

D I E S E L   B O O S T E R   T E S T

EF 5 ELECTRIC LOCOMOTIVE WITH 3 GP9 DIESEL UNITS

FREIGHT SERVICE

BETWEEN TACOMA AND OHELLO

Sept. 23-26, 1960

The Milwaukee Road  
Electrification Department  
Tacoma, Washington  
October 31, 1960

DIESEL BOOSTER TEST

EF5 + 3 GP9's

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### DIESEL BOOSTER OPERATION

The success of the booster operation in Montana lead to thoughts of a similar operation on the Coast Division, using an EF 5 locomotive with one or more GP 9 diesel locomotives. In Montana the objective was elimination of helper operation out of Three Forks - up Sixteen Mile Canyon. On the Coast Division there were several objectives. One was to transfer diesel units from Othello to Tacoma for maintenance. Another was to eliminate helper service in the several helper districts.

At the same time the desirability of setting up the diesel locomotives to brake dynamically while the electric locomotive was braking by regeneration was recognized. With this thought in mind, circuitry was developed to accomplish this on the Montana combination. This was successfully tested on June 14, 1960, and AFE has now been assigned to apply this to the Montana locomotives.

The development of circuitry to accomplish this booster operation, both motoring and braking, on the Coast Division was progressed at the same time. Due to the limitations of space, a full electric circuitry was developed instead of the mechanical-electric system used in Montana. This full electric installation was made on locomotive E 39, which had been converted to Class EF 5 by inclusion of unit E 23C. Preliminary test was made on September 12, 1960 and showed that altho several minor changes were desirable, the circuitry was in the main correct. Formal test was made September 22 to 28, 1960. Results of this test follow.

H.R. Morgan,  
Electrical Engineer.

Electrification Dept.,  
Tacoma, Washington,

TEST OF EF-5 ELECTRIC LOCOMOTIVE WITH DIESEL BOOSTERS

BETWEEN TACOMA AND OTHELLO

Sept. 22 to 28, 1960

An EF-5 electric locomotive (E-39) and 3 GP-9 diesel locomotive units (DE 282-284-293) were set up with multiple unit circuitry so that full control was vested in the operating cab of the electric locomotive. This control enabled the engineer to operate the composite locomotive, or electric alone, or the diesel alone.

The dynamometer car was placed immediately back of the locomotive. Graphic instruments for recording voltage and current were installed in the E-39D and in the DE 282 cabs. Data from these instruments, the dynamometer car, and the regular cab instruments, along with data and charts from the substations furnished the statistical background for this study. The usual station log was kept.

Tests were witnessed by various company officials and employees. Their names are shown on attached sheet.

During the test the locomotive handled successfully, without the use of helpers, the following trains:

#264S23 with 5491 tons out of Cedar Falls  
#263C20 with 4260 tons out of Beverly  
#264S26 with 5638 tons out of Cedar Falls

The tests demonstrated that:

1. The booster circuitry was correct.
2. The operation with all power at the head end was satisfactory within the tonnage limits currently in use.
3. Helper service could be eliminated.
4. By judicious use of the two types of power, time over the line could be reduced.

Still to be determined are the economy and practicability of this type of operation.

Further comments and data covering the operation of the test trains are attached.

*H. R. Morgan.*  
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Electrical Engineer

Electrification Department,  
Tacoma, Washington  
October 20, 1960

OBSERVERS AND TEST FORCE

During the course of the test, the following officials and employees witnessed or took an active part in the test:

R. G. Scott	Asst. General Manager
N. H. McKegney	Superintendent, Coast Division
F. A. Upton	Superintendent Motive Power
Paul Lucas	Asst. Superintendent Motive Power
J. M. Hemsey	Superintendent Air Brakes
M. J. Biller	Engineer, Mechanical Engineering Dept.
E. w. Krueger	Engineer, Office Engineer of Tests
G. J. Johnston	District Master Mechanic
C. W. McMillan	Traveling Engineer, Coast Division
George Girard	Chief Electrical Foreman
H. R. Morgan	Electrical Engineer
T. B. Kirk	Assistant Electrical Engineer
G. R. Frazier	Assistant Engineer, Electrification Dept.
W. T. Hardy	Draftsman, Electrification Dept.

Electrification Department,  
Tacoma, Washington  
October 20, 1960

DIESEL BOOSTER TESTEF 5 With 3-GP9'sCOMMENT AND DISCUSSION

After observing these tests and studying the data developed therefrom, the following comments and discussion on pertinent phases of the operation are made.

Helpers

This test introduces a new type of operation to the mountain divisions-- the placing of sufficient power at the head end, under the control of one engineer, to handle the train over the profile without the use of helpers on the mountain grades. This necessarily uses on the valley grades more power than needed and to that extent is not an efficient operation. However, it does eliminate the use of helpers and that may compensate for the increased cost in locomotive maintenance, fuel and enginemen's wages.

The helper district comprises 23.6% of the run, so on 76.4% of the run more power is being used than is needed. See page 23. A cost study will be required to determine the most economical operation.

Transfer of Power

There are other factors which come into the picture. The operation enables transfer of diesel locomotive maintenance from Othello to Tacoma, which is presumed to be a move in the direction of increased efficiency in locomotive maintenance.

Faster Time

The tests all showed faster time over the run. See graphic chart and data sheet attached. This may be attributed to placing so much horsepower at the head of the train. (Like the EP-1 Diesel Test, February 1, 2, 3, 1960). See pages 9 to 11.

It was also due to the characteristics of the composite locomotive. The diesel locomotive has a top speed of 65 miles per hour and produces a fair amount of tractive effort at 45 miles per hour. The top speed of the electric locomotive is 45 miles per hour, at which speed its tractive effort is comparatively low, but on the heavy grades at 14 to 16 miles per hour, the electric locomotive develops the most tractive effort. The composite locomotive therefore shows a fair tractive effort from zero to 45 miles per hour.

As previously noted the control is flexible so that either diesel or electric components may be cut out of service. By judicious use of this feature the engineer may help improve the overall speed over the run.

Tractive effort and braking characteristic curves for the composite locomotive are attached, pages 13 and 14.

#### Power and Fuel

The booster locomotive operation does reduce the electric power consumption and does increase diesel fuel consumption, which is the most expensive of the two fuels. Possibly of more importance is the subject of regeneration. Regeneration has usually reduced our power bill from 13 to 17 percent. In this operation regeneration will be reduced about 50%.

#### Tonnage Limit

In motoring, tonnage limit on the grades is controlled by locomotive capacity and by drawbar capacity.

In braking, tonnage has always been limited to the capacity of the locomotive in regeneration. With the composite booster locomotive, it should be limited to the capacity of the locomotive in regenerative and dynamic braking. With all power at the head end, a new factor, buffer pressure comes into the picture and this modifies the above requirement by introducing the use of air brakes to limit buffer pressure.

#### Motoring Tonnage Limit - Locomotive Capacity

As noted above this introduces a new type of operation. New thoughts and new methods of handling are conspicuous in the proposed operation. For instance the limiting tonnage eastbound on the Coast Division has always been, not the tonnage capacity on the Cedar Falls hill, but the tonnage that could be safely handled by regeneration on the Beverly hill. Air was to be used only in emergency. Through the years that tonnage gradually worked up to about 5500 tons. Now, the thought is to handle up the Cedar Falls hill the capacity of the locomotive and to use air to reduce buffer pressure and thereby assist braking on the Beverly hill. Air has been used before but not as a regularly programmed method of operation on this hill. Application of air will naturally heat wheels and brakes, but experience has shown that a 4 to 5 pound reduction will not cause enough heating to endanger the operation.

In final analysis, tonnage must be limited to that which can be started on the maximum ascending grade in the direction of the train involved. In the case of eastbound movements, there is very little if any tonnage added between Hyak and Beverly, so that generally speaking the tonnage up the Cedar Falls hill will be the tonnage down the Beverly hill. The motoring tonnage ratings for the Cedar Falls hill exceed the braking capability of the booster locomotive on the Beverly hill. Air braking is therefore required on the Beverly hill to fill a locomotive braking deficiency as well as to reduce buffer pressure.

Tonnage ratings for the EF5-GP9 composite locomotive are given on page 15.

### Motoring Tonnage Limit- Draft Gear Capacity

When operating on the grades with all power at the head end, the limiting factor becomes the drawbar pull that the draft gear can stand. On the first test run a knuckle on a car near the dynamometer car broke. Replacement was effected in about 20 minutes. When starting, drawbar pull went up to about 275,000 pounds. On the return trip about the same drawbar pull was noted when pulling out of Doris siding. From past experience we know that with some trains it has been necessary to go to 400 to 450+ amperes to start on the grade. This with two 4-unit electric locomotives means a momentary drawbar pull ranging from 320,000 to about 375,000 pounds per locomotive, the helper locomotive being placed in the middle of the train. With the composite locomotive under test a similar experience would mean a drawbar pull ranging from 435,000 to 490,000 pounds.

From these observations it is apparent that a drawbar pull ranging from 275,000 pounds to about 490,000 pounds must be anticipated when operating on mountain grades with all types of trains. Page attached shows published data on drawbar strength. This year, a series of new tests indicate higher values, but actual results have not been released at this time. From inspection of this sheet, it appears that starting a good running train on the grade should cause no trouble unless an older type drawbar is found near the head of the train. If the train is not good running, and if there are any old type drawbars involved, trouble may be expected if necessary to start on the grade with all power at the head end. This we recognize as a calculated risk. As far as this factor is concerned, only operation over a period of time will indicate the tonnage limits to be observed to insure a good operation. For this operation locomotive capacity, as noted in previous paragraph, will control.

### Braking Tonnage Limit- Buffer Pressure

The use of air brakes to supplement regenerative and dynamic braking has already been mentioned. With all the braking power, electric and dynamic, located at the head of the train, a buffing pressure of about 224,000 pounds (#264S26) might be developed back of locomotive on Beverly hill. Operating on a curve with a lightly loaded car back of the locomotive, such pressure might be disastrous, causing jack knifing and a bad derailment. The use of sufficient air to reduce the buffer pressure is therefore, almost, a must. On the Denver and Rio Grande we understand buffing pressure is limited to 160,000 pounds on 3-degree curves or over. Until we have had more experience we might adopt 160,000 pounds as our limit. Then with a train developing 224,000 pounds pressure back of the locomotive, air braking of 64,000 pounds

would be required. This means an air reduction of about 2.12 pounds. In the test run, a reduction of about 4 pounds was used and this is figured to result in air braking of about 115,000 pounds. This is confirmed by test data which indicates that the electric locomotive was lightly loaded in regeneration.

The air brake system on the EF 5 does not lend itself to such refined handling. Method of making the reduction through the feed valve is unorthodox and a fine control such as desirable in this case may be impossible of attainment.

For the most economical operation, air reduction of about 3 pounds should be made, and then the necessary additional braking supplied by the locomotives. On the locomotives, control should be so handled that the electric locomotive develops near full braking capacity and the diesel locomotives used to supply whatever additional braking is required. By so handling, the operation should result in near maximum regeneration which means a direct reduction in the electric power bill. In every case engineer should so handle as to preserve safety of the operation.

#### Locomotive Operation

The various units in the electric locomotive performed credibly. These units had been out of service for a year or more and, therefore, were open to suspicion until they had seen some service. Early in the test several tripouts were experienced. Then motors steadied and gave no further trouble. On the return trip, a compressor and M.G. set flashed over. Since then there has been no trouble.

The diesel units performed satisfactorily. On the grades considerable slipping occurred and test operators on those units sanded manually. This is thought to be a weak spot in the set up. Experience with these GP9's (#280-332) indicates that sanders are inadequate. They are automatic and are set up to operate when slipping occurs. If correction is not made, that is, slipping stopped, locomotive will reduce its loading. It is suggested that the electric locomotive manual sanding control be extended to include electrical operation of the diesel sanders. This would provide sanding on both electric and diesel units at the will of the engineer. At the same time the automatic sanding on the diesel units would not be disturbed and would be effective if need developed. Cost of this change would be about \$20 to \$25. It is also suggested that additional sanders be installed on the diesel units in booster service.

The composite locomotive is about 392 feet long and weighs about 958 ton. It is cumbersome to use in train switching. Turning requires separation of the diesel and electric units.

#### Substations

The substations experienced no difficulty. With this operation they are not called on to use their full capacity and, except in some cases when two trains meet, are never put in a position where they have to back away from a load to protect themselves. Normally the General Electric

stations carry 3400 volts, and the Westinghouse stations 3250 to 3300 volts on the trolley. Exceptions to this occur in regeneration where assigned voltages are carried on a time schedule, so that locomotive voltage will be more uniform on the grade.

In this test with only one EF 5 locomotive pulling, charts show trolley voltage to be above that normally experienced by these trains.

  
H. R. MORGAN,  
Electrical Engineer

Electrification Department,  
Tacoma, Washington  
October 31, 1960

AG-648

COMPARATIVE RUNNING TIMES  
DIESEL BOOSTER TEST TRAINS

EASTBOUND 264

Section	MINUTES		AND		TONNAGE
	Time Card	Test 9/23/60	Trains 9/26/60	Test Train Using 4 Unit EP-1 and 2-CP9's Run 2/1-2-3/1960	Average 10 Trains Dec. '59 Jan. '60
	Min.	Min.Tons	Min.Tons	Min.Tons	Min.Tons
Tac.Jct. to Blk. Riv.	50	38-1099	53-2454	53-2111	66-3251
Renton to Ced.Falls	164*	57-4599	69-4797	71-3942	84-4868
Cedar Falls to Hyak	100	89-5491	78-5638	83-5065	90-5219
Hyak to Cle Elum	49	49-5491	58-5638	42-5065	51-5219
Cle Elum to Kittitas	60	46-5491	57-5638	50-5065	56-5089
Kittitas to Boylston	45	36-5491	40-5686	37-5065	46-5089
Boylston to Beverly	65	75-5491	70-5686	66-5065	63-5089
Beverly to Othello	161*	60-4685	68-5082	61-5065	84-5256
Total	694" 11'34"	460" 7'40"	493" 8'13"	463" 7'43"	540" 9'0"

WESTBOUND 263

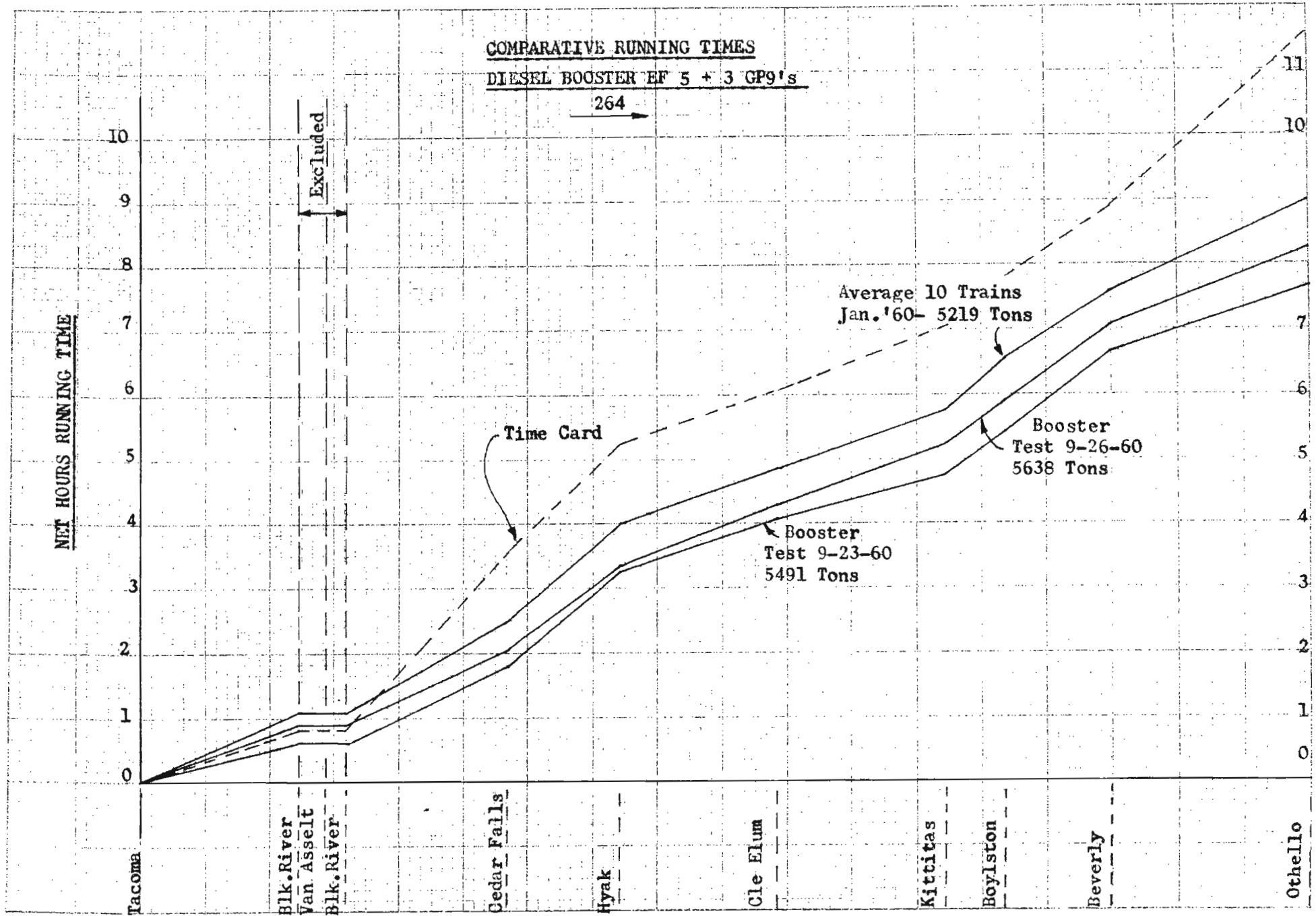
Othello to Beverly	57	67-4260		56-4831	63-4557
Beverly to Boylston	75	61-4260		75-4831	76-4372
Boylston to Kittitas	22	19-4260		12-4831	28-4372
Kittitas to Cle Elum	56	60-4260		47-4831	69-4372
Cle Elum to Hyak	54	58-4160		70-4831	70-4352
Hyak to Cedar Falls	74	75-4160		78-4831	63-4352
Cedar Falls to Renton	61	59-4160		59-4735	51-4102
Blk.Riv. to Tac.Jct.	40	55-2666		38-2121	56-2956
Total	439" 7'19"	454" 7'34"		435" 7'15"	476" 7'56"

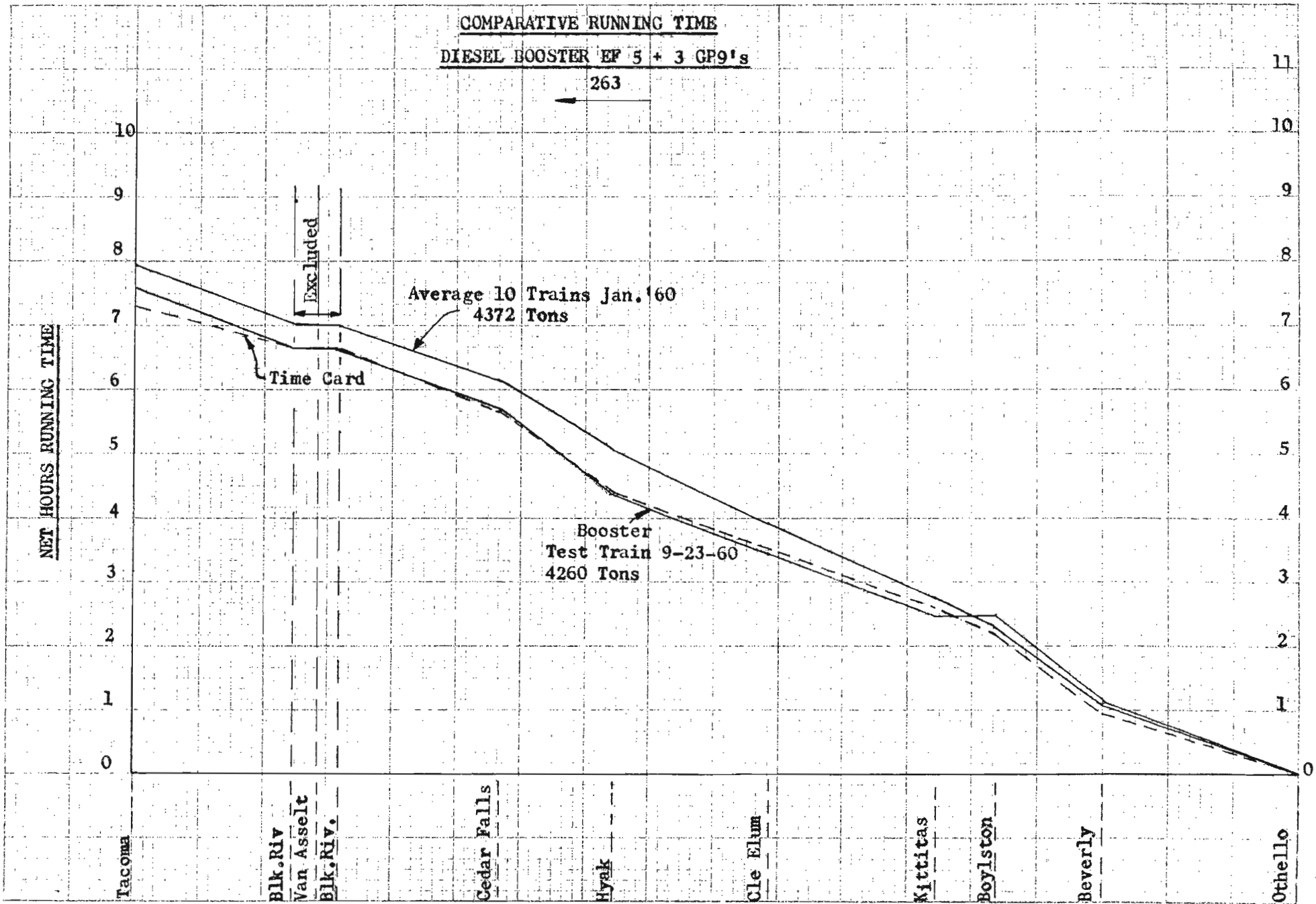
## Note:

Time from Blk.River-Van Asselt-Renton excluded

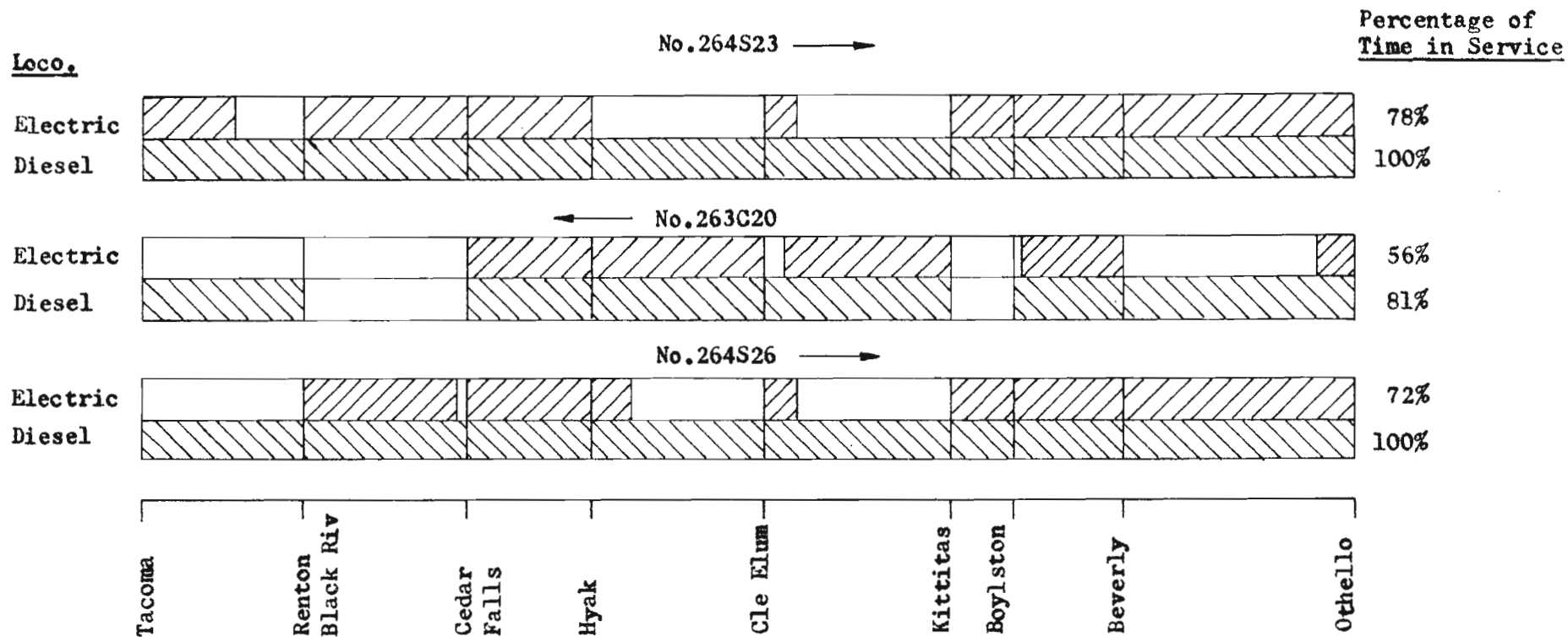
\*Apparently allows for train makeup.



The Milwaukee Road,  
Electrification Dept.,  
Tacoma, Wash- Oct.13,1960

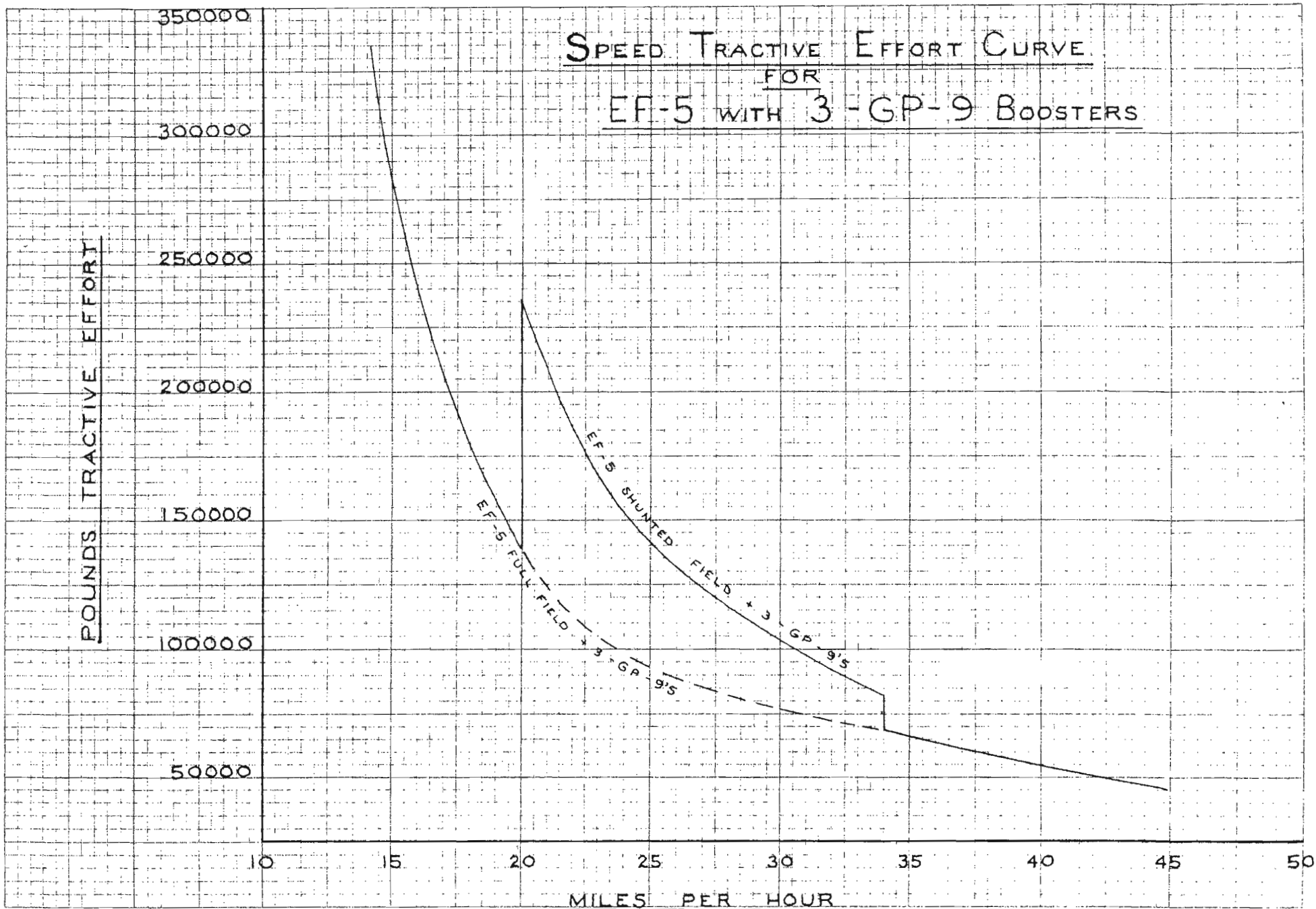




TEST OF ELECTRIC LOCOMOTIVE WITH DIESEL BOOSTER  
RELATIVE USAGE OF ELECTRIC AND DIESEL COMPONENTS



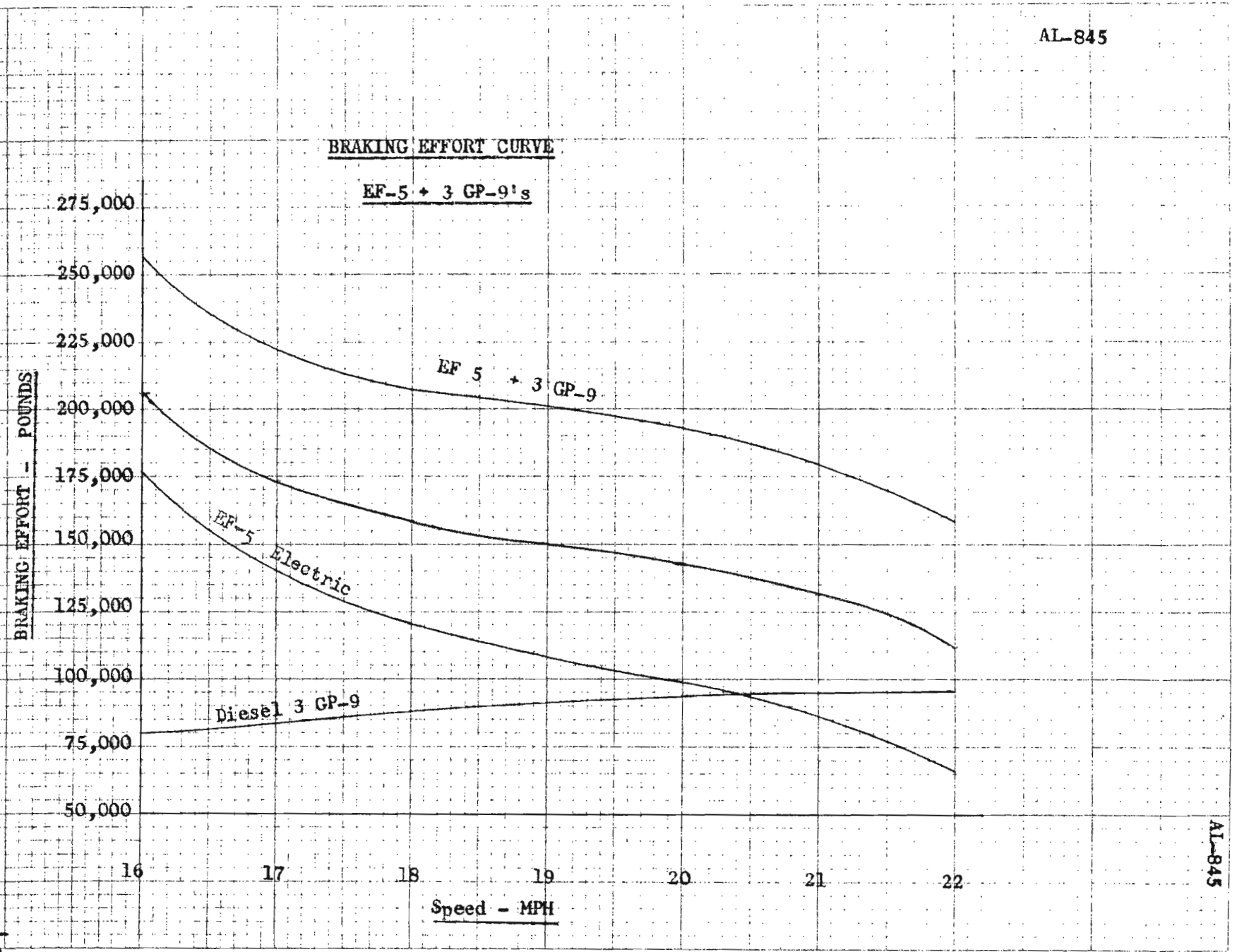
Note:  Indicates locomotive in service  
 Indicates locomotive cut out



AL-845

BRAKING EFFORT CURVE

EF-5 + 3 GP-9's



Elec. Dept.,  
Tacoma, Wash-  
Oct. 27, 1960

AL-845

TONNAGE RATINGS

DIESEL BOOSTER OPERATION ON COAST DIVISION

EF 5 With GP9 Diesel Units

<u>Motoring</u>	<u>EF 5 Locomotive With</u>			
	<u>1- GP9</u>	<u>2-GP9's</u>	<u>3-GP9's</u>	<u>4-GP9's</u>
Cedar Falls to Hyak	4160	4930	5700	6460 6470
Kittitas to Boylston	4520	5370	6220	7070
Beverly to Boylston	3000	3600	4200	4800
 <u>Braking *</u>				
Hyak to Cedar Falls	6950	8000	9050	10,100
Boylston to Beverly	3880	4500	5120	5,740
Boylston to Kittitas	7220	8360	9500	10,640

\* Based on locomotive capability using regenerative and dynamic braking only. Tonnages over those indicated will require additional braking from the air brake system.

BOYLSTON BEVERLY  
 5120 EF5 + 3 GP9's  
 3880 2 GP9's  
 5720 TONS

CEEDAR HYAK  
 7220  
 2550  
 9770 TONS

Electrification Department,  
 Tacoma, Washington  
 October 31, 1960

DRAWBAR STRENGTH

Following values were published in 1955. New tests have just been completed which indicate higher values, but formal report has not been released at this date.

<u>TYPE</u>	<u>Yield Point Pounds</u>	<u>Ultimate Strength Pounds</u>	<u>Safe Pounds</u>
Older type "E" couplers with E 50 knuckles, grade B steel normalized average 225,000#	225,000	560,000 to 600,000	200,000
New type "E" couplers with E 50 knuckles, normalized and tempered.	300,000	<sup>510,000</sup> 535,000 to 630,000	250,000
Type "E" couplers for <u>diesel locomotive</u> with type "E" quenched and tempered HTS knuckles.	400,000	700,000 to 750,000	350,000

DRAWBAR LOADING OBSERVED DURING TEST

<u>Train</u>	<u>Section</u>	<u>Drawbar Loading From Dynamometer Car</u>		
		<u>R u n n i n g</u>		<u>S t a r t i n g</u>
		<u>Average</u>	<u>Maximum</u>	<u>Peak</u>
264S23	Cedar-Hyak	211,000 lbs.	247,200 lbs.	277,000 lbs.
263C20	Beverly-Boylston	201,000 lbs.	207,000 lbs.	277,000 lbs.
264S26	Cedar- Hyak	217,000 lbs.	226,200 lbs.	--

<u>Buffing Pressure</u>				
264S23	Boylston-Beverly	108,900 lbs.	118,900 lbs.	173,200 lbs.
263C20	Hyak-Cedar	102,000 lbs.	122,000 lbs.	--
264S26	Boylston-Beverly	141,000 lbs.	179,000 lbs.	--

Electrification Department,  
Tacoma, Washington,  
October 20, 1960.

LOCOMOTIVE KWH FOR DIESEL BOOSTER TEST TRAIN  
FIRST RUN 9-23-60

<u>SECTION</u>	<u>Sub KWH @ 2300 AC</u>	<u>KWH at E-39 Using</u>		<u>Diesel KWH</u>	<u>Sub KWH Switch- ing between Runs</u>
		<u>Sub Ammeter</u>	<u>Loco Meter</u>		
Tac.Jct.- Blk Riv.	400	222	133	1050	1000
Renton-Cedar Falls	2900	2625	2533	3763	1000
Cedar Falls- Hyak	8980	7370	7525	4974	
Hyak- Cle Elum	1800	....	....	433	
Cle Elum- Kittitas	750	471	128	Meter Stopped	400
Kittitas-Boylston	3030	2655	2629		
Boylston-Beverly	-1160	-1390	-1470	-2257	800
Beverly- Othello	1910	1560	1343	3189	450
<hr/>					
Total East	+19770 - 1160	14903 - 1390	14291	13409	3650
<hr/>					
Othello -Beverly	900	*	251	1406	900
Beverly- Boylston	*	*	4379	3675	
Boylston-Kittitas	*	*	....	Air	
Kittitas-Cle Elum	1150	610	630	2418	300
Cle Elum-Hyak	1860	1229	1374	3191	
Hyak-Cedar Falls	-1760	-2276	-2617	-1745	
Cedar Falls-Renton	200	....	....	Air	1100
Blk Riv.-Tac.Jct.	1610	....	....	1320	100
<hr/>					
Total West			6634 -2617	12010	2400

\* Reading not assignable because other train in section

.... Electric not used- diesel only

The Milwaukee Road,  
 Electrification Dept.,  
 Tacoma, Wash. Oct. 13, 1960

COMPARATIVE HORSEPOWERSDEVELOPED ON TEST 9-23-60

For

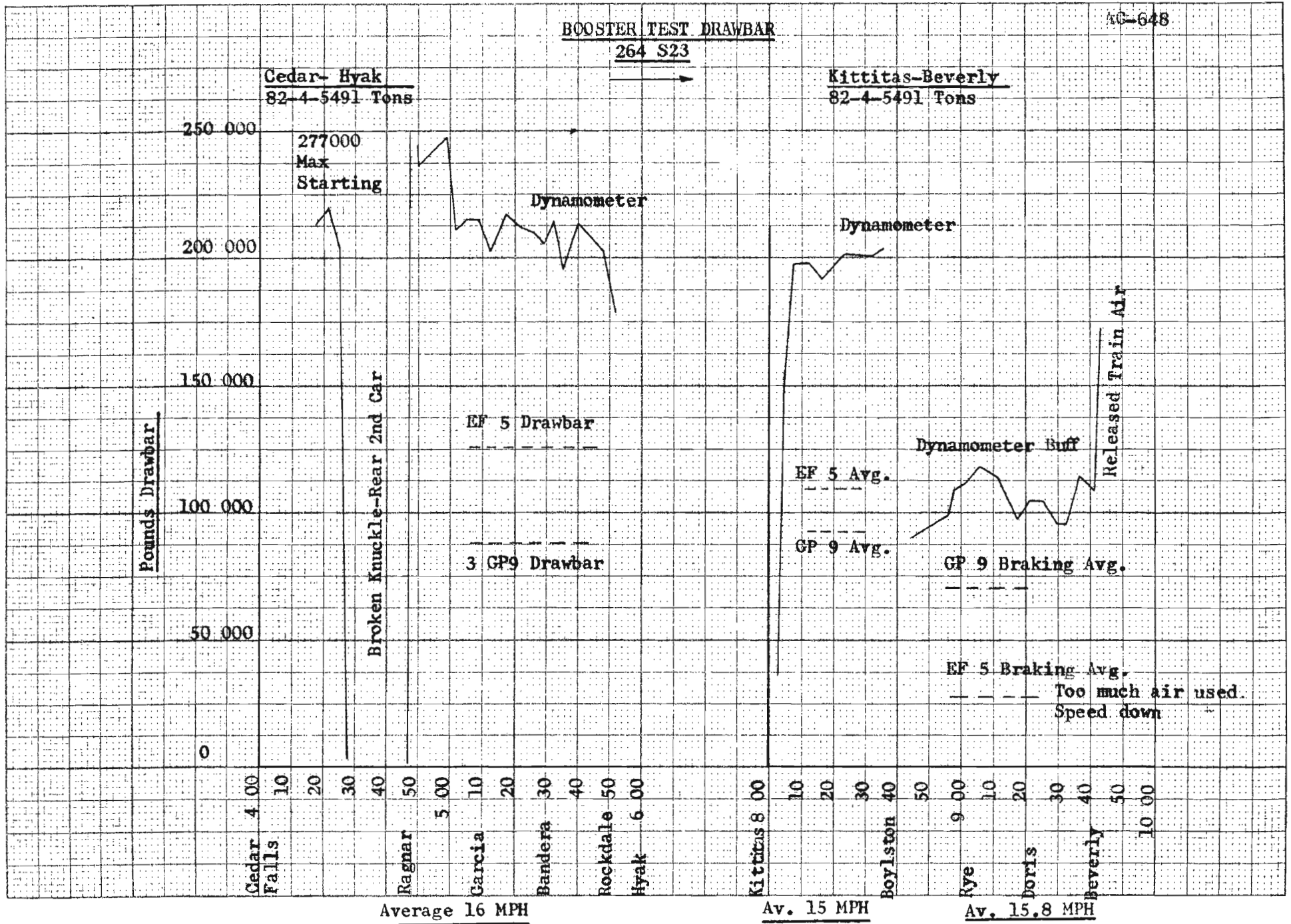
HEAVY GRADES

<u>Section</u>	<u>Average Electric Horsepower to Traction Motors Developed from Recording Meters</u>			<u>Average Drawbar H P From Dynamometer Car</u>
	<u>EF 5</u>	<u>3 GP9's</u>	<u>Total</u>	
<u>EAST</u>				
Renton - Cedar Falls	2960	4525	7485	—
Cedar Falls- Hyak	5430	4500	9930	9050
Kittitas- Boylston	5310	<sup>3100</sup> Meter Stopped	—	8410 <sup>5210</sup> <sup>3100</sup>
Boylston- Beverly	-1645	-3020	-4665	-4590
<u>WEST</u>				
Beverly - Boylston	4770	4850	9620	8170
Cle Elum- Hyak	1745	4430	6175	—
Hyak - Cedar Falls	-2815	-2340	-5155	-4690

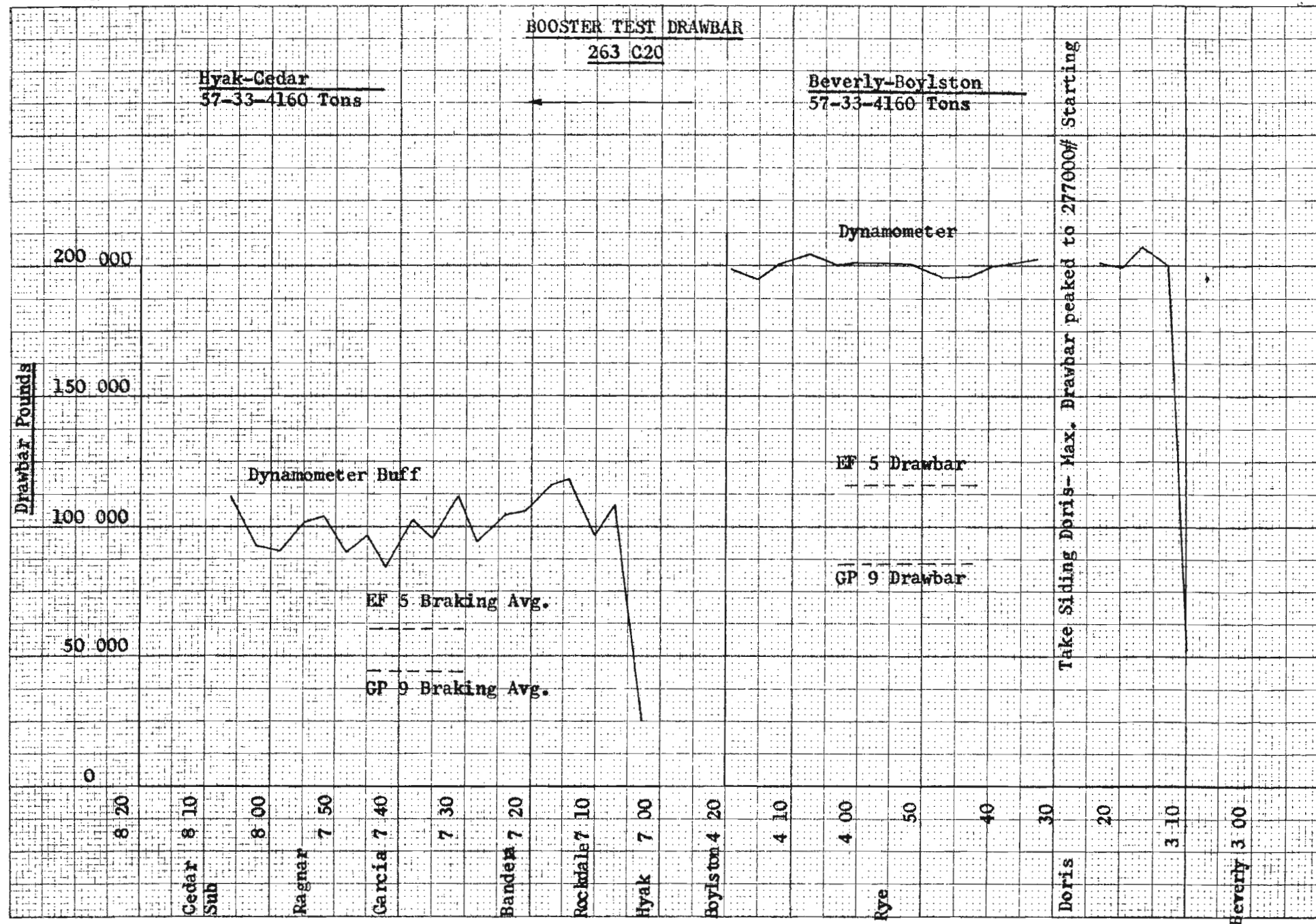
COMPARATIVE LOCOMOTIVE RAIL HORSEPOWER

<u>Locomotive</u>	<u>15.5 MPH (Cont. Rating EF 5)</u>	<u>14.5 MPH (One Hour Rating EF 5)</u>
<u>Test Train</u>		
EF 5 (4 Units)	6,680	8,200
3 GP9 Units	4,500	4,400
Total	11,180	12,600
<u>Regular Train</u>		
EF 5 (4 Units)	6,680	8,200
Hlpr. EF 3 (3 Units)	5,010	6,150
	11,690	14,350

Electrification Dept.,  
Tacoma, Washington  
Oct. 20, 1960



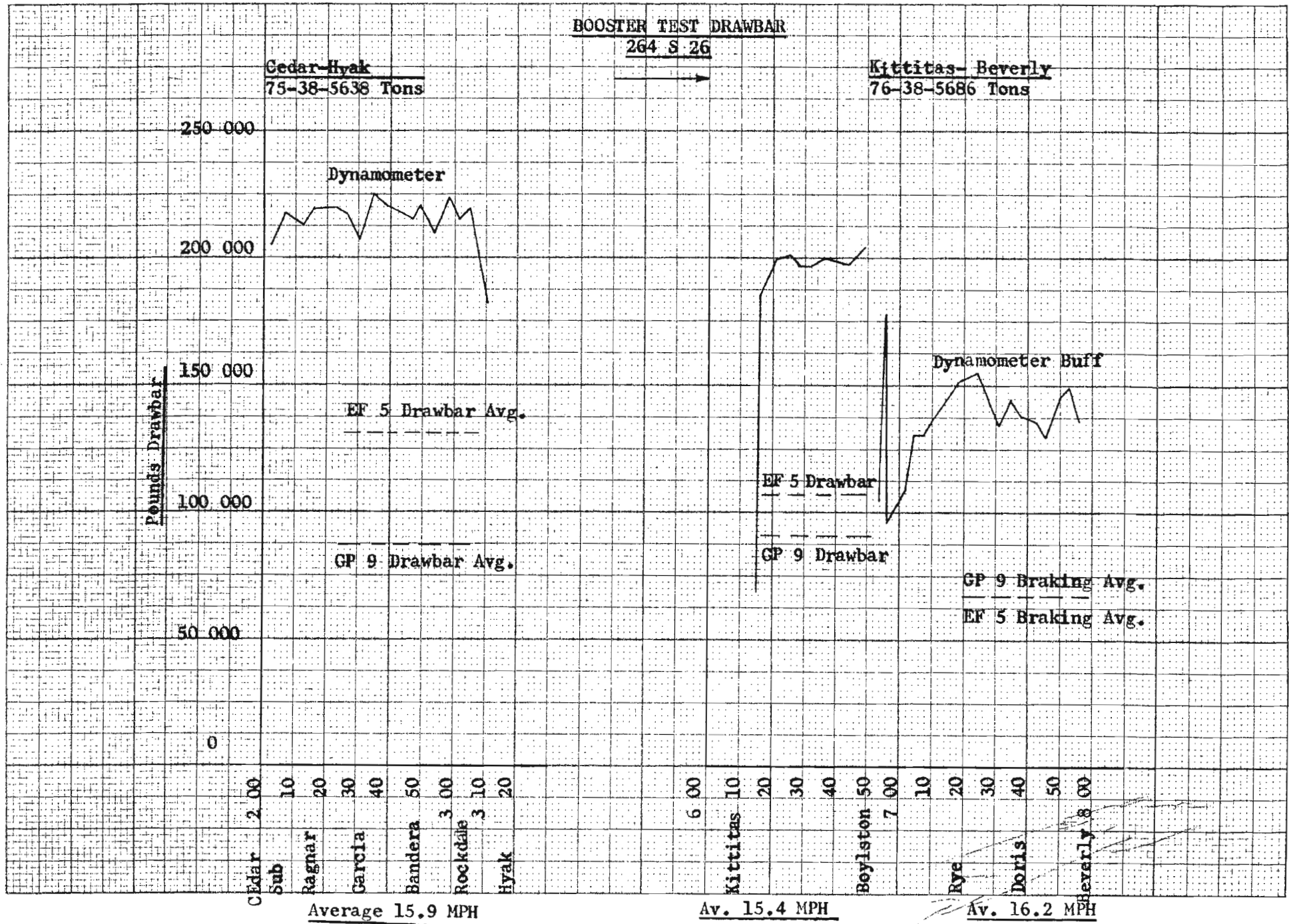
PRINTED IN U.S.A.



Av. 17.25 MPH

Av. 15.25 MPH

PRINTED IN U.S.A.



C O M P A R I S O N  
DIESEL BOOSTER TEST TRAINS  
 Vs.  
AVERAGE 10 REGULAR TRAINS

<u>Section</u>	<u>TONS MILES/HOUR</u>			<u>TON MILES/HOUR/M CONT. RAIL H P</u>		
	<u>Average</u> <u>10 Trains</u>	<u>Test</u> <u>9-23-60</u>	<u>Train</u> <u>9-26-60</u>	<u>Average</u> <u>10 Trains</u>	<u>Test</u> <u>9-23-60</u>	<u>Train</u> <u>9-26-60</u>
<u>EAST</u>						
Tac.Jct.-Blk. Riv.	77,433	48,659	77,792	11,592	4,352	6,958
Renton -Cedar	94,926	118,194	116,087	14,210	10,571	10,383
Cedar -Hyak	75,849	80,717	94,718	6,488	7,220	8,472
Hyak -Cle Elum	178,060	193,283	167,449	26,656	17,288	14,977
Cle Elum-Kittitas	172,906	227,327	188,309	25,884	24,806	16,843
Kittitas-Boylston	70,330	97,190	90,407	5,264	8,693	8,086
Boylston-Beverly	91,117	82,365	81,820	6,820	7,367	7,318
Beverly -Othello	141,917	177,093	169,230	21,244	15,840	15,136
Total East	108,617	115,090	116,117	13,400	10,294	10,386
<u>WEST</u>						
Othello -Beverly	164,052	144,414		24,559	12,917	
Beverly- Boylston	64,873	78,810		4,856	7,049	
Boylston-Kittitas	99,236	142,284		14,856	12,726	
Kittitas-Cle Elum	120,515	135,042		18,041	12,078	
Cle Elum-Hyak	108,147	123,552		16,190	11,051	
Hyak -Cedar	90,356	72,384		13,526	6,474	
Cedar -Renton	131,797	117,312		19,723	10,493	
Blk.Riv.-Tacoma	83,009	81,046		12,426	7,249	
Total West	105,468	91,807		14,907	8,211	

## Note:

Black River- Van Asselt excluded  
 Delays for meets excluded

Electrification Department,  
 Tacoma, Washington  
 October 20, 1960

COAST DIVISION ELECTRIFICATIONWater Grade and Mountain Grade Miles

	<u>Water Grade</u>	<u>Mountain Grade</u>	<u>Total</u>
Tacoma to Black River	28.2		28.2
Black River to Van Asselt	4.3		4.3
Van Asselt to Black River	4.3		4.3
Black River to Cedar Falls	29.7		29.7
Cedar Falls to Hyak		21.8	21.8
Hyak to Cle Elum	29.0		29.0
Cle Elum to Kittitas	31.7		31.7
Kittitas to Beverly		29.4	29.4
Beverly to Othello	<u>37.8</u>	<u>          </u>	<u>37.8</u>
	165.0	51.2	216.2
Percentage	76.4%	23.6%	100.0%