	138.0	139.7	128.0	136.2	147.3
Lbs.water/Lb.coal(from 212°)	6.47	6.78	6.77	6.47	6.22
-Pressures-					
Boiler	243	245	247	245	244
Front cylinders	192	188	174	196	191
Back "	197	199	183	201	197
Back Press-Front Cyl.	11.6	12.4	14.2	12.0	13.0
" " Back "	10.8	11.0	11.5	13.9	11.9
Stoker Engine	37	43	42	41	44
" Jets	166	157	131	168	157
F.W.to boiler - cab	255	254	258	-	255
Steam to F.W.H.turb.nozzles	160	156	150	-	163
Exh.steam to F.W.H.	8.8	8.7	10.5	-	10.0
-Temperatures °F-					
Front Steam Chest	659	656	655	669	659
Back " "	669	677	662	686	676
Smoke box gas	513	545	506	540	533
Exh.steam of front cyls.	315	337	303	326	315
" " to F.W.H.	325	347	316	-	325
F.W. at boiler check	211	211	214	-	215
Tender water temp.	73	75	82	70	70
Water at F.W. pump suct.	123	119	126	-	121
Degrees superheat-Back eng.	283.2	290.0	282.6	298.9	290.2
Average draft in smoke box back of dia.	15.3	16.1	15.9	16.3	16.3
Av.draft in smoke box front of dia.	10.6	10.7	11.2	11.0	10.9
Co2 Content of flue gas	8.4	-	9.7	10.7	10.5
Boiler efficiency	53.17	53.54	56.90	51.10	48.62
ø Light Load					



LOCOMOTIVE PERFORMANCE

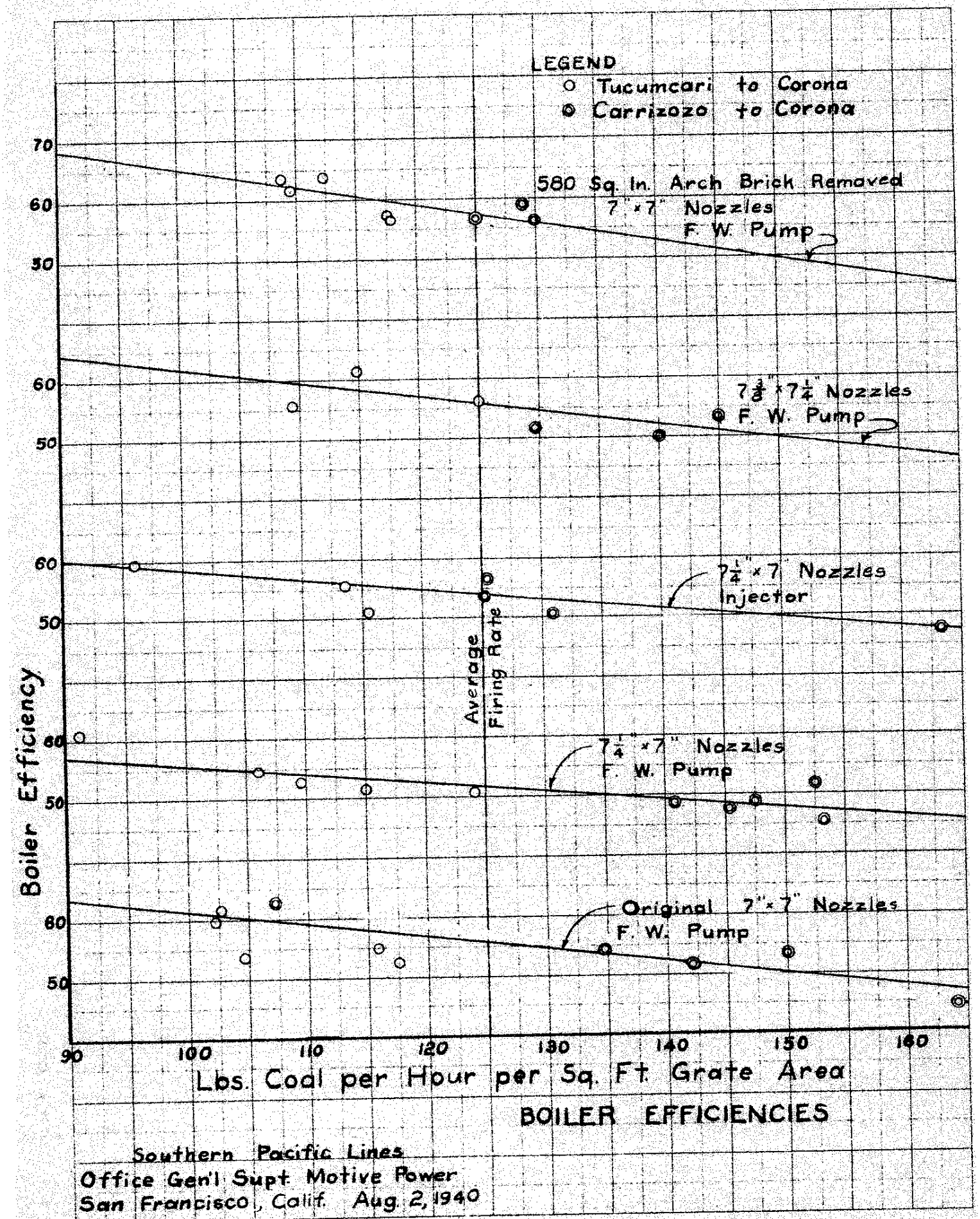
Locomotive No. 3803 Class AC-9
Data taken from Dynamometer Test No. 7
Taken from curves at firing rate of 125 lbs. coal per hr per sq. ft. of grate area.
Tests made on Rio Grande Division during April to July, 1940.

Southern Pacific Lines
Office Gen'l. Supt. Motive Power
San Francisco, Calif. Aug 6, 1940



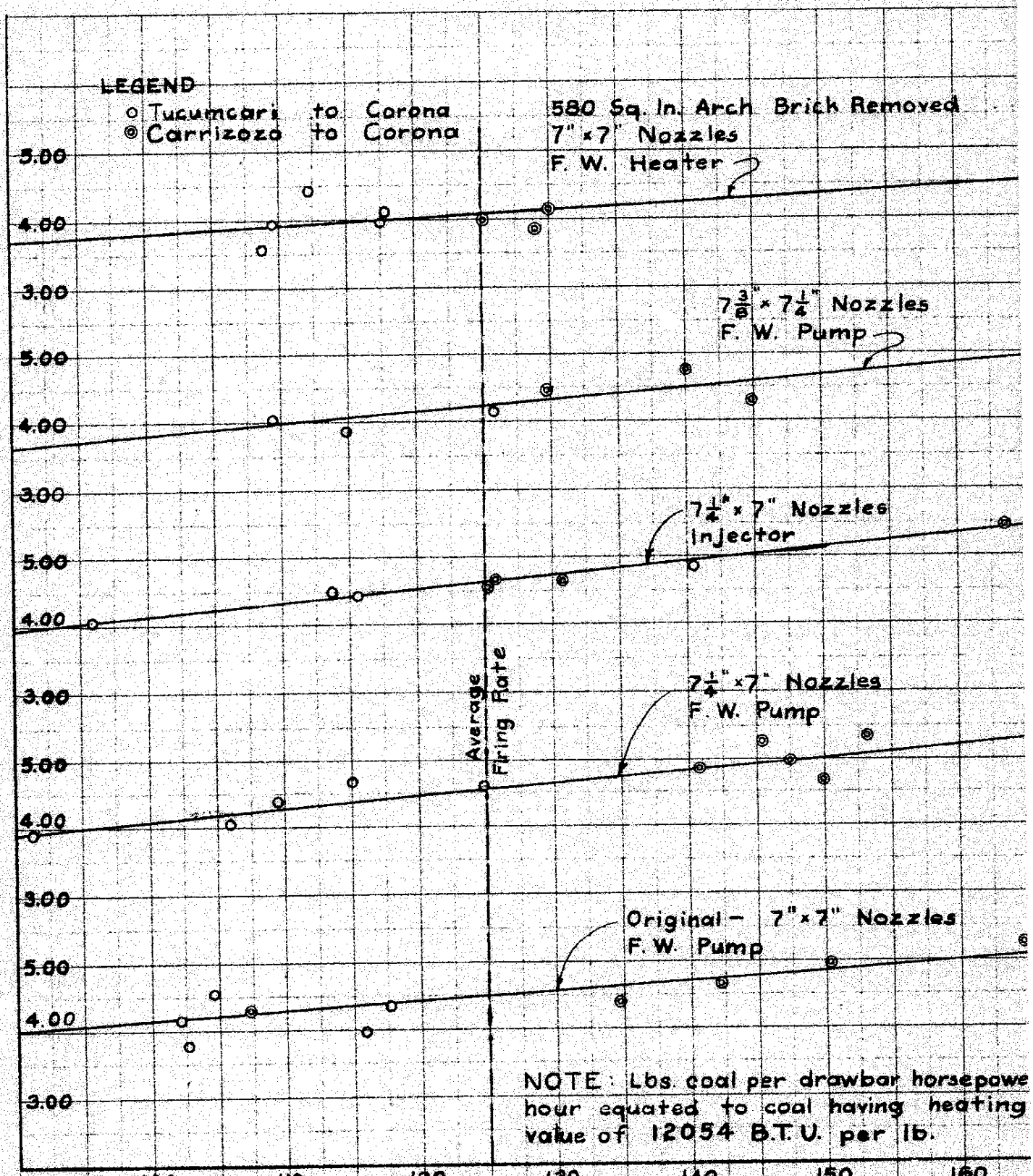
EVAPORATION RATIOS

Southern Pacific Lines
Office Genl Supt Motive Power
San Francisco, Calif. Aug. 7, 1940



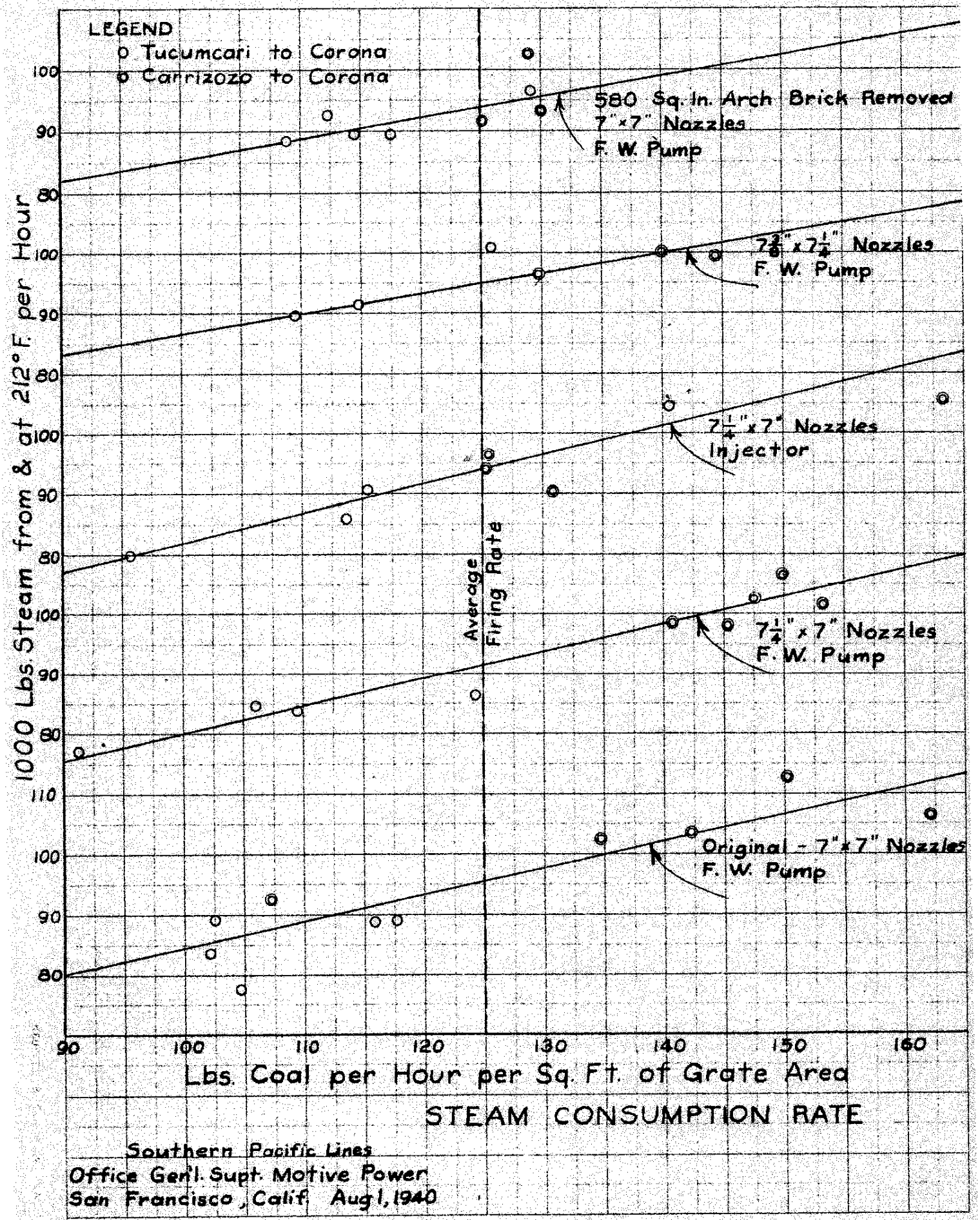
BOILER EFFICIENCIES

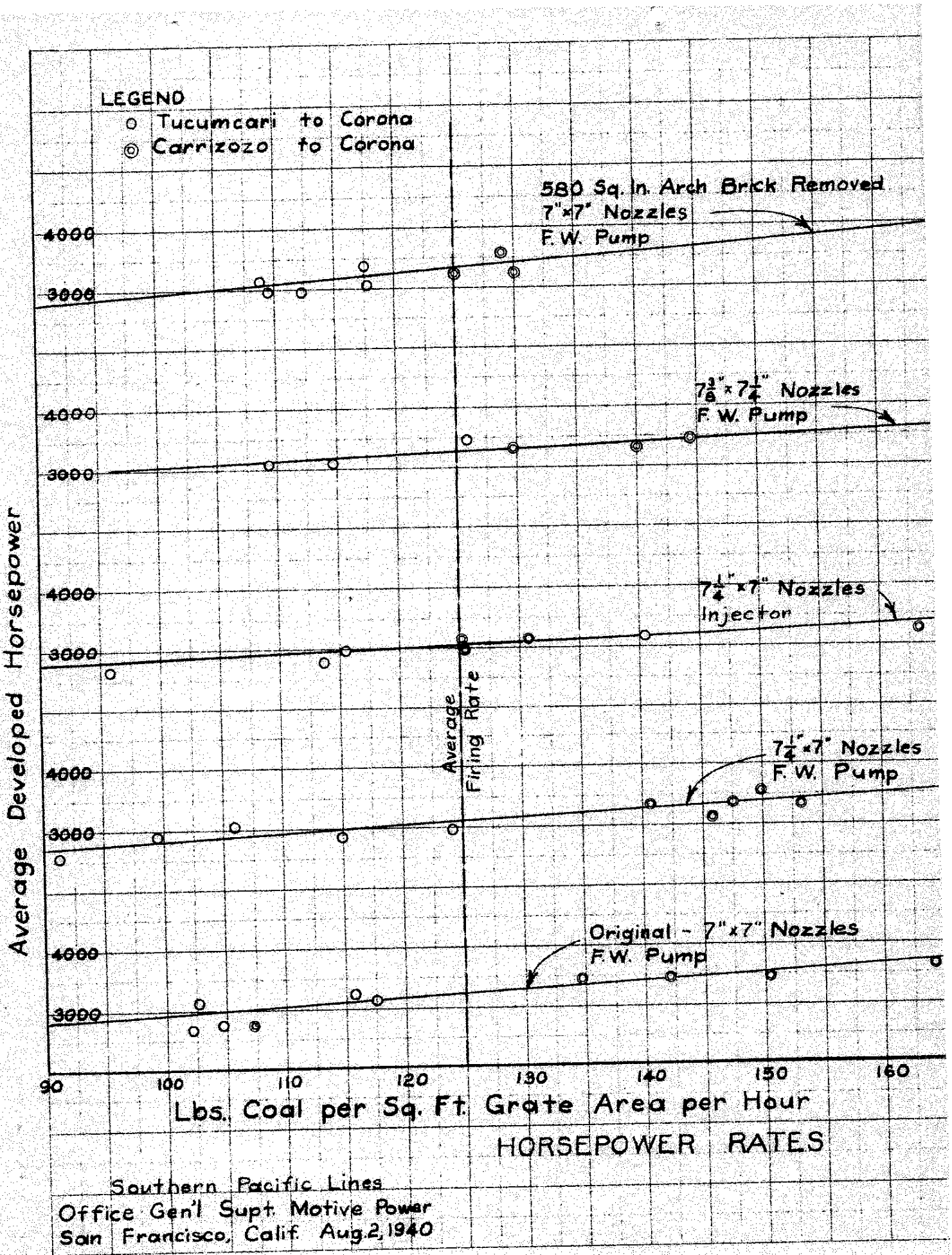
Southern Pacific Lines
Office Gen'l Supt. Motive Power
San Francisco, Calif. Aug. 2, 1940



HORSEPOWER - COAL CONSUMPTION RATE

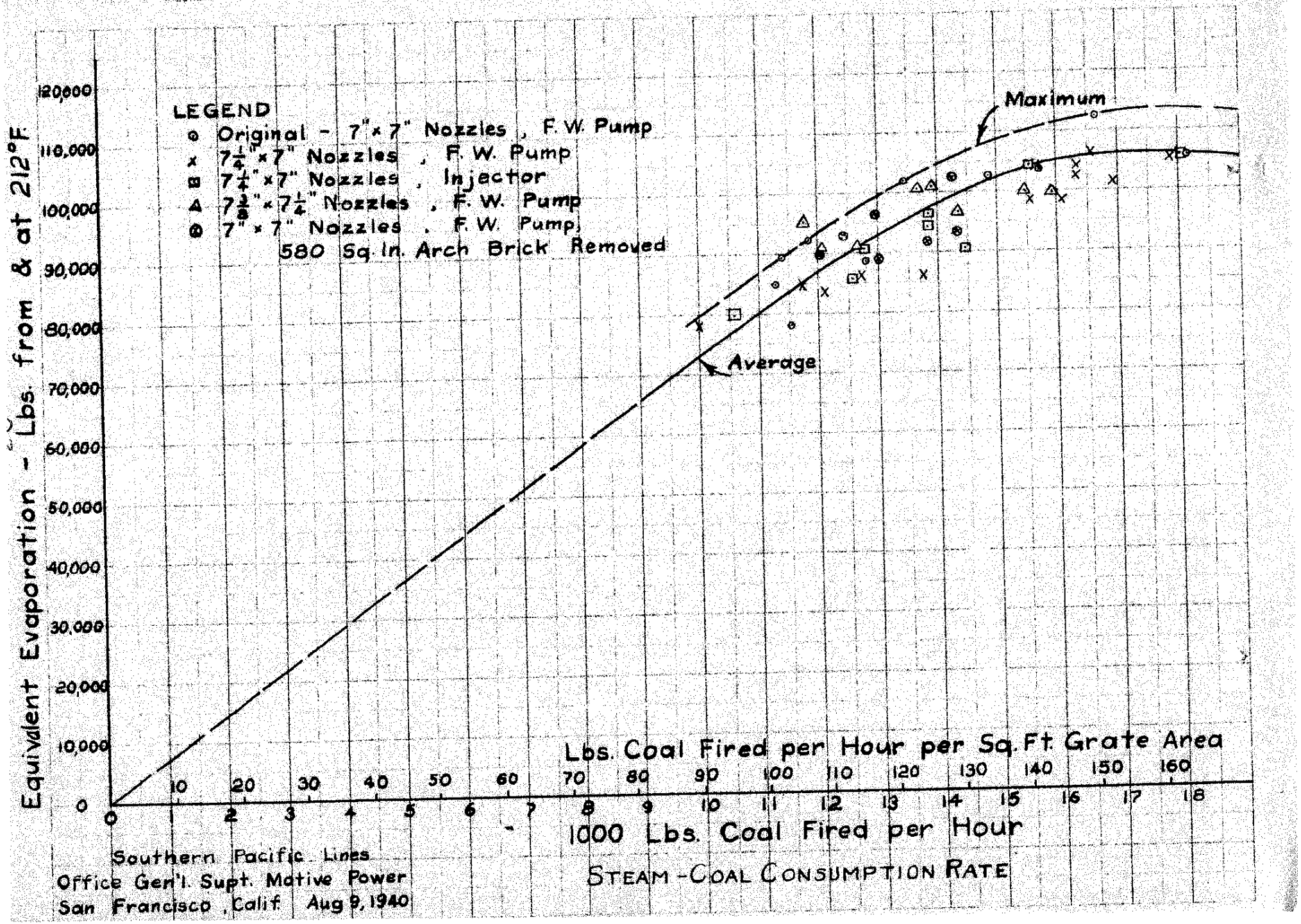
Southern Pacific Lines
Office Gen'l Supt Motive Power
San Francisco, Calif. Aug. 7, 1940

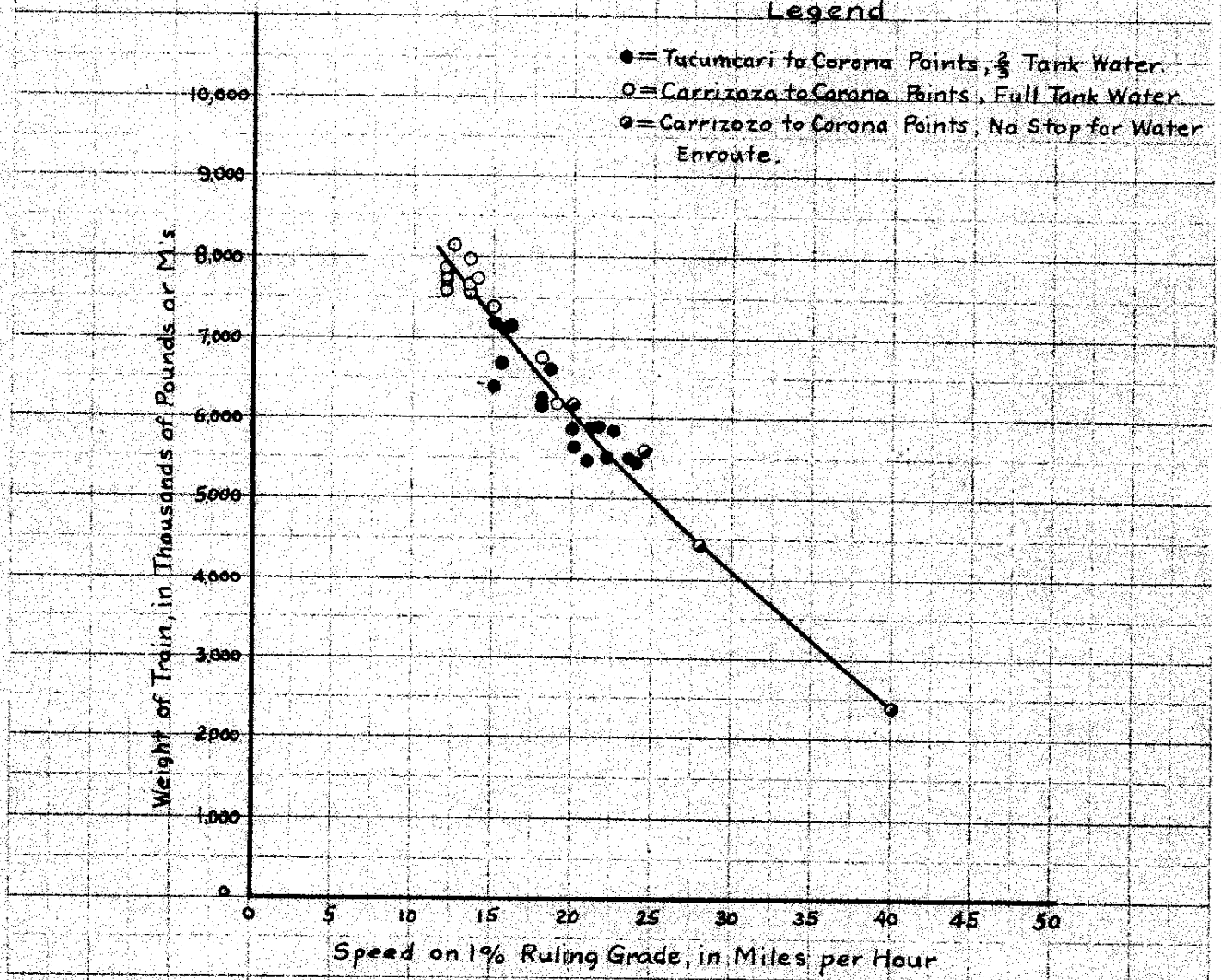

LEGEND
o Tucumcari to Corona
o Carrizozo to Corona
580 Sq. In. Arch Brick Removed
7" x 7" Nozzles
F. W. Pump
7 2/8" x 7 1/4" Nozzles
F. W. Pump
7 1/4" x 7" Nozzles
Injector
7 1/4" x 7" Nozzles
F. W. Pump
Original - 7" x 7" Nozzles
F. W. Pump
Average Firing Rate
1000 Lbs. Steam from & at 212° F. per Hour
Lbs. Coal per Hour per Sq. Ft. of Grate Area
STEAM CONSUMPTION RATE
Southern Pacific Lines
Office Gen'l. Supt. Motive Power
San Francisco, Calif. Aug 1, 1940



HORSEPOWER RATES

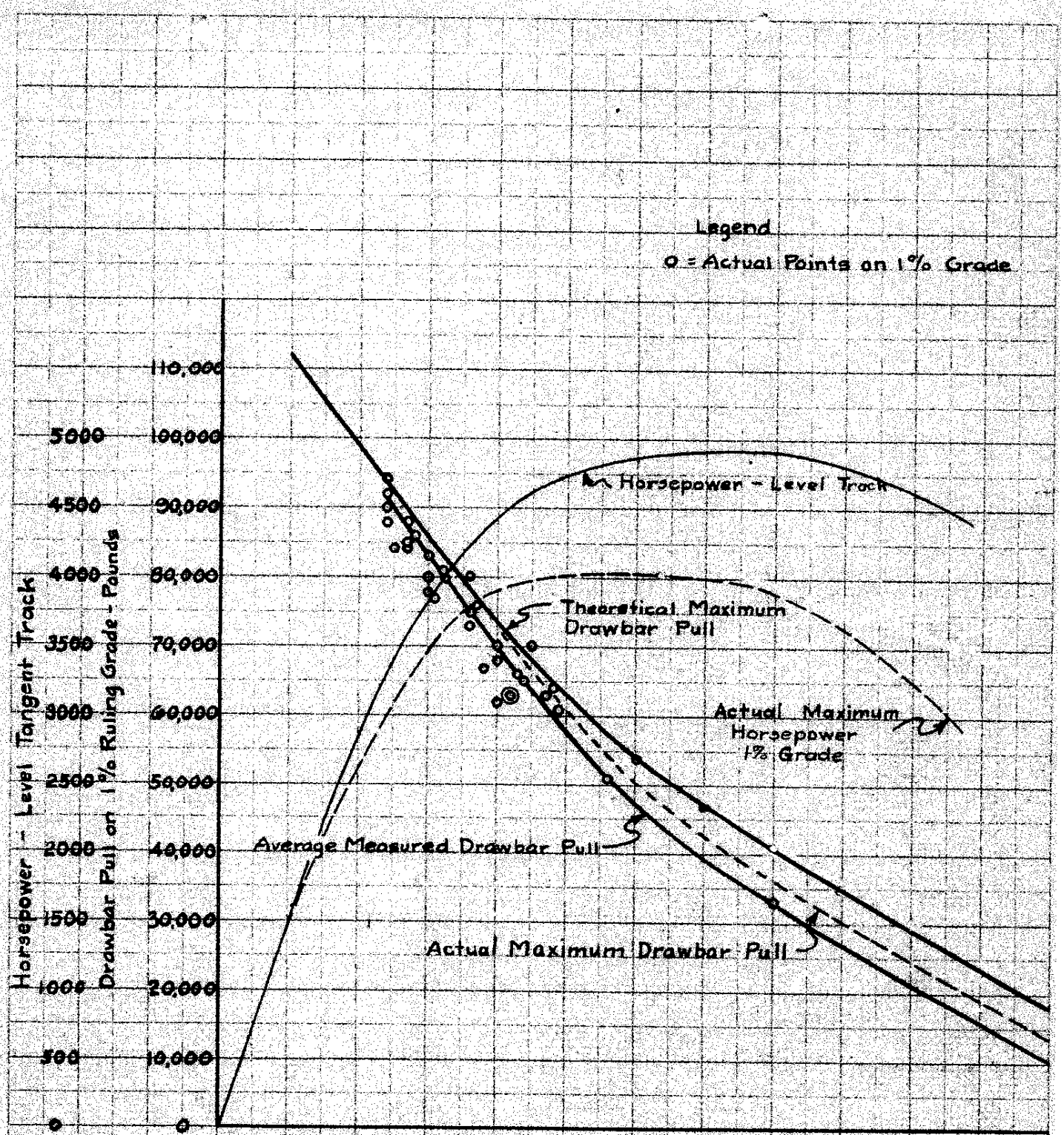
Southern Pacific Lines
Office Gen'l Supt. Motive Power
San Francisco, Calif. Aug. 2, 1940


LEGEND
Original - 7" × 7" Nozzles, F.W. Pump
7¼" × 7" Nozzles, F.W. Pump
7¼" × 7" Nozzles, Injector
7⅜" × 7¼" Nozzles, F.W. Pump
7" × 7" Nozzles, F.W. Pump,
580 Sq. In. Arch Brick Removed
Maximum
Average
Equivalent Evaporation - Lbs from & at 212°F.
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Lbs. Coal Fired per Hour per Sq. Ft. Grate Area
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
1000 Lbs. Coal Fired per Hour
Southern Pacific Lines
Office Gen'l. Supt. Motive Power
San Francisco, Calif. Aug 9, 1940
STEAM - COAL CONSUMPTION RATE



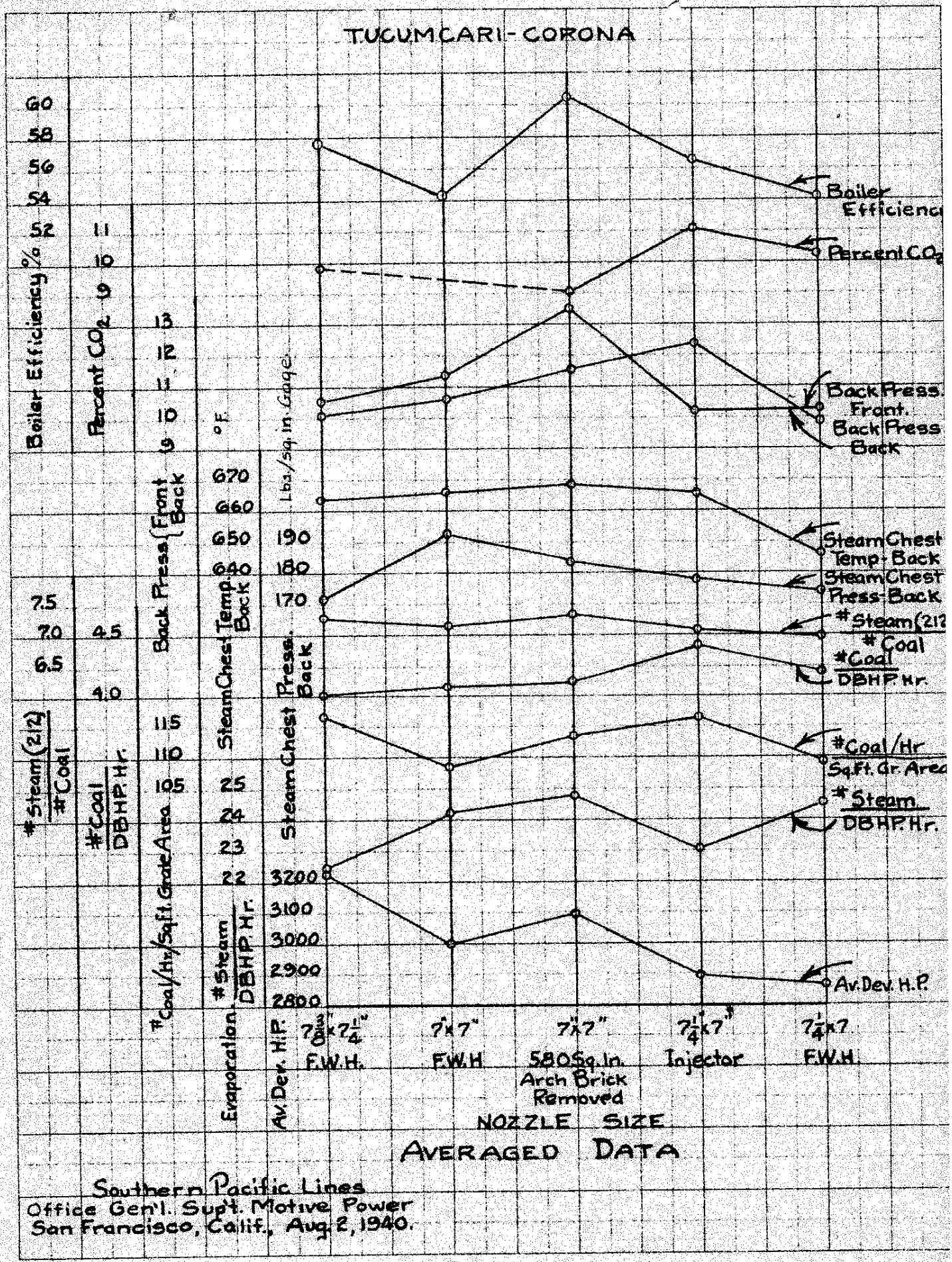
HAULING CAPACITY
ENGINE 3803, CLASS AC-9
1% RULING GRADE

Southern Pacific Lines
Office of Genl. Supt Motive Power
San Francisco Calif., July 29, 1940

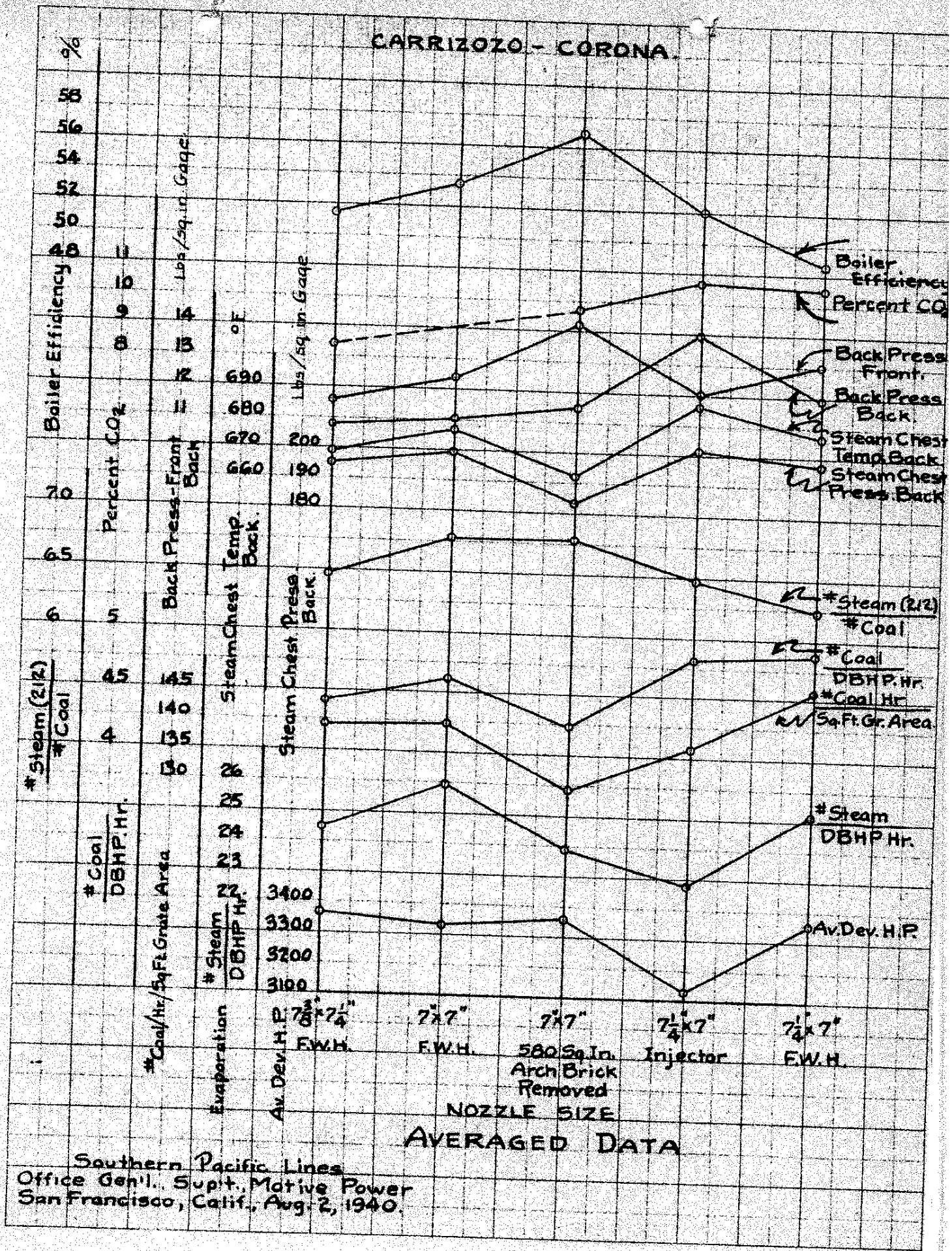


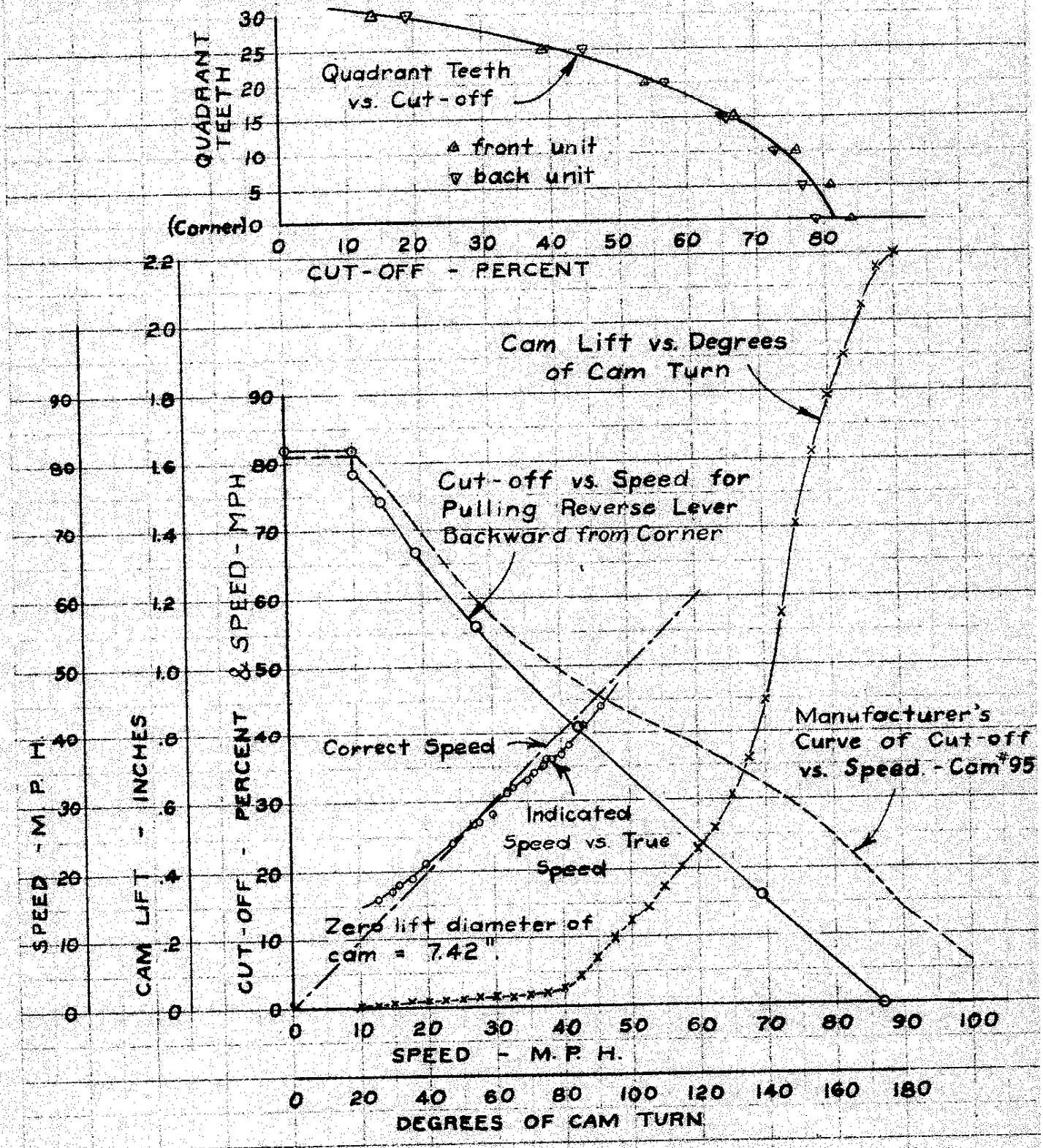
DRAWBAR PULL - 1% GRADE
ENGINE 3803, CLASS AC-9
HORSEPOWER - BACK OF TENDER - LEVEL TANGENT TRACK

Southern Pacific Lines
Office Gen'l. Supt. Motive Power
San Francisco, Calif., July 24, 1940.



Southern Pacific Lines
Office Gen'l. Sup't. Motive Power
San Francisco, Calif., Aug. 2, 1940.

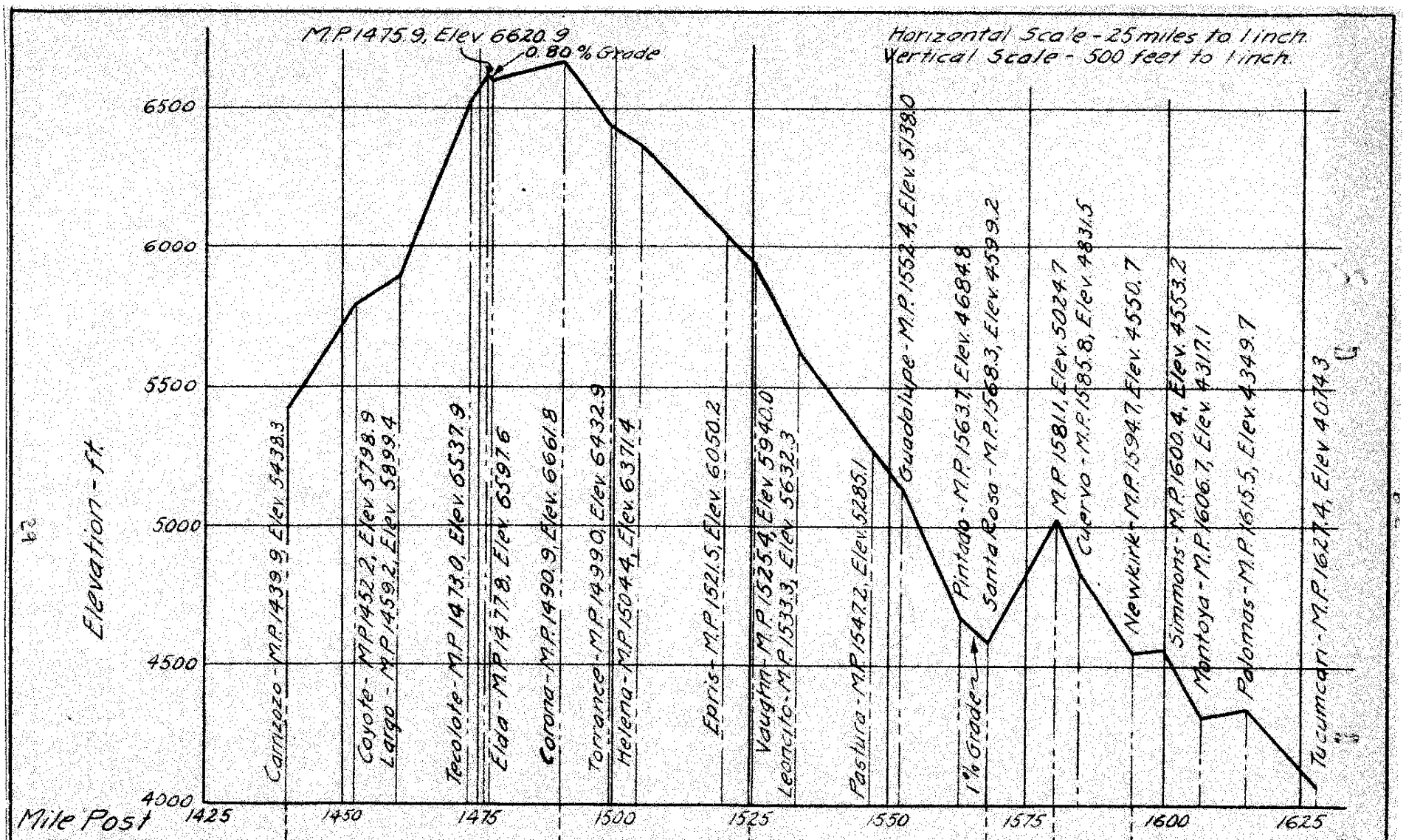

CARRIZOZO - CORONA.
Boiler Efficiency
Percent CO2
Back Press. Front.
Back Press. Back.
Steam Chest Temp. Back.
Steam Chest Press. Back.
*Steam (212) / *Coal
*Coal / DBHP. Hr.
*Coal Hr. / Sq. Ft. Gr. Area
*Steam / DBHP Hr.
Av. Dev. H.P.
Boiler Efficiency %
Percent CO2
Back Press-Front Back Lbs./Sq. in. Gage
Steam Chest Temp. Back. °F
Steam Chest Press Back. Lbs./Sq. in. Gage
*Steam (212) / *Coal
*Coal / DBHP. Hr.
*Coal/Hr./Sq. Ft. Grate Area
*Steam / DBHP Hr. Evaporation
Av. Dev. H.P.
7 3/8" x 7 1/4" F.W.H.
7" x 7" F.W.H.
7" x 7" 580 Sq. In. Arch Brick Removed
7 1/4" x 7" Injector
7 1/4" x 7" F.W.H.
NOZZLE SIZE
AVERAGED DATA
Southern Pacific Lines
Office Genl. Supt., Motive Power
San Francisco, Calif., Aug. 2, 1940.



VALVE PILOT DATA

Office of Gen'l. Supt. Motive Power

San Francisco, Calif. July 24, 1940



Ruling Grade - %		1	1	1	1	1	1
Curved Track (miles)	From 0° to 2° inc.	11.16	5.9	7.6	10.31		
	"2° 01' to 4°"	5.43	2.75	3.65	—		

PROFILE of ROAD

Carrizozo to Tucumcari

Office of Gen'l. Sup't. Motive Power
San Francisco, Calif. July 20, 1940.

DISCUSSION

As stated in the opening paragraph, the object of this test was to determine if any improvement could be affected in the evaporating qualities, or the ability to produce steam by the use of the heat obtained from the combustion of coal; to reduce the coal consumption per unit of work without adversely affecting the ability of the locomotive to produce work; to test the efficiency and reliability of the Hancock Turbo Feedwater heater-pump system; to test the reliability of the Nathan injector; and to test the operating indications of the Loco Valve Pilot.

EVAPORATING QUALITIES

During the progress of the test several changes were made and at no time during the 49 test runs did the locomotive fail to steam or to produce sufficient steam for normal requirements. On one or two occasions when certain operating characteristics of the Valve Pilot were being obtained and the power units were working against 19 or 20 lbs. back pressure, the boiler could not keep up with the demand for steam; however these were extraordinary demands and would not be duplicated under normal conditions of operation. It may therefore be stated that the ability of the locomotive to produce steam is entirely adequate.

COAL COMBUSTION

Due to the construction of the grates, which limits the amount of combustion air, and the construction of the air openings to the

under sides of the grates, changes in the amount of air available for combustion would have taken a great deal of time and, in view of the favorable steaming qualities of the locomotive, as discussed in the preceding paragraph, no changes were made in the combustion air supply. However, several changes were made in the draft arrangement in the smokebox by varying the diameters of the exhaust nozzles, as will be discussed in later paragraphs.

FEEDWATER HEATER AND PUMP SYSTEM

Soon after the test was started, it was noted that, due to the construction of the hot well in the tender, the hot water returned from the feedwater pump was excessively heating the main body of water in the tender, which adversely affected the ability of the injector, in operation, to pick up the water and supply it to the boiler. In addition, the heating of the water ultimately would result in the failure of the feedwater pump to supply more than a small percentage of its capacity to the boiler. At the end of Run No. 15 the hot well in the tender was modified in a manner such that the hot water returned to the tender was returned to a point adjacent to the suction line of the pump and the tendency of the hot water to mix directly with the main supply was practically eliminated.

Before modifying the hot well the temperature of the water in the main section often increased as much as 15 degrees or more between fillings. After the hot well was changed this increase in temperature was reduced to not more than one or two degrees between fillings.

At the same time the hot well was modified, a change was made in the governor of the feedwater pump steam turbine. This change resulted in more reliable regulation of the steam turbine speed.

STOKER ENGINE EXHAUST PIPE

At the same time the hot well was modified, the stoker engine exhaust pipe, which originally passed through the main water section of the tender, was disconnected and repiped in such a manner that it discharged under the tender between the rails. At the end of Run No. 38, when it had been determined that, with the modified hot well, the temperature of the water in the tender did not increase more than one or two degrees in temperature between fillings, the exhaust piping was again connected in the original manner.

It was found that the temperature did not increase more than three degrees between fillings and it was determined that this arrangement would be satisfactory, as a 3 degree rise would not affect adversely the operation of the injector nor the feedwater pump, and the temperature increase would result in about a 1/4% heat saving and, in addition, this feature would be valuable during extremely cold weather in offsetting the possibility of freezing the tender water. At temperatures near freezing the heat transfer would of course be greater and as much as 5 degrees increase can be expected.

INJECTOR

As stated before, considerable trouble was experienced with the injector due to its failure to put all the water in the boiler.

It was considered, at first, that this was entirely due to the hot water present in the main tank. At the time the hot well was modified, an automatic device perfected by the manufacturer of the injector was applied to the injector. The purpose of this device was to automatically close the overflow valve of the injector, immediately after delivery of water to the boiler had commenced. The device is so constructed that it automatically opens if the injector "breaks" or momentarily fails to deliver water to the boiler.

This device performed in an entirely satisfactory manner and at no time while in operation did more than approximately 5% of the water fail to enter the boiler, and then only on rare occasions.

On one trip the automatic device was disconnected before leaving Tucumcari. On arrival at Santa Rosa it was estimated that 10% of the water was being put "on the ground", through the overflow pipe. On arrival at Vaughn it was estimated that 25% of the water was being put on the ground. Immediately after this was determined at Vaughn, the automatic overflow control was again connected and there was no further loss of water out of the overflow.

LOCO VALVE PILOT

The design of the cam of the Valve Pilot, which controls the cutoff indication in terms of miles per hour, is such that for maximum horsepower output, the black, or cutoff hand, should be kept directly under the red, or speed hand, by adjusting the reverse lever as the speed changes.

It had been reported that the class AC-9 locomotives could not

be operated according to the Valve Pilot indication without developing excessive back pressure and, as a result, requiring more steam than the engine could produce.

Therefore, it was part of the purpose of this test to make a study of the Valve Pilot and to determine what practical changes should be made in order that the locomotive could be operated according to Valve Pilot indication.

Soon after the start of the test it was found that the engine did develop excessive back pressures when operated according to the Valve Pilot. On checking the speed indication of the instrument it was found that the speed was high at low speeds and low at high speeds, varying from a maximum of 4 M.P.H. high at 12 M.P.H. to correct at 24 M.P.H. and 3 M.P.H. low at a speed of 40 M.P.H. As it was considered inadvisable to delay the test to correct the speed indication and the Valve Pilot was an invaluable instrument in the operation of the test, in that one run could more nearly be made to compar with another when both runs were made according to the indications of the instrument, the speed indication was not corrected during the test. However the error in speed was considered and compensated for during the test.

At the start of the test it was found that these locomotives were being operated at a recommended maximum back pressure of 15 lbs. per sq.in. The combination steam pipe - back pressure gauge in the cab is equipped with an adjustable stationary brass hand and this had been placed at 15 lbs., indicating the recommended back pressure.

After a sufficient number of runs had been made to determine the operating characteristics of the locomotive, it was found that,

with 7x 7" nozzles, maximum power output was obtained when the engine was worked with 17 lbs. back pressure. As the back pressure varies with speed, the cutoff being maintained constant, this statement holds true principally for the range of speed between 12 and 20 M.P.H

The Valve Pilot instrument does not indicate below the figure 12, the figures representing both speed and cutoff in terms of speed. As originally set, the cutoff hand indicated 12 when the reverse lever was placed for maximum valve travel or cutoff. After careful study of the problem the instrument was adjusted to indicate cutoffs 3 M.P.H. lower than formerly, the initial reading or indication being 9 instead of 12. As there was no figure below 12 on the dial face the number 9 is relative. With this setting the engine could be operated, with the hands together, at maximum power output without exceeding a back pressure of 17 lbs.

This, of course, did not correct the false indication of the speed hand but sufficient data has been presented on the graphic chart, page 28, to enable the Valve Pilot Corporation to redesign the cam in a manner such that the engine can be operated at maximum power by reference to the instrument.

TONNAGE RATING

Prior to the start of this test the tonnage rating of class AC-9 locomotives had not officially been established and was not shown on the current Rio Grande Division time table. An additional purpose of this test was to obtain sufficient data to determine the time table rating of this class of power. On page 24 is shown a

graph of tonnage versus speed on ruling grade and, as shown on this graph, a 7200 M train can be handled on a ruling grade of 1% at a minimum speed of 15 M.P.H.

COMPARISON OF TEST DATA

As previously stated, odd numbered runs were made from Tucumcari west to Corona and even numbered runs were made from Carrizozo east to Corona, the top of the grade. Due to the variation in train weights it was found inadvisable to rely on a direct comparison of averaged data. The averaged data has, however, been tabulated for informative purposes only, and certain data has been shown graphically on pages 26 and 27.

It was found that the principal data, such as lbs. steam per lb. coal, developed horsepower, coal and water consumption, and boiler efficiency, varied more or less in direct relation with the hourly rate of firing the coal. Within the fairly close range of variation of the firing rate the principal data may be assumed to have a straight line relation and this data therefore was plotted against the lbs. of coal fired per hour per square foot of grate area, the lbs. of coal being equated to a coal having an average heat value of slightly more than 12,000 BTU per lb. The average of the firing rates for all runs was found to be 125.1. The value of the plotted data at the average firing rate was, therefore, taken from the graphs and plotted on page 17. The data presented on this latter page has been used for comparing one set of conditions with another.

RESULTS

In comparing the data presented on page 17 it will be noted that the engine performed most economically with 7 x 7" nozzles, the standard arrangement for this class of locomotive, and with 580 sq. ins. of arch brick removed from the middle section of the arch nearest the firedoor. During the progress of the test it had been noted that increasing the diameter of the front nozzle from 7 to 7-1/4" and later increasing this to 7-3/8" and the back nozzle to 7-1/4", had not resulted in a fuel saving. It had been noted, however, that the coal being fired had a high percentage of fines, or small sized coal ranging from coal dust to lumps about the size of match heads. Due to the high velocity of the flame around the back end of the arch, nearest the firedoor and the point where the coal is blown into the firebox, these fines were being picked up before reaching the coal bed and were being carried out through the stack as evidenced by the considerable volume of cinders coming out of the stack, particularly at high firing rates.

It is impractical to measure the stack loss of a locomotive on the road but from tests made by other railroads and colleges on stationary test plants, the loss of unburned coal out of the stack has been found to be as high as 12% at high firing rates. It is roughly estimated that the stack loss of engine 3803 approached or possibly exceeded that figure. A sample of the cinders was analyzed and it was found to have a heat value of 9300 BTU per lb. As the original coal averaged 12,000 BTU per lb. this indicates that in passing through the firebox and flues only 2700 BTU was extracted from

each pound of cinders.

Obviously, anything that can be done to reduce this stack loss and which does not adversely affect the ability of the boiler to produce steam, will result in some saving of fuel. As the increase in the nozzle diameters, which has the effect of reducing the draft in the front end and should reduce the amount of unburned fines thrown out of the stack, had not resulted in any material saving, the arch brick (in part) was removed for the purpose of reducing or displacing the velocity of the flame around the end of the arch. 580 sq. ins. of arch brick was removed from the central section nearest the fire door and the stoker jets. The area removed approximated that of the casting just inside the firedoor which protects the coal, inside the firebox, which is being forced up by the action of the coal in the stoker conveyor screw behind it, to a point where the jets pick it up and project it into the firebox.

It was found that, with this amount of arch brick removed, the stoker jet pressure could be reduced approximately 10 lbs. gauge. This indicated that less force was required to project the coal through the path of the flame and therefore the velocity of the flame in front of the stoker jets had been reduced.

As compared with the test made with 7 x 7" nozzles without arch brick removed, the test made with the arch brick removed resulted in a 6.8% decrease in lbs. coal per drawbar horsepower hour, a 2.68% increase in boiler efficiency, and a 3.17% increase in the lbs. of steam per lb. of coal. Taking the latter value as a basis of comparison, the saving in coal for equal amounts of steam generated would be 3.1%. Assuming a maximum error of 1,000 in 60,000 lbs. of coal, fired

due to the inherent inaccuracy in the method of weighing coal by volume measurement, and also assuming that the error resulted in a lower coal consumption, the error would be 1/60 or 1.3%. Subtracting this from the expected saving would show a minimum coal saving to be expected of at least 1.8%.

Considering only the coal used from Tucumcari to Corona and from Carrizozo to Corona, the average coal consumption for the round trip would be 104,000 lbs. or 52 tons. Assuming 14 round trips per month and coal at the current rate of $3.06 per ton at the mine, this will result in a saving of $5,760.00 per year for the total of 12 engines of this class.

In comparing the results of the feedwater pump versus the injector, it was found that runs with the same nozzle diameter were not comparable, apparently because, with the injector in operation and the feedwater pump not being used, the pressure of the exhaust of the back power unit, at the nozzle, was increased due to not taking off the steam for the heater. This increased the draft in the smokebox and affected the combustion. Therefore, the injector runs with 7-1/4x 7" nozzles were compared with the feedwater pump with 7x 7" nozzles. It was found that there was a 4.35% decrease in lbs. of coal per drawbar horsepower when using the feedwater pump as compared with use of the injector, a 3.71% increase in boiler efficiency and a 3.41% increase in lbs. of steam per lb. of coal. In addition, the feedwater pump system averaged a 13% return of condensate.

CONCLUSIONS

1. That the removal of 580 sq.ins. of arch brick from the center of the arch section between the Nos. 6 and 7 circulators will result in a fuel saving of approximately 1.8%.
2. That the present standard air opening to the firebox and standard front end arrangement will result in the most economical performance.
3. That the modified hot well and the change in the pump governor has resulted in a more reliable operation of the feedwater heater pump system.
4. That the application of the automatic overflow control to the injector has resulted in dependable operation of that device.
5. That the information obtained will make it possible to correct the Valve Pilot and permit operation of the engine in accordance with its indication.

RECOMMENDATIONS

1. That for fuel economy and reliability, and flexibility in service part of the arch brick be removed from the arch of all engines of this class, according to Motive Power drawings covering the change, and that the present standard front end arrangement and draft opening to the firebox be maintained.
2. That the hot well in the tenders behind all engines of this class be modified in the same manner as that behind engine 3803.
3. That automatic overflow controls be applied to the injectors of all engines of this class.

4. That the cam design of the Valve Pilot be modified, on all engines of this class, to agree with the graphical data presented herein.

5. That the stoker exhaust pipe be maintained at present standard; that is, to pass through the main body of the water in the tender.

Office of Genl.Supt.Motive Power
San Francisco, September 5, 1940