FRA-OR&D

CALCULATED PERFORMANCE OF THE RC4A AND CC14500 LOCOMOTIVE HAULED AMFLEET CONSISTS

NEW YORK – WASHINGTON, D.C.

January 1977

FINAL REPORT

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16. Abstract

This report presents a description and the results of Train Performance Calculations performed to determine the performance of specific Swedish and French Locomotive Hauled Amfleet Consists on the existing Northeast Corridor track route between New York City and Washington, D.C., assuming a maximum authorized speed of 120 mph.

17. Key Words
Northeast Corridor, New York, N.Y.-Washington, D.C., ASEA RC4A, Alsthom CC14500, Amfleet, Train Performance Calculator.

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INTRODUCTION

SECTION 1 - INTRODUCTION AND FINDINGS

1.1 Introduction

The Train Performance Calculator (TPC) is a computer program which simulates the movement of a train with specific performance characteristics over a track profile with known speed limits, grades, and curves. It provides valuable information describing the requirements and actions of the train which can then be used in vehicle, track, and electrification system design. TPC provides necessary data to allow for a systems design approach, with strong economic support.

In this report the Bechtel TPC program has been executed for two vehicle types and two consist lengths as specifically directed by FRA, over the New York-Washington Northeast Corridor track system, incorporating certain modifications (described later) over today's system. The following is a brief summary of the results of those four runs. Section 2 is a description of the TPC model. Section 3 is a description of the corridor route over which the vehicles were simulated. Section 4 provides the definition of specific vehicle performance characteristics for each of the vehicles. Finally, in Section 5, the results of the four runs are summarized and discussed. Appendix A contains the TPC route input data for the locomotive consists. Appendix B contains the actual TPC velocity/distance plots.

1.2 Findings

The four consists for which the TPC program was executed are:

(1) Loco - 1

One Alsthom CC14500 Locomotive and six Amcoaches with 120 mph top speed

(2) Loco - 2

One Alsthom CC14500 Locomotive and four Amcoaches with 120 mph top speed

(3) Loco - 3

One ASEA RC4A Locomotive and six Amcoaches with 120 mph top speed

(4) Loco - 4

One ASEA RC4A Locomotive and four Amcoaches with 120 mph top speed.

These vehicles are described completely in Section 3. The corridor route is based on the existing alignment assuming no slow orders, using 1970 Railroad Timetable civil restrictions, and certain diversions as described in Section 3.

Table 1-1 summarizes the results of the TPC runs, which are based on the simulated runs with no allowances for delays associated with congestion or reliability.

TABLE 1-1

TPC RESULTS - NEW YORK TO WASHINGTON, D.C.

		Elapsed Time*	Energy Command	Energy Consumed Per Car Mile
Run Loco 1	CC14500 + 6 trailers	2H 54M 57S	9521 KWH	7.03 KWH
Run Loco 2	CC14500 + 4 trailers	2H 52M 48S	7610 KWH	8.42 KWH
Run Loco 3	ASEA RC4A + 6 trailers	2H 58M 13S	8701 KWH	6.42 KWH
Run Loco 4	ASEA RC4A + 4 trailers	2H 54M 51S	7027 KWH	7.77 KWH

* Includes 5 stops of 1.25 min. dwell, 6 min. 15 sec. total.

In addition to these four runs, an analysis was completed utilizing these and the previous six runs made as part of the Locomotive Evaluation, included in a report entitled "Calculated Performance of the Metroliner and Locomotive Hauled Amfleet Consists, New York - Washington, D.C. completed for the FRA under Contract DOT-FR-64251. Summary points of this analysis are itemized below, and are described more completely in Section 5.

(1) When all three of the route profiles used in these ten runs are normalized to negate the effects of vehicle performance, the increase in elapsed time, above the Metroliner route, attributable to estimates in route restrictions is on the order of five minutes for the French and Swedish route profile, and in excess of twenty-five minutes for the profile estimated for the E60CP locomotive.

(2) Judicious selection of time effective right of way improvements, which must be made to fulfill the goals of the NEC Program, may benefit the locomotive consists more than the Metroliner and allow locomotive hauled trains to remain a formidable competitor for NEC service.

(3) While differences in four and six car consist trip times are reasonably small for the French and Swedish vehicles, the probable future requirement of a ten car train would

require the Swedish locomotive consist to be "double headed" to remain competitive with a single French locomotive.

(4) Although large increases in vehicle performance between zero and 50 mph will have virtually no effect on elapsed running times on the New York to Washington route, moderate increases in performance in the speed range above 50 mph may effect a marked improvement in run times.

(5) The operating requirements and route profile characteristics for the New York to Washington segment of the Corridor are markedly different than those of the Northern segment from New York to Boston. The final identification of vehicle performance requirements must equally consider both segments of the railroad before an optimal vehicle can be defined.

TPC MODEL

SECTION 2

THE TRAIN PERFORMANCE CALCULATOR MODEL

2.1 General

The Train Performance Calculator (TPC) is a computer program which simulates the movement of a train with specified performance characteristics over a track profile with known speed limits, grades and curves. The program computes the following:

At any corridor location	At each Station Stop and Total Run Summary
o elapsed time	o percentage of run time in each speed range
o instantaneous power	o distance traveled
o tractive effort ($\pm$)	o run time
o train resistance	o average speed
o acceleration ($\pm$)	o station dwell
o velocity	o RMS energy consumed
o accumulated energy consumption	o acceleration and constant speed energy consumed running time
	o braking energy consumed braking time

Power and braking capabilities can be varied and track characteristics modified or improved until satisfactory time goals are obtained.

2.2 Program Description

The Train Performance Calculator is an iterative program in which equations for acceleration, velocity, and distance are applied to determine the behavior of the train. Using input data which defines the speed limit at any point on the track, the program logically decides whether to accelerate to a higher speed or decelerate in anticipation of a lower speed restriction. The velocity of the vehicle, its characteristics, and track information are combined to determine the net force acting to accelerate or decelerate the train. This force, applied over the iteration time period, produces a change in velocity. The velocity, in turn, determines how far the train moves in the time interval. The duration of the interval is automatically adjusted so that the train neither travels more than 1 second, nor violates any speed limits in one iteration. The one second time interval has been found to assure sufficient accuracy of the results without incurring undue computer expense.

The product of the tractive effort and the distance traveled is a measure of the energy required during the time period, and is summed over the run to yield the total energy consumed. The magnitude of this energy is important in evaluating the economy of various train/track configurations and forms one basis for optimization.

2.3 Vehicle Input Information

In order to adequately describe the train, the following data must be provided: plots or equations defining the tractive and braking efforts as a function of speed; the locomotive weight, length, number of axles, the coach weight, length and number of axles and frontal area; the consist size(number of cars); and the auxiliary power used per car. In addition, coefficients used to determine the train resistance must be specified.

The tractive and braking effort information is supplied as a function of velocity and is used by the program to determine the acceleration or deceleration capability. This input arrangement allows the analyst to stipulate any given performance and evaluate its impact on run times and power consumption. A series of points lying on the curve of tractive efforts vs. speed is input, and the computer will interpolate.

The weight per car and the number of cars are used in the dynamics relations and also in formulating the train resistance. The latter is calculated using the Davis equation which is of the form:

$$R = 1.3 + \frac{29}{w} + bV + \frac{CAV^2}{wn}$$

where R = Train Resistance (lb/ton)

w = Weight per axle (tons)

n = Number of axles

C = Coefficient of drag

A = Cross-sectional area of vehicles in FT^2

V = Velocity in mph

b = Coefficient of flange resistance.

This is added to the effects of grade and track curvature to determine the resultant, which is added to the acceleration or braking effort, producing a net force on the train.

2.4 Track Input Information

The track characteristics provide the input that the program logic uses to determine whether acceleration or deceleration is required. Therefore, the length of the track and the speed limit in each segment must be supplied. Data on grade and curvature is used to compute the remaining terms in the train resistance equations and must be furnished.

The speed limits input to the computer must take account of the fact that the program does not consider train length in determining where to accelerate. Therefore, the programmer must extend speed restrictions far enough to prevent overspeeding the rear of a long train after passing each speed restriction. Factors such as the condition of the track, the radius of a curve, and the superelevation must be considered when deciding the speed limit applied to any portion of the road.

The input must include the grade at every point on the track route. Positive (uphill) grades add 20 lbs/ton/% of grade to the train resistance. Downhill grades reduce the magnitude of the resistance by a like amount.

ROUTE DESCRIPTION

SECTION 3 - CORRIDOR ROUTE DESCRIPTION

The purpose of this section is to describe the track system over which the hypothetical trains were simulated in the TPC program. The existing system is described, followed by changes as a result of track specific modifications. Last, the speed table used in TPC will be discussed.

To define the existing track system, the following primary data sources were used:

1. Penn Central Eastern Timetable #5, 5/17/70.
2. Penn Central Track Charts.
3. Penn Central-AMTRAK letter of 9/30/74 (E60CP allowable speeds)

From these sources the existing system was described, including the following items which affect running speed and performance:

1. Degree of curve
2. Stationing of curve
3. Superelevation
4. Bridge, tunnel, station, and interlocking location
5. Grade and percentages
6. Intermediate station stops at Metro Park, Trenton, Philadelphia, Wilmington, and Baltimore (75 seconds/stop)

Having established the "as exists" track system, the speed tables developed for TPC included the following modifications:

1. All temporary slow orders ignored
2. Trackage rehabilitated to "as constructed" condition
3. Speeds projected to 120 mph for the locomotives
4. Estimated speed increases due to reduced locomotive weight.

Also considered in the estimated allowable speed profiles were the following:

1. Best case Metroliner's speed ("A" trains TT #5-120 mph)
2. Best case locomotive hauled train ("B" train TT #5-100 mph)
3. Originally planned allowable speeds for E60 locomotives - 100 mph.

Based on the existing track system, modified as described, a speed table identified as NEC-3S was developed. The speed table identifies the maximum allowable speed over the entire New York-Washington, D.C. route, and is included in Appendix A.

VEHICLE DESCRIPTION

SECTION 4 - CORRIDOR VEHICLE DESCRIPTION

Vehicles depicted in this study are a portion of a group considered as primary candidates for corridor operation in the near term, namely the Swedish ASEA RC4A locomotive and the French Alsthom CC14500 locomotive, both with Amfleet trailer cars. Various consist combinations were compared to determine possible differences in elapsed time due to changes in the power to weight ratios of the vehicles.

The specific consist combinations tested are as follows:

Run No.	Consist
Loco 1	CC14500 Locomotive and 6 Amcoach cars
Loco 2	CC14500 Locomotive and 4 Amcoach cars
Loco 3	ASEA RC4A and 6 Amcoach cars
Loco 4	ASEA RC4A and 4 Amcoach cars.

Specific vehicle information was acquired from vehicle manufacturers, published data, and AMTRAK through the FRA offices. In addition, estimates were made for modifications which would be required to make the subject locomotives compatible with AMTRAK fleet requirements. Both Alsthom and ASEA units would require installation of head end power. In addition, the ASEA unit would require a gear ratio change, the addition of dynamic braking capability, and improvement of the collision strength of the cab. As an aid in inputting vehicle characteristics to the TPC Program, a TPC Vehicle Data Form was developed, encompassing all vehicle information required to complete a TPC run. Table 4-1 through 4-4 show vehicle data inputs for the runs made in this study. Figures 4-1 through 4-3 depict specific tractive effort curves and braking rates established in conjunction with FRA, from which values were obtained for use in the TPC runs. Figure 4-4 shows a comparison of the tractive effort of all the consists reduced to a common base of tractive effort per ton of weight for each complete consist.

TABLE 4-1

TPC VEHICLE DATA

A	RUN NUMBER	Loco 1
B	SPEED TABLE NUMBER	NEC-3S

TRAIN CONSIST INPUT DATA
(Alsthom 14500 Locomotive)

CAR TYPE

C	ITEM	Loco	Amclub	Amcoach	Amcafe
D	# OF UNITS	1	1	3	1
E	POWERED	Yes	No	No	No
F	WEIGHT (#)	296,000(2)	121,200(1)	120,800(1)	121,200(1)
G	FRONTAL AREA ($FT.^2$)	130	105	105	105
H	LENGTH (FT.)	67.4	85	85	85
I	JOURNAL CON.	1.3	1.3	1.3	1.3
J	JOURNAL COEF.	29	29	29	29
K	FLANGE COEF.	.045	.045	.045	.045
L	AIR DRAG. COEF.	.0027	.0003	.0003	.0003
M	# OF AXLES	6	4	4	4

N	TOTAL TRAIN LENGTH	=	577.4	FEET
O	TOTAL TRAIN WEIGHT	=	511	TONS
P	TOTAL TRAIN AUXILIARY LOAD	=	300	KW
Q	ELECTRICAL EFFICIENCY	=	0.85	
R	TIME INCREMENT	=	1.0	SEC
S	MAXIMUM SPEED ALLOWED	=	120	MPH
T	ACCELERATION ADHESION LIMIT	=	500	#/TON
U	DECELERATION ADHESION LIMIT	=	500	#/TON
V	MAXIMUM ACCELERATING ALLOWED	=	2.0	MPH/SEC
W	MAXIMUM DECELERATION ALLOWED	=	2.0	MPH/SEC
X	POWER DENSITY	=	See Figure 4-1	

(1) Assumes all seats occupied at 180 lbs. each.

(2) Includes estimated modifications.

TABLE 4-2

TPC VEHICLE DATA

A	RUN NUMBER	Loco 2
B	SPEED TABLE NUMBER	NEC-3S

TRAIN CONSIST INPUT DATA
(Alsthom 14500 Locomotive)

CAR TYPE

C	ITEM	Loco	Amclub	Amcoach	Amcafe
D	# OF UNITS	1	1	2	1
E	POWERED	Yes	No	No	No
F	WEIGHT (#)	296,000(2)	121,200(1)	120,800(1)	121,200(1)
G	FRONTAL AREA ($FT.^2$)	130	105	105	105
H	LENGTH (FT.)	67.4	85	85	85
I	JOURNAL CON.	1.3	1.3	1.3	1.3
J	JOURNAL COEF.	29	29	29	29
K	FLANGE COEF.	.045	.045	.045	.045
L	AIR DRAG. COEF.	.0027	.0003	.0003	.0003
M	# OF AXLES	6	4	4	4

N	TOTAL TRAIN LENGTH	=	407.4	FEET
O	TOTAL TRAIN WEIGHT	=	390	TONS
P	TOTAL TRAIN AUXILIARY LOAD	=	200	KW
Q	ELECTRICAL EFFICIENCY	=	0.85	
R	TIME INCREMENT	=	1.0	SEC
S	MAXIMUM SPEED ALLOWED	=	120	MPH
T	ACCELERATION ADHESION LIMIT	=	500	#/TON
U	DECELERATION ADHESION LIMIT	=	500	#/TON
V	MAXIMUM ACCELERATING ALLOWED	=	2.0	MPH/SEC
W	MAXIMUM DECELERATION ALLOWED	=	2.0	MPH/SEC
X	POWER DENSITY	=	See Figure 4-1	

(1) Assumes all seats occupied at 180 lbs. each.
(2) Includes estimated modifications.

TABLE 4-3

TPC VEHICLE DATA

A	RUN NUMBER	Loco 3
B	SPEED TABLE NUMBER	NEC-3S

TRAIN CONSIST INPUT DATA
(ASEA RC4A Locomotive)

CAR TYPE

C	ITEM	Loco	Amclub	Amcoach	Amcafe
D	# OF UNITS	1	2	3	1
E	POWERED	Yes	No	No	No
F	WEIGHT (#)	214,000(2)	121,200(1)	120,800(1)	121,200(1)
G	FRONTAL AREA (FT.^{2})	140	105	105	105
H	LENGTH (FT.)	64(2)	85	85	85
I	JOURNAL CON.	1.3	1.3	1.3	1.3
J	JOURNAL COEF.	29	29	29	29
K	FLANGE COEF.	.045	.045	.045	.045
L	AIR DRAG. COEF.	.0027	.0003	.0003	.0008
M	# OF AXLES	4	4	4	4

N	TOTAL TRAIN LENGTH	=	574	FEET
O	TOTAL TRAIN WEIGHT	=	470	TONS
P	TOTAL TRAIN AUXILIARY LOAD	=	300	KW
Q	ELECTRICAL EFFICIENCY	=	0.85	
R	TIME INCREMENT	=	1.0	SEC
S	MAXIMUM SPEED ALLOWED	=	120	MPH
T	ACCELERATION ADHESION LIMIT	=	500	#/TON
U	DECELERATION ADHESION LIMIT	=	500	#/TON
V	MAXIMUM ACCELERATING ALLOWED	=	2.0	MPH/SEC
W	MAXIMUM DECELERATION ALLOWED	=	2.0	MPH/SEC
X	POWER DENSITY	=	See Figure 4-2	

(1) Assumes all seats occupied at 180 lbs. each.

(2) Includes estimated modifications.

TABLE 4-4

TPC VEHICLE DATA

A	RUN NUMBER	Loco 4
B	SPEED TABLE NUMBER	NEC-3S

TRAIN CONSIST INPUT DATA
(ASEA RC4A Locomotive)

CAR TYPE

C	ITEM	Loco	Amclub	Amcoach	Amcafe
D	# OF UNITS	1	1	2	1
E	POWERED	Yes	No	No	No
F	WEIGHT (#)	214,000 (2)	121,200(1)	120,800(1)	121,200(1)
G	FRONTAL AREA (FT.^{2})	140	105	105	105
H	LENGTH (FT.)	64(2)	85	85	85
I	JOURNAL CON.	1.3	1.3	1.3	1.3
J	JOURNAL COEF.	29	29	29	29
K	FLANGE COEF.	.045	.045	.045	.045
L	AIR DRAG. COEF.	.0027	.0003	.0003	.0008
M	# OF AXLES	4	4	4	4

N	TOTAL TRAIN LENGTH	=	404	FEET
O	TOTAL TRAIN WEIGHT	=	349	TONS
P	TOTAL TRAIN AUXILIARY LOAD	=	200	KW
Q	ELECTRICAL EFFICIENCY	=	0.85	
R	TIME INCREMENT	=	1.0	SEC.
S	MAXIMUM SPEED ALLOWED	=	120	MPH
T	ACCELERATION ADHESION LIMIT	=	500	#/TON
U	DECELERATION ADHESION LIMIT	=	500	#/TON
V	MAXIMUM ACCELERATING ALLOWED	=	2.0	MPH/SEC
W	MAXIMUM DECELERATION ALLOWED	=	2.0	MPH/SEC
X	POWER DENSITY	=	See Figure 4-2	

(1) Assumes all seats occupied at 180 lbs. each.

(2) Includes estimated modifications.

ALSTHOM CC 14500 TRACTIVE EFFORT CURVE

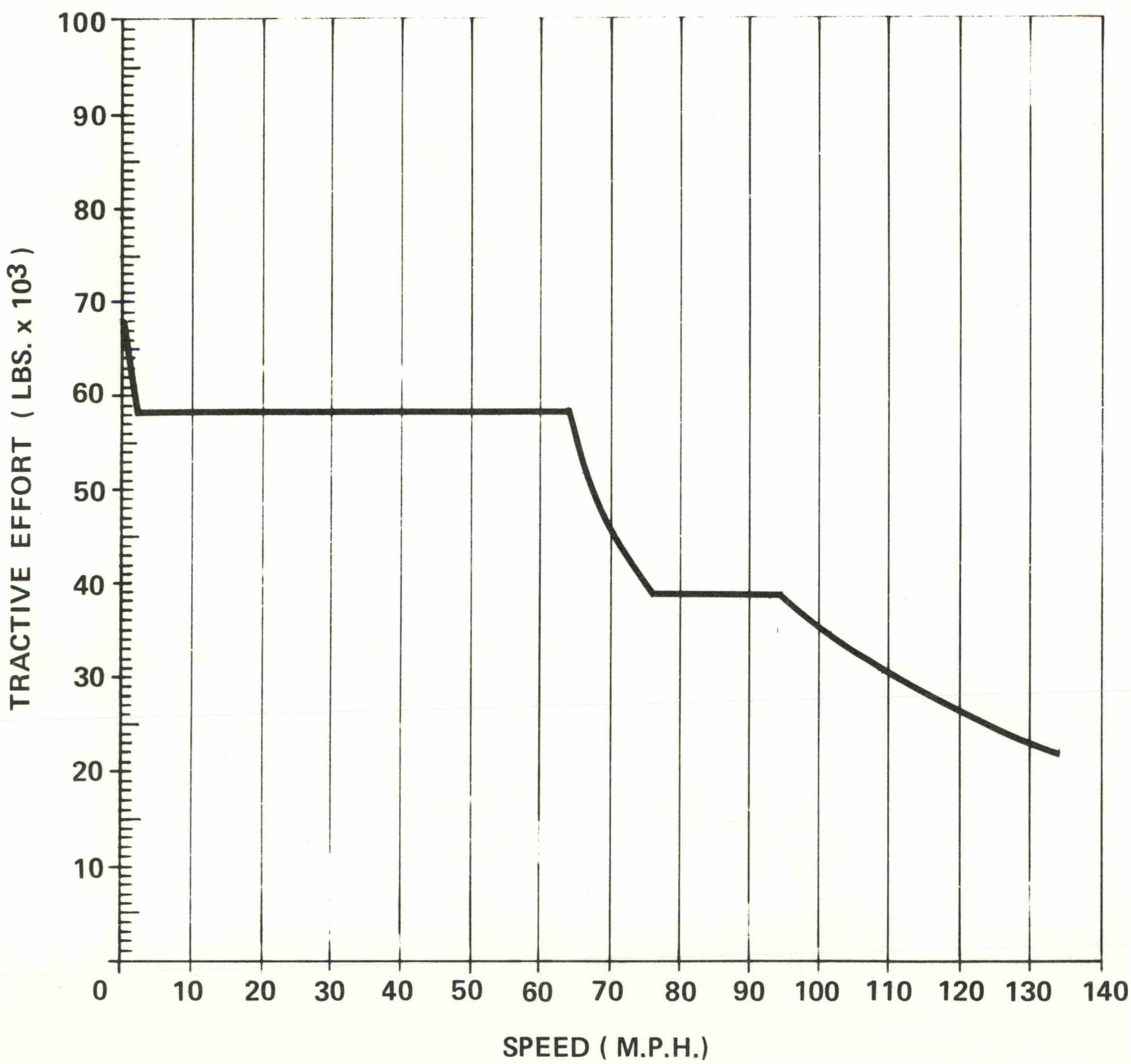

FIGURE 4-1

Federal Railroad Administration	NORTHEAST CORRIDOR HIGH-SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT	Date 1/77
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ASEA RC 4A TRACTIVE EFFORT CURVE

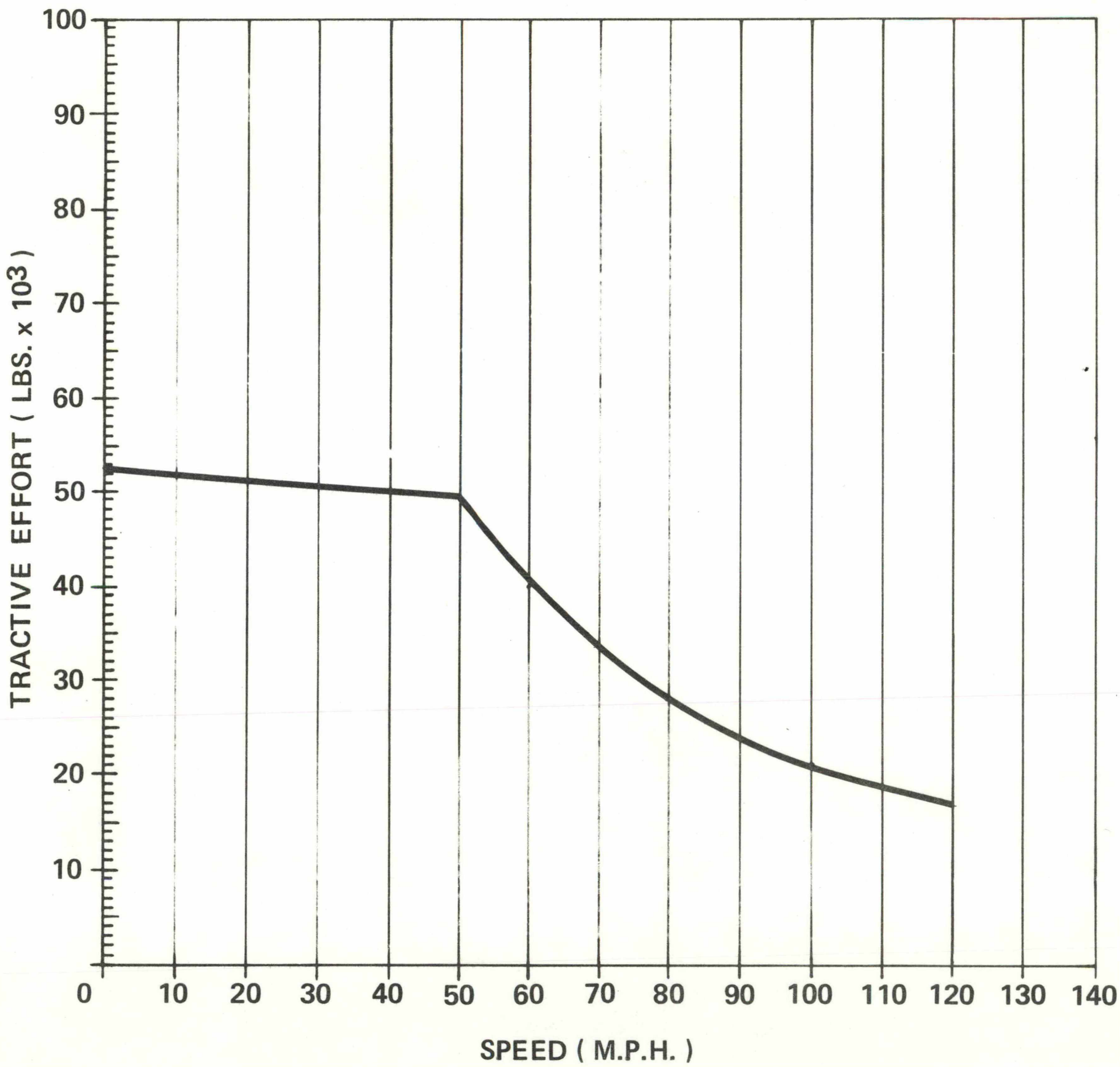

FIGURE 4—2

Federal Railroad Administration	NORTHEAST CORRIDOR HIGH-SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT	Date 1/77
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BRAKING CHARACTERISTICS
ALL VEHICLE CONSISTS

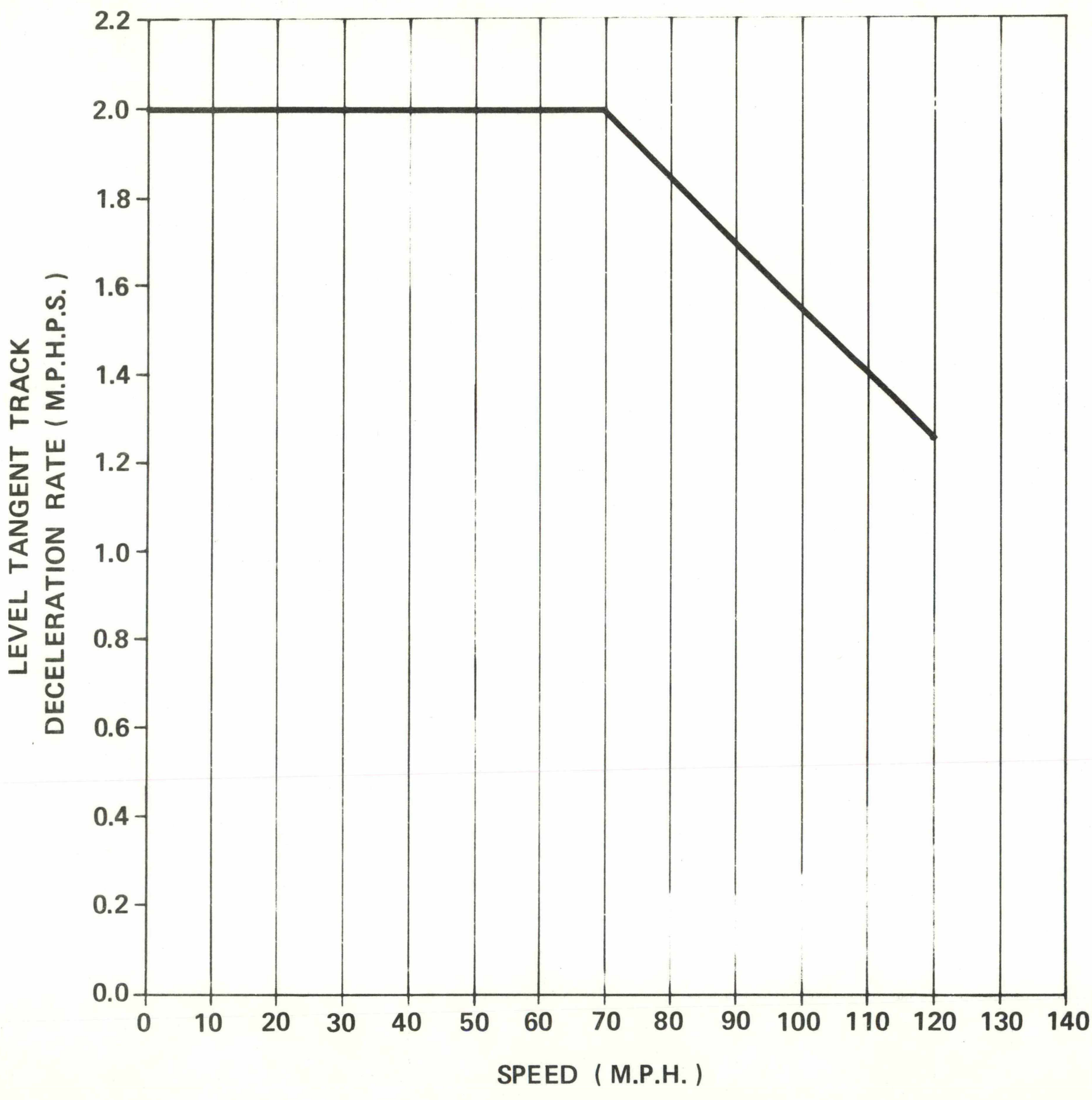

FIGURE 4–3

Federal Railroad Administration	NORTHEAST CORRIDOR HIGH-SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT	Date 1/77
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CONSIST POWER DENSITY COMPARISION
TRACTIVE EFFORT VS. SPEED ON LEVEL TANGENT TRACK

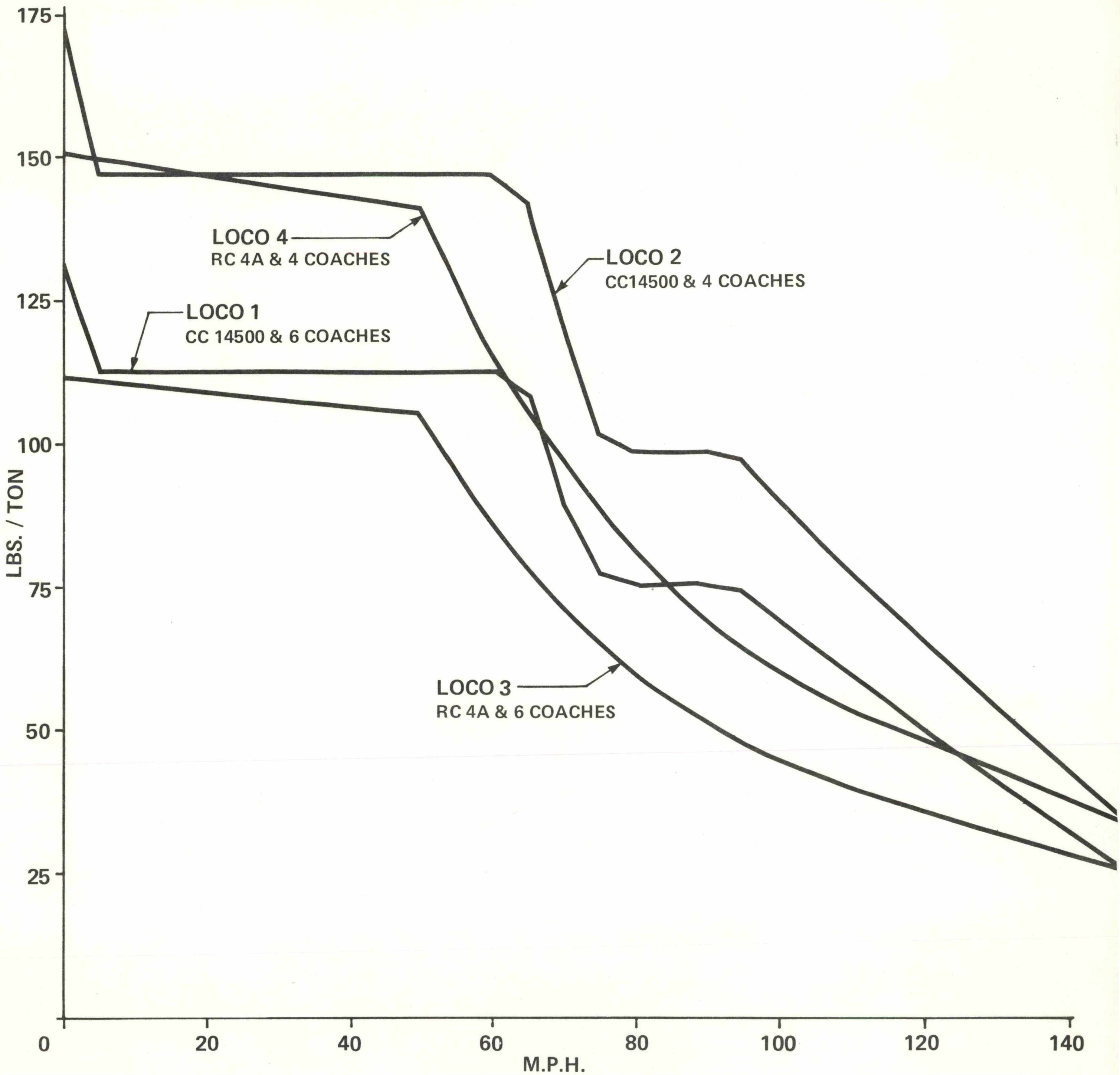

FIGURE 4-4

Federal Railroad Administration	NORTHEAST CORRIDOR HIGH-SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT	Date 1/77
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TPC RESULTS

SECTION 5 - TPC RESULTS

5.1 Simulation Summary

Information from the TPC run summary sheets using data as previously described in Sections 3 and 4 is summarized below in Table 5-1.

TABLE 5-1

TPC RESULTS - NEW YORK TO WASHINGTON, D.C.

Run #	Consist	Elapsed* Time (H:M:S)	Energy Consumed (KWH)	Average Speed (mph)
LOCO-1	CC14500 & 6 coaches	2:54:57	9521	80.3
LOCO-2	CC14500 & 4 coaches	2:52:48	7610	81.3
LOCO-3	RC4A & 6 coaches	2:58:13	8701	78.8
LOCO-4	RC4A & 4 coaches	2:54:51	7027	80.4

* Includes 6 minutes 15 seconds station dwell

Review of the above figures indicates a relatively small difference in total performance of the simulated locomotives. The Alsthom locomotive is 3 minutes 16 seconds faster than the ASEA unit in the six car consist, and 2 minutes 3 seconds faster than its counterpart in the four car train. The increase in energy consumption for these time savings in both cases is on the order of 8-9%. As this work is a continuation of the Locomotive Evaluation Program sponsored by the FRA Office of Research and Development, a comparison with earlier TPC simulations is in order. The prior TPC study included simulations of Standard Metroliners, Improved

Metroliners, and E60 CP locomotive consists. Figure 5-1 depicts a graphic comparison of the six previous TPC runs with the present 4 runs, as they relate to the legislated NEC goal of 2 hours and 40 minutes between New York and Washington, D.C.

Figures 5-5 through 5-10 contain TPC Run Summary Sheets for each of the runs including histograms depicting the percentage of run time spent in each speed range.

5.2 Route Profile Normalization

Note must be made in this comparison of the route profiles used to make the comparisons. While on the surface, the study appears to be a comparison of vehicles, the final result is a comparison of vehicle-route combinations. Three distinct route profiles were used in this analysis. NEC-1S, the route profile used for the Metroliner runs, was an estimate of the best speeds a Metroliner could be operated over the railroad. NEC-2S, by far the most restrictive of the three profiles, included severe restrictions for the E60CP locomotive runs primarily to this unit's higher weight. The route profile used in the current series of runs, NEC-3S, is another estimate of restrictions necessary for operation of the Swedish and French locomotives over the Corridor Route.

In order to correlate these variations in route profiles and to separate the estimated route restrictions from vehicle performance, TPC normalization runs were performed. Previous study work in Tasks 9 and 18 of the Northeast Corridor High Speed Rail Passenger Service Improvement

COMPARISON OF VARIOUS CONSIST ELAPSED TIMES TO NEC TRIP TIME GOALS

NEW YORK TO WASHINGTON ,D.C.

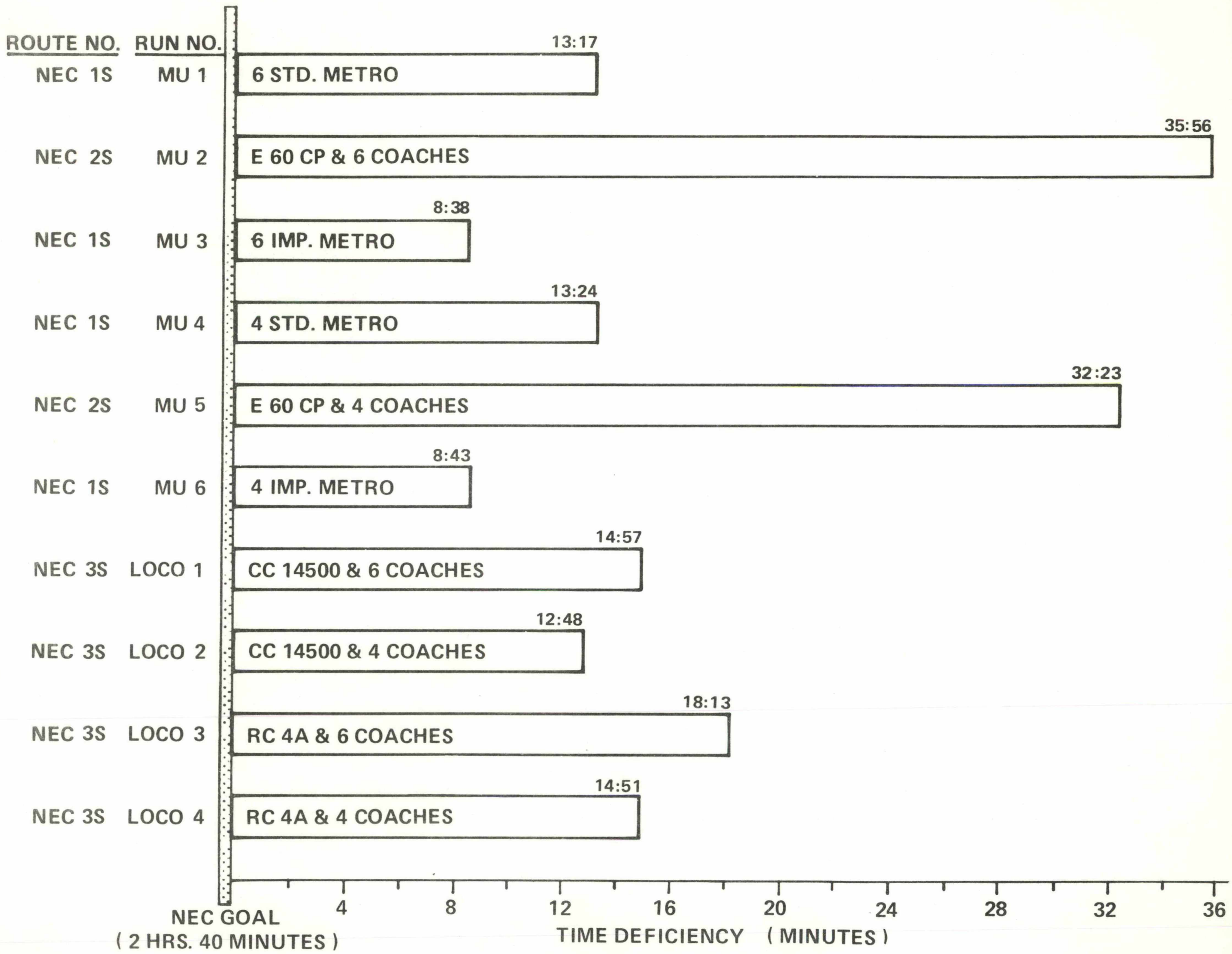

FIGURE 5 – 1

Federal Railroad Administration	NORTHEAST CORRIDOR HIGH-SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT	Date 1/77
Bechtel Incorporated		Job No 12131

Program has shown that all vehicles need not be run on every route profile to obtain adequate results, provided the normalization case vehicle is reasonably within the range of specific power density of the vehicle study group. The vehicle selected for the normalization run in this analysis was the same vehicle used in run MU-1, the presently operating Standard Metroliner. By simulating the Standard Metroliner on the NEC-2S and NEC-3S route profiles, a reasonable estimate can be made of the running time differential effected by route profile estimate variations irrespective of specific vehicle performance. Results of the normalization runs are shown in Table 5-2.

TABLE 5-2

TPC NORMALIZATION SUMMARY

Run #	Route Profile	Elapsed* Time	Δ to Baseline
MU-1 (baseline)	NEC-1S	2:53:17	———
MU-Loco A	NEC-2S	3:19:03	25 min 46 sec
MU-Loco B	NEC-3S	2:58:58	5 min 41 sec

* Includes 6 minutes 15 seconds station dwell

In general terms, elapsed time attributable to route profile restriction estimates amounts to 25 minutes 46 seconds for NEC-2S runs, and 5 minutes 41 seconds for NEC-3S runs.

The effect of the normalization is shown in Figure 5-2. This aspect of the analysis indicates that all three locomotives can be competitive with the Standard Metroliner in the six car configuration and even with the Improved Metroliners in the four car consist. The point to be made from all this is that selection of the right-of-way improvements to be undertaken to allow achievement of the 2 hour 40 minute time goal can influence vehicle selection by either narrowing or increasing the field of possible candidates. While the twenty-five minute normalization for the E60 is admittedly a special case, the five minute normalization for the French and Swedish units provides a case in point. Note that even the Improved Metroliners will require in excess of eight minutes in right-of-way improvements to achieve the 2 hour 40 minute time goal. If the selection of time effective ROW improvements includes consideration of benefits to the currently estimated locomotive restrictions in the NEC-3S route profile, a possible mutual savings may be realized. Conceivably some improvements to the ROW may alleviate locomotive restrictions as well, affecting a double savings for this locomotive, leaving the final vehicle selection more flexible. For example: If four of the eight minutes of ROW savings required by the Improved Metroliner benefited locomotive restrictions as well, the ultimate difference between the performance of the Alsthom locomotive and the Improved Metroliner would be approximately two minutes in favor of the Metroliner for a six car consist, and virtually a tie between the contenders in a four car consist.

NORMALIZED VEHICLE PERFORMANCE COMPARISON TO NEC GOALS

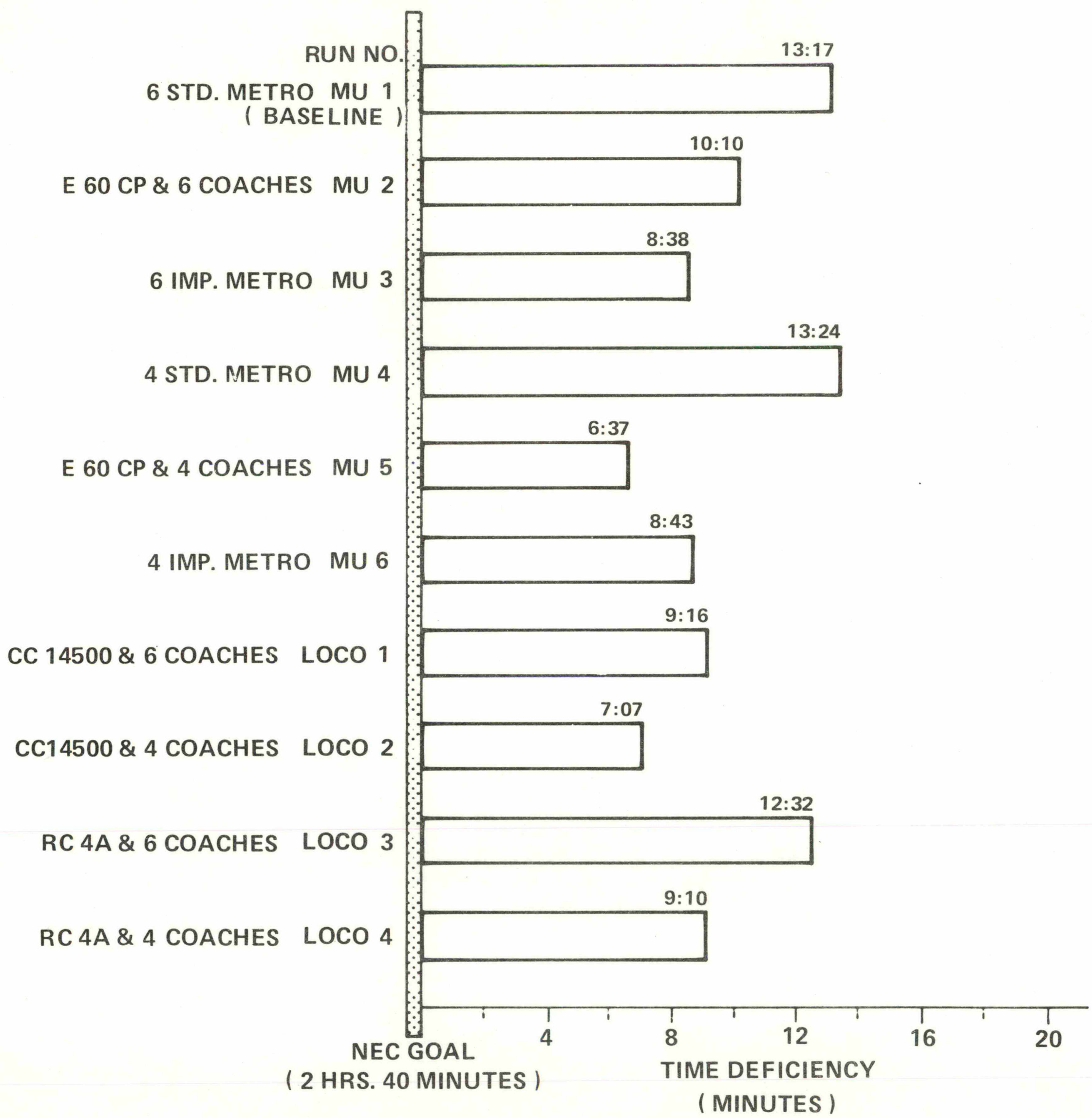

FIGURE 5 – 2

Federal Railroad Administration	NORTHEAST CORRIDOR HIGH-SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT	Date 1/77
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5.3 Consist Length Variation

Although the scope of this study was limited to four and six car consists, earlier studies completed for the FRA Northeast Corridor High Speed Rail Passenger Service Improvement Program have shown that, depending on the particular demand projections used, train lengths of ten to fourteen cars will be required by 1990. In order to gain insight into the question of performance of longer consists behind the candidate locomotives, two additional TPC simulations were performed. The same route profile and vehicle characteristics were used as those of runs Loco 1 and Loco 3, but four additional cars were added to each consist to simulate ten car trains. The results are shown in Table 5-3 below.

TABLE 5-3

TPC - 10 CAR CONSIST SUMMARY

Run No.	Consist	Elapsed Times* (H:M:S)
Loco 5	CC14500 & 10 coaches	2:59:37
Loco 6	ASEA RC4A & 10 coaches	3:05:31

* Includes 6 minutes 15 seconds station dwell

When these ten car runs are compared with the four and six car simulations, the value of the greater power of the Alsthom locomotive over the ASEA unit becomes more obvious. Whereas the ASEA is only two to three minutes slower than the Alsthom unit in four and six car consists, the difference increases to nearly six minutes in the ten car case. From Figure 5-3, showing the general tendencies indicated by this group of simulations, it can be seen that in the ten car consist, the ASEA RC4A would require double heading to remain competitive with the single CC14500 locomotive.

5.4 Analysis of Vehicle Characteristics

While actual tractive effort curves in this study were dictated by existing locomotives, it is interesting to note the relationship of their differences to the elapsed running times. Two significant comparisons can be made with data developed in this study. The first, shown in Figure 5-4A, compares power densities of runs Loco 1 and Loco 4. As the figure indicates, the greatest overall difference in the performance characteristics of these two vehicles occurs between zero and approximately 50 mph. Beyond 50 mph the average performance differences are negligible. In the second case, Figure 5-4B, the comparison of runs Loco 2 and Loco 4 shows the opposite to be true. The performance curves are nearly equal from zero to about 50 mph, while a marked differential above the knee of the curves exists.

Inspection of the run time differentials between these two types of curves shows that for the first case, a high power density advantage below the mid point in the speed range yields only a six second advantage in run time, while in the second case, the power advantage above about 50 mph gives a savings of two minutes and three seconds. The effect of the power

TPC SUMMARY FINDINGS

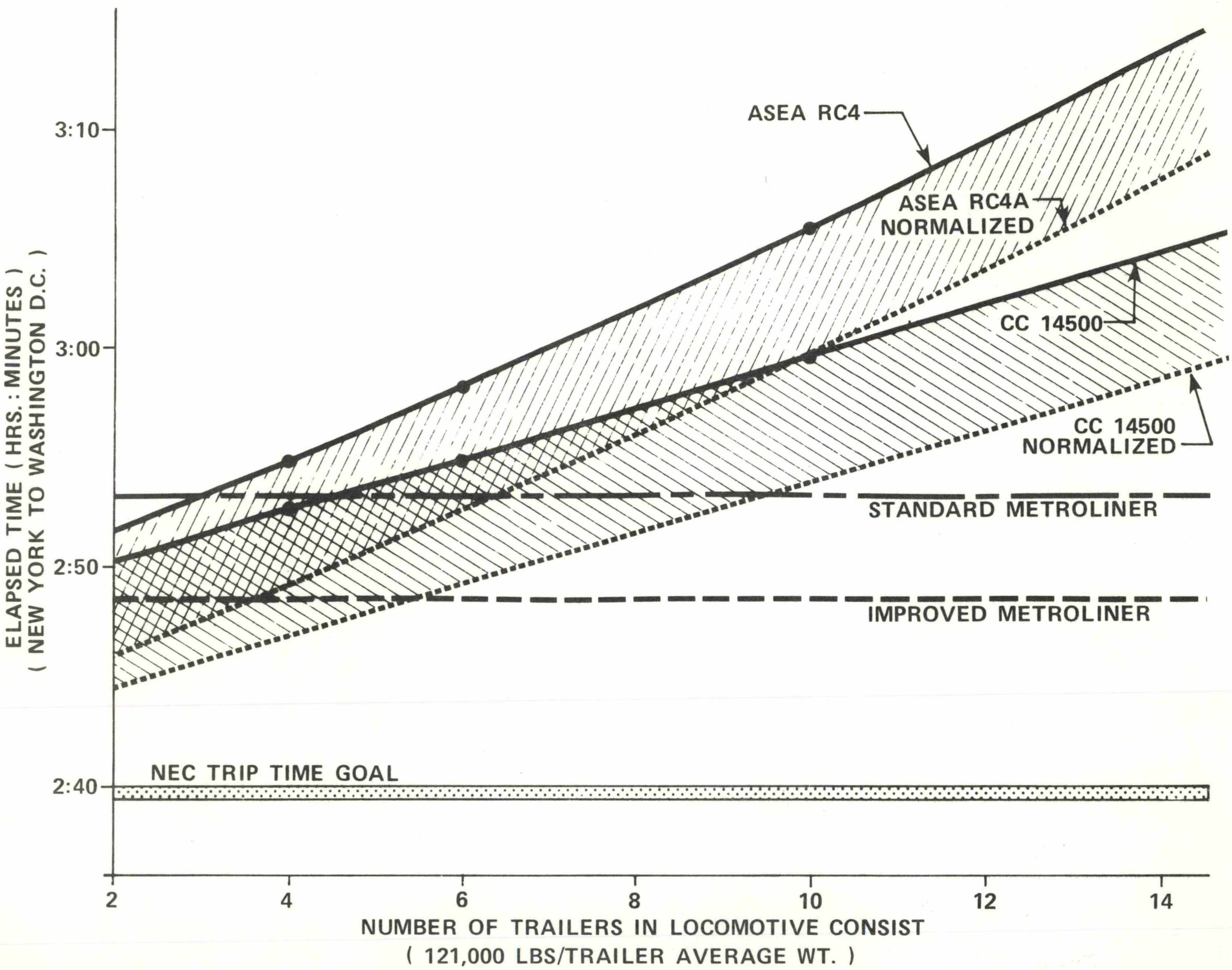


FIGURE 5 — 3

Federal Railroad Administration	NORTHEAST CORRIDOR HIGH-SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT	Date 1/77
Bechtel Incorporated		Job No 12131

TRACTIVE EFFORT COMPARISON

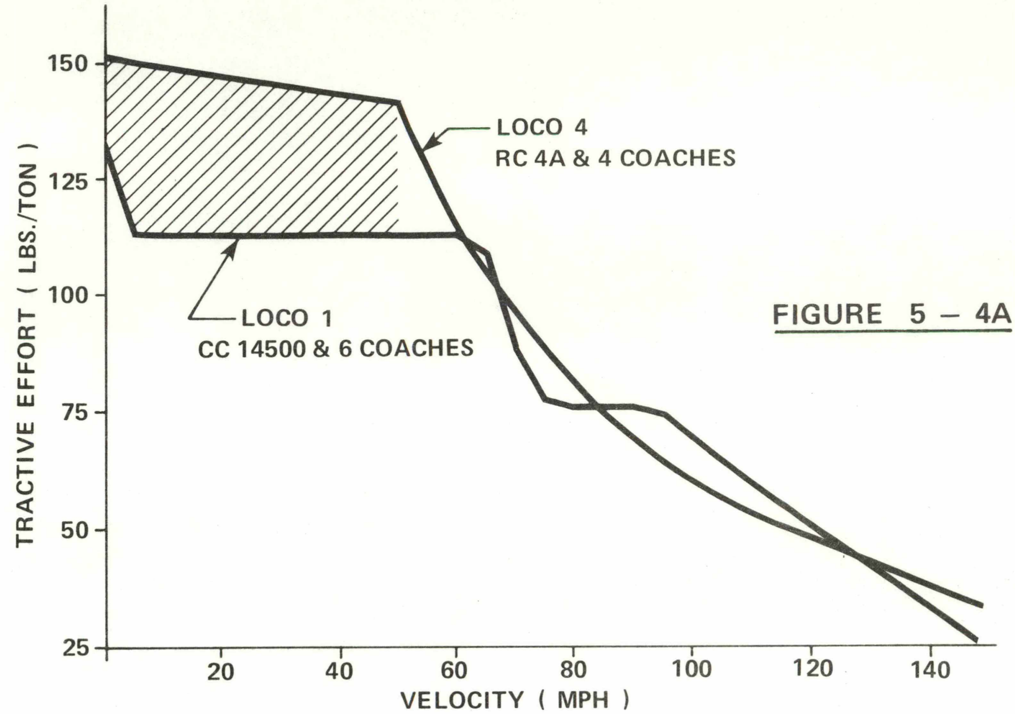


FIGURE 5 – 4A

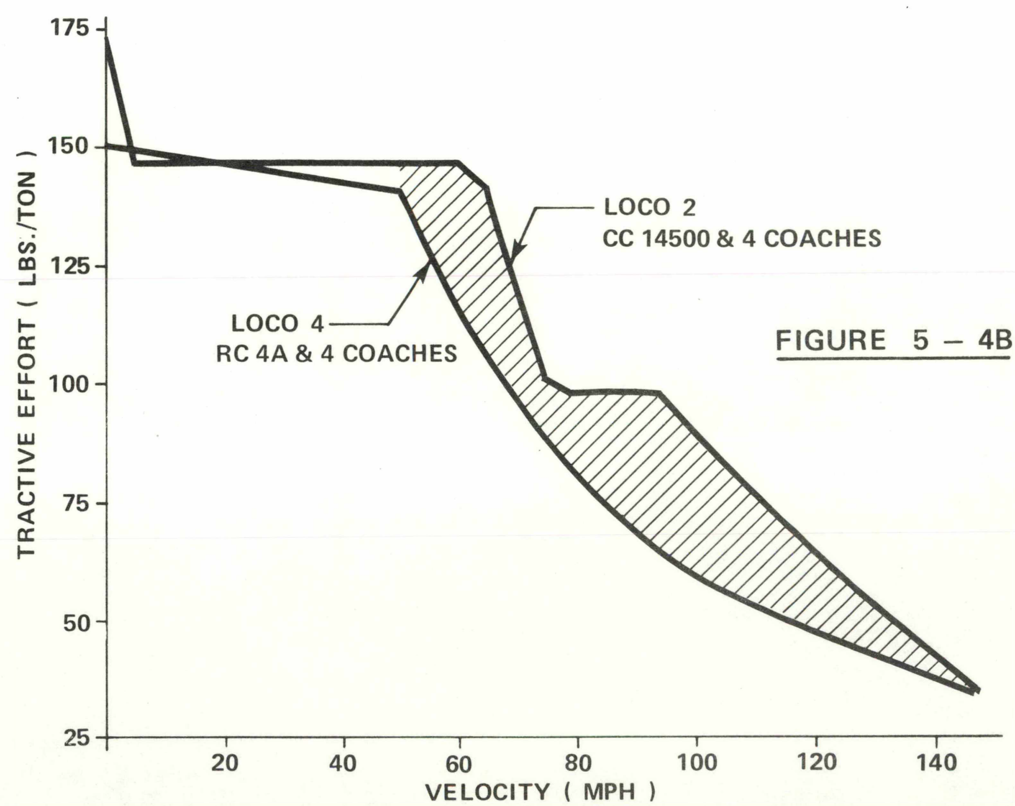


FIGURE 5 – 4B

Federal Railroad Administration	NORTHEAST CORRIDOR HIGH-SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT	Date 1/77
Bechtel Incorporated		Job No 12131

density distribution may be directly related to specific characteristics of the particular route profile. Inspection of the histograms of the TPC run summaries for all runs in this analysis shows that only 20% (± 1%) of each total run time was spent at velocities of 50 mph or less. Thus it may be seen that an advantage in power density in this range can only benefit the vehicle performance during less than one-fifth of its running time, and then only during the accelerating modes between constant speed increments. These findings may have application in optimizing future vehicle gear ratios and performance requirements when the schedule and route profiles are specifically identified.

However, this particular analysis concerns itself only with the southern half of the NEC. In Task 18 of FRA's NEC Program, a similar route profile was run for both north and south segments of the corridor in run Number 76010. Histograms of these runs show that while the south end had 19.2% of its travel time below 50 mph, the segment from Boston to New York City contained 27.7% of the run below that speed. This points up a caution that since the NEC vehicle will be required to travel the entire corridor route, consideration must be equally given to the vastly different route configurations and characteristics of the north and south route segments. While simulations identifying vehicle characteristic differences need not be repeated on the Boston-New York segment, a reasonable optimization of vehicle requirements for a single Northeast Corridor vehicle must at some point include full system integration to be effective.

FIGURE 5-5

TPC RUN SUMMARY - LOCO - 1

RUN NUMBER LOCO-1 NEW YORK CITY TO WASHINGTON D.C. NEC-3S SPEED TABLE

FROM STATION NEW YORK CITY TO STATION WASHINGTON D.C.

PERCENTAGE OF RUN TIME IN EACH SPEED RANGE

(scale: 0% 5% 10% 15% 20% 25% 30% 35% 40% 45% 50%)

Speed range	ACTUAL VALUE
0- 10	,83 %
10- 20	6,20 %
20- 30	,84 %
30- 40	6,58 %
40- 50	5,95 %
50- 60	5,66 %
60- 70	7,24 %
70- 80	6,96 %
80- 90	6,95 %
90-100	9,47 %
100-110	20,23 %
110-120	14,19 %
120-130	8,88 %
130-140	,00 %
140-150	,00 %

TOTAL RUN SUMMARY		ACCELERATION + CONSTANT SPEED		BRAKING	
DISTANCE TRAVELED	225,85 MILES				
RUN TIME	2:56:12 HMS	ENERGY CONSUMED	9520,65 KWH	ENERGY CONSUMED	3309,27 KWH
AVERAGE SPEED	80,31 MPH	RUNNING TIME	2:20: 1 HMS	BRAKING TIME	0:28:42 HMS
DWELL	450,00 SEC	RMS ENERGY USED	4383,36 KW		

FIGURE 5-6

TPC RUN SUMMARY - LOCO - 2

```
RUN NUMBER LOCO-2  NEW YORK CITY  TO WASHINGTON D.C. NEC-3S SPEED TABLE

         FROM STATION NEW YORK CITY                    TO STATION WASHINGTON D.C.

                     PERCENTAGE OF RUN TIME IN EACH SPEED RANGE

          0%        5%        10%       15%       20%       25%       30%       35%       40%       45%       50%  ACTUAL
          +---------+---------+---------+---------+---------+---------+---------+---------+---------+---------+   VALUE
          +         +         +         +         +         +         +         +         +         +         +
  0- 10   +*                                                                                                         .71 %
          +         +         +         +         +         +         +         +         +         +         +
 10- 20   +************                                                                                             6.16 %
          +         +         +         +         +         +         +         +         +         +         +
 20- 30   +*                                                                                                         .72 %
          +         +         +         +         +         +         +         +         +         +         +
 30- 40   +*************                                                                                            6.56 %
          +         +         +         +         +         +         +         +         +         +         +
 40- 50   +************                                                                                             5.81 %
          +         +         +         +         +         +         +         +         +         +         +
 50- 60   +***********                                                                                              5.35 %
          +         +         +         +         +         +         +         +         +         +         +
 60- 70   +**************                                                                                           6.84 %
          +         +         +         +         +         +         +         +         +         +         +
 70- 80   +*************                                                                                            6.53 %
          +         +         +         +         +         +         +         +         +         +         +
 80- 90   +**************                                                                                           6.67 %
          +         +         +         +         +         +         +         +         +         +         +
 90-100   +******************                                                                                       8.82 %
          +         +         +         +         +         +         +         +         +         +         +
100-110   +******************************************                                                              20.28 %
          +         +         +         +         +         +         +         +         +         +         +
110-120   +******************************                                                                          14.59 %
          +         +         +         +         +         +         +         +         +         +         +
120-130   +**********************                                                                                  10.75 %
          +         +         +         +         +         +         +         +         +         +         +
130-140   +                                                                                                          .00 %
          +         +         +         +         +         +         +         +         +         +         +
140-150   +                                                                                                          .00 %
          +---------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
          0%        5%        10%       15%       20%       25%       30%       35%       40%       45%       50%

        *                                 * ACCELERATION + CONSTANT SPEED   *        BRAKING                       *
TOTAL   *** DISTANCE TRAVELED =  225.85 MILES ***                            ***                                     ***
RUN     *** RUN TIME          = 2:54: 3 HMS   *** ENERGY CONSUMED = 7609.98 KWH *** ENERGY CONSUMED =  2582.53 KWH ***
SUMMARY *** AVERAGE SPEED     =   81.34 MPH   *** RUNNING TIME    = 2:18:18 HMS *** BRAKING TIME    =  0:28:15 HMS ***
        ***  DWELL            =  450.00 SEC   *** RMS ENERGY USED = 3773.45 KW  ***                                  ***
        *                                 *                                 *                                      *
```

FIGURE 5-7

TPC RUN SUMMARY - LOCO - 3

RUN NUMBER LOCO-3 NEW YORK CITY TO WASHINGTON D.C. NEC-3S SPEED TABLE

FROM STATION NEW YORK CITY TO STATION WASHINGTON D.C.

PERCENTAGE OF RUN TIME IN EACH SPEED RANGE

Speed Range	0% 5% 10% 15% 20% 25% 30% 35% 40% 45% 50%	ACTUAL VALUE
0- 10	+**	.85 %
10- 20	+************	6.08 %
20- 30	+**	.85 %
30- 40	+*************	6.48 %
40- 50	+************	5.93 %
50- 60	+************	5.95 %
60- 70	+****************	8.03 %
70- 80	+***************	7.33 %
80- 90	+****************	7.76 %
90-100	+***********************	11.38 %
100-110	+**	22.90 %
110-120	+***************************	13.37 %
120-130	+******	3.08 %
130-140	+	.00 %
140-150	+	.00 %

		ACCELERATION + CONSTANT SPEED	BRAKING
TOTAL	DISTANCE TRAVELED = 225.85 MILES		
RUN	RUN TIME = 2:59:28 HMS	ENERGY CONSUMED = 8701.10 KWH	ENERGY CONSUMED = 2763.59 KWH
SUMMARY	AVERAGE SPEED = 78.78 MPH	RUNNING TIME = 2:25:36 HMS	BRAKING TIME = 0:26:22 HMS
	DWELL = 450.00 SEC	RMS ENERGY USED = 3599.10 KW	

FIGURE 5-8

TPC RUN SUMMARY - LOCO - 4

```
RUN NUMBER LOCO-4  NEW YORK CITY  TO WASHINGTON D.C. NEC-3S SPEED TABLE

            FROM STATION NEW YORK CITY                            TO STATION WASHINGTON D.C.

                              PERCENTAGE OF RUN TIME IN EACH SPEED RANGE

            0%        5%        10%       15%       20%       25%       30%       35%       40%       45%       50%  ACTUAL
            +---------+---------+---------+---------+---------+---------+---------+---------+---------+---------+  VALUE
            +         +         +         +         +         +         +         +         +         +         +
   0- 10    +*                                                                                                        .71 %
            +         +         +         +         +         +         +         +         +         +         +
  10- 20    +************                                                                                            6.12 %
            +         +         +         +         +         +         +         +         +         +         +
  20- 30    +*                                                                                                        .73 %
            +         +         +         +         +         +         +         +         +         +         +
  30- 40    +*************                                                                                           6.50 %
            +         +         +         +         +         +         +         +         +         +         +
  40- 50    +************                                                                                            5.79 %
            +         +         +         +         +         +         +         +         +         +         +
  50- 60    +***********                                                                                             5.57 %
            +         +         +         +         +         +         +         +         +         +         +
  60- 70    +***************                                                                                         7.37 %
            +         +         +         +         +         +         +         +         +         +         +
  70- 80    +**************                                                                                          6.76 %
            +         +         +         +         +         +         +         +         +         +         +
  80- 90    +***************                                                                                         7.35 %
            +         +         +         +         +         +         +         +         +         +         +
  90-100    +*********************                                                                                  10.44 %
            +         +         +         +         +         +         +         +         +         +         +
 100-110    +*******************************************                                                            21.38 %
            +         +         +         +         +         +         +         +         +         +         +
 110-120    +****************************                                                                           14.22 %
            +         +         +         +         +         +         +         +         +         +         +
 120-130    +**************                                                                                          7.08 %
            +         +         +         +         +         +         +         +         +         +         +
 130-140    +                                                                                                         .00 %
            +         +         +         +         +         +         +         +         +         +         +
 140-150    +                                                                                                         .00 %
            +---------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
            0%        5%        10%       15%       20%       25%       30%       35%       40%       45%       50%


          *                                  *  ACCELERATION + CONSTANT SPEED   *      BRAKING                         *
 TOTAL  *** DISTANCE TRAVELED =   225.85 MILES ***                                ***                                ***
  RUN   *** RUN TIME          =  2:56: 6 HMS   *** ENERGY CONSUMED =  7027.09 KWH *** ENERGY CONSUMED =  2179.98 KWH ***
SUMMARY *** AVERAGE SPEED     =    80.35 MPH   *** RUNNING TIME    =  2:21:15 HMS *** BRAKING TIME    =  0:27:22 HMS ***
        ***  DWELL            =   450.00 SEC   *** RMS ENERGY USED =  3118.46 KW  ***                                ***
          *                                  *                                  *                                  *
```

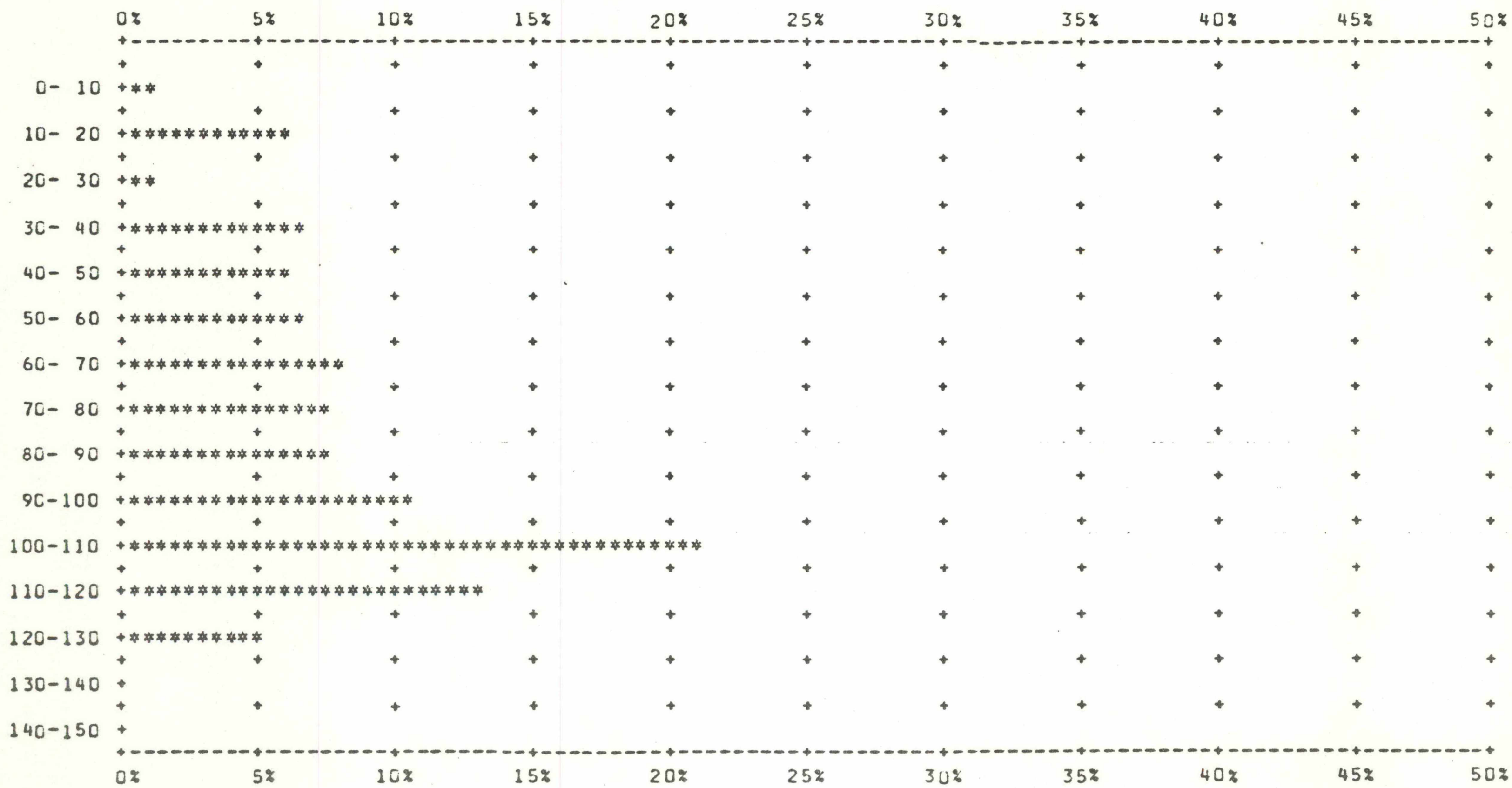
FIGURE 5-9

TPC RUN SUMMARY - LOCO - 5

RUN NUMBER LOCO-5 NEW YORK CITY TO WASHINGTON D.C. NEC-3S SPEED TABLE

FROM STATION NEW YORK CITY TO STATION WASHINGTON D.C.

PERCENTAGE OF RUN TIME IN EACH SPEED RANGE



		ACCELERATION + CONSTANT SPEED	BRAKING
TOTAL RUN SUMMARY	DISTANCE TRAVELED = 225.85 MILES		
	RUN TIME = 3: 0:52 HMS	ENERGY CONSUMED = 13040.79 KWH	ENERGY CONSUMED = 4555.74 KWH
	AVERAGE SPEED = 78.14 MPH	RUNNING TIME = 2:25:40 HMS	BRAKING TIME = 0:27:43 HMS
	DWELL = 450.00 SEC	RMS ENERGY USED = 5396.89 KW	

FIGURE 5-10

TPC RUN SUMMARY - LOCO - 6

RUN NUMBER LOCO-6 NEW YORK CITY TO WASHINGTON D.C. NEC-3S SPEED TABLE

FROM STATION NEW YORK CITY TO STATION WASHINGTON D.C.

PERCENTAGE OF RUN TIME IN EACH SPEED RANGE

(scale 0% 5% 10% 15% 20% 25% 30% 35% 40% 45% 50%)

Speed Range	ACTUAL VALUE
0- 10	1.11 %
10- 20	6.05 %
20- 30	1.12 %
30- 40	6.43 %
40- 50	6.15 %
50- 60	6.84 %
60- 70	9.63 %
70- 80	7.73 %
80- 90	9.19 %
90-100	14.93 %
100-110	24.07 %
110-120	6.75 %
120-130	.00 %
130-140	.00 %
140-150	.00 %

TOTAL RUN SUMMARY		ACCELERATION + CONSTANT SPEED	BRAKING
DISTANCE TRAVELED	= 225.85 MILES		
RUN TIME	= 3: 6:46 HMS	ENERGY CONSUMED = 11493.91 KWH	ENERGY CONSUMED = 3535.49 KWH
AVERAGE SPEED	= 75.57 MPH	RUNNING TIME = 2:34:26 HMS	BRAKING TIME = 0:24:50 HMS
DWELL	= 450.00 SEC	RMS ENERGY USED = 4290.22 KW	

APPENDIX A - LOCOMOTIVE SPEED TABLE

APPENDIX A

SPEED TABLE NEC-3S

NEC TRAIN PERFORMANCE CALCULATOR INPUT TABLE

NEW YORK TO WASHINGTON, D.C.

TABLE NEC - 3S

NEC TRAIN PERFORMANCE CALCULATOR INPUT TABLE
NEW YORK TO WASHINGTION

CURVE NO.	CURVE DATA D°	CURVE DATA Ea (in.)	MILEPOST STATION		TPC LOCATION DATA		SPEED LIMIT MPH	REMARKS
					W0.0		STOP	NEW YORK
238A	2^{o} 00'	1/4	0.14	0.16	W0.0	W0.9	15	
238B	2^{o} 00'	1/4	0.16	0.19	W0.9	W3.0	60	West-50 East
238C	2^{o} 00'	1/4	0.31	0.36	W3.0	W3.4	75	
239	0^{o} 30'	1/4	0.53	0.62	W3.4	W6.0	90	
240	1^{o} 54'	3 1/4	2.92	3.59	W6.0	W6.2	45	Drawbridge
241	0^{o} 30'	1	5.53	5.80	W6.2	W8.0	90	Note 7325' between MP W8.0 and MP 7.0 MP W8.4=MP7.0
242	0^{o} 30'	1	7.39	8.11	W8.0	7.9	60	
243	3^{o} 15'	3 1/2	7.78	8.03	7.9	8.6	45	
244	0^{o} 40'	1/4	8.17	8.36				
245	0^{o} 40'	1/4	8.36	8.47				
246	1^{o} 30'	1/4	8.50	8.62				
246A	1^{o} 30'	0	8.68	8.80	8.6	8.8	35	
247	0^{o} 40'	1/4	8.91	9.00	8.8	10.6	70	
248	1^{o} 30'	1/2	9.20	9.27				
249	1^{o} 00'	2 1/2	10.22	10.52	10.6	12.2	100	
250	0^{o} 20'	1	12.30	12.58	12.2	12.6	80	
251	0^{o} 04'	0	13.03	13.18	12.6	14.1	100	
252	2^{o} 00'	3	14.05	14.27	14.1	14.8	55	
253	2^{o} 43'	5	14.29	14.70	14.8	19.6	120	
254	0^{o} 19'	3/4	18.26	18.45				
255	0^{o} 15'	3/4	18.85	18.98				
256	0^{o} 35'	1 1/2	19.29	19.44				
257	0^{o} 26'	1/2	19.66	19.74	19.6	19.8	45	Divert

TABLE NEC - 3S

NEC TRAIN PERFORMANCE CALCULATOR INPUT TABLE
NEW YORK TO WASHINGTION

CURVE NO.	CURVE DATA		MILEPOST STATION		TPC LOCATION DATA		SPEED LIMIT MPH	REMARKS
	D°	E_a (in.)						
258	0° 15'	3/4	19.74	19.82	19.8	23.5	80	
259	0° 30'	2	20.44	20.74				
260	0° 22'	1	20.75	20.83				
261	0° 45'	2 3/4	21.69	21.87				
262	0° 45'	3	21.91	22.06				
263	0° 40'	2 3/4	22.48	22.87				
264	0° 50'	3 1/4	22.89	23.57	23.5		STOP	METRO PARK
265	1° 20'	4 1/2	23.67	23.93	23.5	25.8	80	
266	1° 30'	6	24.15	24.58	25.8	26.0	45	Divert
267	1° 15'	5 3/4	24.71	25.52	26.0	26.3	100	
268	1° 41'	6	26.40	26.69	26.3	26.8	80	
269	1° 25'	5 1/2	26.76	27.18	26.8	27.1	90	
270	0° 50'	3	27.46	27.69	27.1	27.7	100	
271	0° 30'	1	28.83	28.97	27.7	32.5	110	
272	0° 30'	2	30.26	30.66				
273	0° 30'	1 1/2	31.16	31.38	32.5	32.9	100	
274	0° 30'	2	33.78	34.21	32.9	40.9	120	
275	0° 20'	1 1/2	39.07	39.34	40.9	41.1	45	Divert
276	0° 34'	2 3/4	39.50	40.21	41.1	46.9	120	
277	0° 22'	1	50.36	50.50	46.9	47.1	45	Divert
278	0° 20'	1 1/2	56.14	56.27	47.1	54.1	120	
279	1° 00'	2 1/4	57.01	57.12	54.1	56.1	80	
280	0° 52'	3 1/2	58.22	59.02	56.1	56.3	45	Divert
282	0° 24'	1 1/4	60.25	60.55	56.3	57.0	60	

TABLE NEC - 3S

NEC TRAIN PERFORMANCE CALCULATOR INPUT TABLE
NEW YORK TO WASHINGTION

CURVE NO.	CURVE DATA D°	CURVE DATA E_a (in.)	MILEPOST STATION		TPC LOCATION DATA		SPEED LIMIT MPH	REMARKS
					57.0		STOP	TRENTON
					57.0	57.0	60	
					57.0	57.2	45	Divert
					57.2	58.1	80	
					58.1	59.2	115	
					59.2	59.8	100	
283	0° 45'	3 1/2	61.41	61.94	59.8	65.0	115	
284	0° 39'	3	64.61	64.95	65.0	65.6	100	
285	0° 43'	3	65.64	66.36	65.6	66.3	115	
286	0° 30'	1 3/4	66.73	67.66	66.3	66.5	100	
					66.5	70.2	115	
288	1° 10'	6	70.05	70.60	70.2	70.8	100	
289	0° 21'	1 1/4	72.20	72.65	70.8	74.1	115	
290	1° 30'	5 1/2	74.08	74.49	74.1	75.1	90	
291	1° 42'	6	74.65	75.09	75.1	76.0	115	
292	0° 43'	2 3/4	75.13	75.44	76.0	80.8	100	
293	0° 42'	2 3/4	76.14	76.46				
294	0° 54'	5	76.71	76.99				
295	0° 21'	1 1/2	78.20	78.43				
296	0° 44'	1 1/2	79.21	79.64				
297	1° 45'	3	80.91	81.32	80.8	81.1	60	
298	4° 03'	4 1/2	81.39	81.76	81.1	81.7	50	
					81.7	82.2	80	
					82.2	83.1	70	

TABLE NEC - 3S

NEC TRAIN PERFORMANCE CALCULATOR INPUT TABLE
NEW YORK TO WASHINGTION

CURVE NO.	CURVE DATA D°	CURVE DATA E_a (in.)	MILEPOST STATION		TPC LOCATION DATA		SPEED LIMIT MPH	REMARKS
299	2° 29'	6	83.11	83.45	83.1	83.8	65	
					83.8	84.2	70	
299A	2° 00'	1/2	84.72	84.77	84.2	85.2	50	#1 & 2 Trk., 40 mph 3 &4 Trk.
300	1° 00'	1 3/4	84.84	84.99				
301	1° 43'	1/4	85.08	85.14				
302	2° 16'	2 1/2	85.36	85.47	85.2	86.2	70	
303	1° 50'	4 1/2	86.27	86.41	86.2	86.5	60	
303B	1° 02'	1	87.23	87.30	86.5	87.5	70	
303C	1° 02'	3/4	87.30	87.37	87.5	89.2	30	
					89.2		STOP	30TH STREET
					89.2	90.7	30	MP 90.7 = MP2.1
304	3° 50'	2	1.80	2.02	2.1	2.8	50	
305	2° 30'	3	2.02	2.22				
306	2° 30'	3	2.40	2.81				
307	1° 10'	3	2.81	2.99	2.8	3.0	60	
					3.0	4.1	90	#4 Trk., 100mph #3 Trk.
					4.1	4.3	45	Divert
					4.3	5.3	100	
308	1° 00'	2 1/2	5.40	6.07	5.3	7.2	70	
309	1° 00'	3	6.07	6.85				
310	1° 00'	3	6.85	7.33				
311	1° 00'	3	7.33	7.76	7.2	11.7	100	
312	1° 00'	5 1/2	9.42	9.66				
313	1° 00'	4 3/4	10.48	11.03				

TABLE NEC - 3S

NEC TRAIN PERFORMANCE CALCULATOR INPUT TABLE
NEW YORK TO WASHINGTION

CURVE NO.	CURVE DATA D°	CURVE DATA E_a (in.)	MILEPOST STATION		TPC LOCATION DATA		SPEED LIMIT MPH	REMARKS
314	0° 50'	2 1/4	11.82	12.73	11.7	16.8	90	South, 85 mph. North(MP14.6 to 15.0)
315	0° 45'	2 1/2	13.95	13.95				
316	0° 30'	2	14.98	14.98				
317	0° 10'	1	15.80	15.91				
318	0° 10'	1	16.40	16.50	16.8	17.0	45	Divert
319	1° 00'	4 3/4	17.97	18.49	17.0	23.0	100	South, 90 mph North
320	1° 00'	4 3/4	19.49	19.84				
321	0° 46'	2 3/4	20.60	21.05				
322	0° 34'	2 1/2	21.20	21.32				
323	1° 15'	6	21.96	22.21				
324	1° 31'	5 3/4	23.00	23.60	23.0	23.5	90	
325	1° 00'	3 1/2	23.60	23.80	23.5	25.2	115	
326	0° 25'	1 3/4	24.24	25.24	25.2	26.3	80	
327	1° 40'	2	26.19	26.95	26.3	26.8	40	
327A	0° 40'	1/2	26.77	26.82	26.8		STOP	WILMINGTON
					26.8	27.5	40	
327B	2° 10'	1/4	26.87	26.93	27.5	28.0	80	
328	3° 44'	3	27.00	27.50				
329	0° 52'	5 1/2	28.61	29.30	28.0	31.0	100	South 85 mph North (MP 30.2 to 31.0)
330	1° 04'	5 1/2	30.07	30.40				
331	0° 35'	2	30.82	31.00				
332	1° 00'	6	32.61	33.08	31.0	32.8	115	
333	0° 30'	2	33.33	33.79	32.8	33.1	100	
334	0° 30'	1 3/4	34.52	34.97	33.1	40.0	120	

TABLE NEC - 3S

NEC TRAIN PERFORMANCE CALCULATOR INPUT TABLE
NEW YORK TO WASHINGTION

CURVE NO.	CURVE DATA		MILEPOST STATION		TPC LOCATION DATA		SPEED LIMIT MPH	REMARKS
	D°	Ea (in.)						
335	0° 20'	1	35.69	35.81				
336	0° 32'	2 1/4	39.45	40.53	40.0	40.2	100	
337	0° 30'	2	41.79	41.96				
338	0° 14'	1	43.70	44.94	40.2	50.0	110	
339	0° 34'	2	45.27	45.87	50.0	50.6	90	
340	0° 57'	5 1/2	46.73	47.29	50.6	51.2	100	
341	1° 00'	6	48.65	49.03	51.2	51.8	80	
342	1° 20'	6	49.90	50.65	51.8	53.3	115	
					53.3	53.8	100	
					53.8	56.1	115	
					56.1	57.0	95	
					57.0	57.4	100	
					57.4	59.4	115	
349	0° 45'	1	60.46	61.32	59.4	60.5	60	
350	0° 40'	2 1/2	62.10	62.79	60.5	65.3	115	
351	1° 00'	5	64.63	65.42	65.3	71.5	120	
352	0° 32'	2	66.21	66.72				
353	0° 15'	3/4	69.80	71.00				
354	0° 30'	1 1/4	71.00	71.20				
354A	0° 34'	1 1/2	71.49	71.61				
354B	0° 50'	3 1/2	71.68	71.73	71.5	71.8	100	
354C	1° 35'	6	71.73	71.82	71.8	77.9	120	
355	0° 10'	1/2	73.80	73.87				
356	0° 30'	1	77.60	77.68				

TABLE NEC - 3S

NEC TRAIN PERFORMANCE CALCULATOR INPUT TABLE
NEW YORK TO WASHINGTION

CURVE NO.	CURVE DATA D^o	E_a (in.)	MILEPOST STATION		TPC LOCATION DATA		SPEED LIMIT MPH	REMARKS
357	1° 15'	6	77.89	78.39	77.9	79.5	100	
358	0° 18'	1/2	82.55	84.52	79.5	85.0	120	
359	0° 58'	5 1/2	85.80	86.27	85.0	89.2	115	
362	0° 57'	5	86.27	87.10				
363	0° 52'	4	88.40	89.70				
365	0° 25'	2 1/4	89.70	89.93	89.2	91.8	100	
369	0° 20'	3/4	90.20	91.28				
371	1° 10'	2 1/4	91.87	92.02	91.8	92.4	50	
372	2° 00'	2 3/4	92.02	92.44	92.4	93.9	60	
373	2° 00'	3 1/2	92.88	93.26				
374	4° 00'	3 1/2	93.85	94.12	93.9	94.1	45	
375	3° 46'	3 1/2	94.23	94.51	94.1	94.5	60	
375A	5° 00'	4 1/4	94.51	94.60	94.5	95.2	45	
					95.2	95.6	15	
375B	1° 40'	1/2	95.67	95.76	95.6		STOP	BALTIMORE
376	4° 00'	0	96.00	96.23	95.6	95.9	15	
					95.9	97.4	30	
378	7° 30'	2 3/4	96.97	97.12	97.4	98.1	40	
380	4° 00'	2 1/4	97.70	98.16	98.1	98.6	50	
381	3° 00'	4	98.24	98.61	98.6	99.3	75	
382	1° 40'	5 1/2	99.37	99.81	99.3	99.7	70	
383	1° 15'	3 1/2	99.83	99.99	99.7	102.1	100	
384	0° 10'	0	100.20	100.31				
385	1° 00'	4 3/4	101.46	102.11	102.1	103.3	115	

TABLE NEC - 3S

NEC TRAIN PERFORMANCE CALCULATOR INPUT TABLE
NEW YORK TO WASHINGTION

CURVE NO.	CURVE DATA		MILEPOST STATION		TPC LOCATION DATA		SPEED LIMIT MPH	REMARKS
	D°	E_a (in.)						
387	1° 00'	5	103.49	103.72	103.3	106.5	100	
388	1° 00'	5	103.89	104.15				
389	0° 30'	1 1/4	104.42	104.71				
390	1° 00'	5 1/4	105.43	106.06				
391	1° 30'	6	106.50	106.97	106.5	106.9	90	
392	0° 30'	1 1/2	108.09	108.51	106.9	110.2	115	
393	0° 22'	0	109.60	109.70				
394	0° 22'	0	109.70	109.80				
395	1° 00'	6	110.20	110.51	110.2	111.6	100	
396	0° 55'	5 1/2	110.75	111.22				
397	1° 00'	5	113.22	113.52	111.6	113.0	115	
398	1° 00'	5 3/4	113.86	114.36	113.0	113.2	45	Divert
399	1° 00'	5 1/4	115.19	115.59	113.2	116.8	100	
400	1° 00'	5 1/2	116.26	116.67	116.8	119.0	90	
401	1° 30'	5 3/4	116.83	117.33				
402	1° 00'	4	117.60	117.74				
403	1° 00'	4 1/4	118.12	118.34				
404	0° 30'	1 1/4	119.11	119.63	119.0	120.3	100	
405	1° 00'	5 1/2	120.01	120.25	120.3	120.5	45	Divert
406	0° 23'	0	121.90	122.12	120.5	125.1	120	
407	1° 00'	6	125.22	125.61	125.1	134.9	100	
408	1° 00'	5 3/4	125.90	126.30				
409	1° 00'	6	126.70	127.00				
410	0° 30'	1 1/4	127.50	127.79				

TABLE NEC - 3S

NEC TRAIN PERFORMANCE CALCULATOR INPUT TABLE
NEW YORK TO WASHINGTION

CURVE NO.	CURVE DATA D°	CURVE DATA E_a (in.)	MILEPOST STATION		TPC LOCATION DATA		SPEED LIMIT MPH	REMARKS
411	1° 00'	4	128.50	128.90				
413	0° 40'	3	129.26	130.86	134.9	135.1	30	
414	1° 05'	3 3/4	133.34	133.91	135.1	135.8	15	
415	3° 00'	0	134.80	134.99	135.8		STOP	WASHINGTON

APPENDIX B - TPC SPEED GRAPHS

APPENDIX B

TRAIN PERFORMANCE CALCULATOR SPEED GRAPHS

NEW YORK CITY TO WASHINGTON

RUN NUMBER LOCO-4

BECHTEL INC.

12/16/1976

NEW YORK CITY TO WASHINGTON

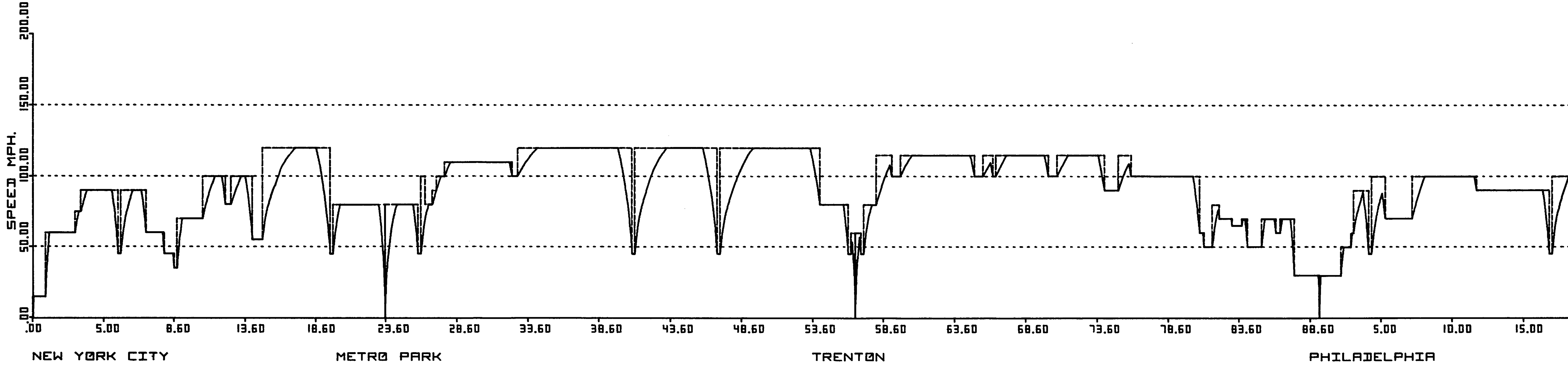
RUN NUMBER LOCO-3

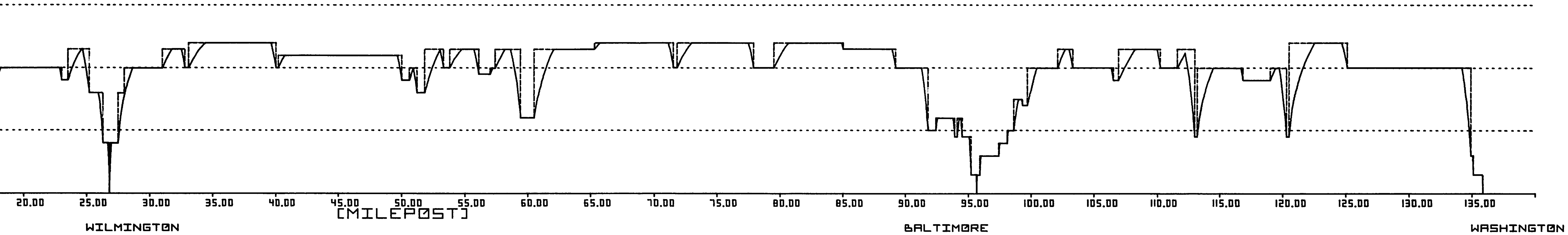
BECHTEL INC.

12/16/1976

NEW YØRK CITY TO WASHINGTON

RUN NUMBER LØCØ-2





BECHTEL INC.

12/16/1976

NEW YORK CITY TO WASHINGTON

RUN NUMBER LOCO-1

BECHTEL INC.

12/15/1976

Calculated Performance of the RC4A and
CC14500 Locomotive Hauled Amfleet
Consists, New York-Washington, Dc, 1977
US DOT, FRA, CC Ronald, SD Ritchie