REPORT NO. DOT-TSC-OST-75-4

EFFECT OF VARIATION OF SPEED LIMITS ON INTERCITY BUS FUEL CONSUMPTION, COACH AND DRIVER UTILIZATION, AND CORPORATE PROFITABILITY

A.J. Broderick
P. Davis
L. Leist
H. Miller
E. Klaubert

NOVEMBER 1975

FINAL REPORT

Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
OFFICE OF THE SECRETARY
Office of the Assistant Secretary
for Systems Development and Technology
Office of Systems Engineering
Washington DC 20590

NOTICE

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT-TSC-OST-75-4		

4. Title and Subtitle EFFECT OF VARIATION OF SPEED LIMITS ON INTER-CITY BUS FUEL CONSUMPTION, COACH AND DRIVER UTILIZATION, AND CORPORATE PROFITABILITY	5. Report Date November 1975
	6. Performing Organization Code
7. Author(s) A.J. Broderick, P. Davis, L. Leist, H. Miller, and E. Klaubert	8. Performing Organization Report No. DOT-TSC-OST-75-4
9. Performing Organization Name and Address U.S. Department of Transportation Transportation Systems Center Kendall Square Cambridge MA 02142	10. Work Unit No. (TRAIS) OS414/R6517
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Office of the Secretary Office of the Assistant Secretary for Systems Development and Technology, Office of Systems Engineering Washington DC 20590	13. Type of Report and Period Covered Final Report Dec. 1973 - July 1974
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The effect of speed limit and passenger load on fuel consumption was determined using actual intercity buses with simulated passenger loads over different types of terrain. In addition to road tests, laboratory type measurements were made on four intercity buses. Studies were also made to ascertain the effect of reduced speed limits on maintenance and operations. Principal conclusions were: 1) Increased fuel consumption results from higher speeds in the 50-60 mph range; 2) Terrain is an important factor in determining the effect of speed limit on fuel consumption; 3) No significant fuel savings are expected for intercity buses if speed limits are reduced in the 50-60 mph range over mountainous terrain; and 4) Reducing speed limits should reduce maintenance costs but increase direct operating costs.

17. Key Words	18. Distribution Statement
Bus Fuel Economy Reducing Speed Limits	DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	142	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

This study was carried out at the DOT/Transportation Systems Center for the Office of the Assistant Secretary of Transportation for Systems Development and Technology under Project Plan Agreement OS414. The objective of this study was to assess the variation in fuel consumption of intercity buses when speed limits are set at 50, 55 and 60 mph.

We acknowledge with thanks the help and cooperation of the officials and personnel of the Continental Trailways of New England, Greyhound Bus Lines, Vermont Transit, and Bonanza Bus Lines. We are especially grateful to Edward Ramsdell, James LaVerdiere, and L.O. Cyrus of Continental Trailways of New England and George Snyder of Greyhound Bus Lines.

SUMMARY

The objective of this study was to assess the variation in fuel consumption of intercity buses when speed limits are set at 50, 55 and 60 mph. Measurements of fuel consumption, using actual intercity buses with simulated passenger loads, were conducted throughout this speed range over different types of terrain. The routes travelled included relatively flat terrain (Washington DC to Norfolk VA), rolling hills (Boston to Westover MA) and rolling hills plus mountains (Boston to western Massachusetts, crossing the Berkshires). Data from these road tests are summarized in Figure S-1.

In addition to road tests, laboratory-type measurements were made on four intercity buses using a chassis dynamometer facility. Fuel flow measurements made during these tests were analyzed in conjunction with data obtained on the road tests to point out possible discrepancies. Computer analysis of the fuel consumption parameters for a typical bus was also performed to further corroborate experimental data.

A brief survey of pertinent literature, users and industrial suppliers of engines was conducted to ascertain the effects of reduced engine-operating speed on maintenance. The operational impact of reduced speed limits on intercity bus companies was also studied. General consideration was given to effects on the industry on a nationwide basis and a specific, in-depth analysis was conducted for one typical operator.

The principal conclusions which may be drawn from this study appear in section 5 of this report.

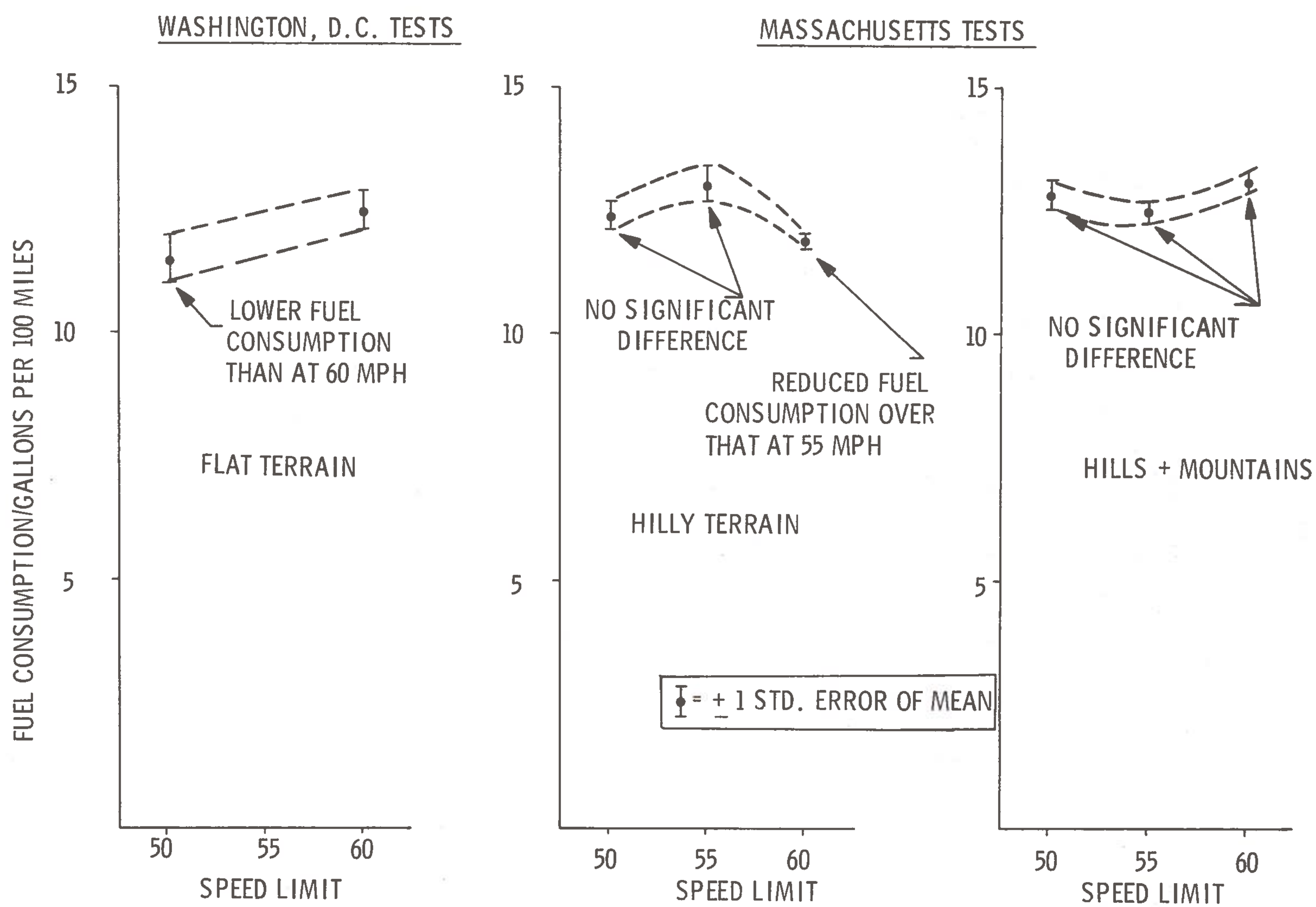


Figure S-1. Data Summary-Fuel Consumption Over Various Terrains vs. Speed Limit

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. INTRODUCTION

1.1 BACKGROUND

This report presents the results of a study conducted by the DOT Transportation Systems Center (TSC) to assess the variation in fuel economy for intercity buses when speed limits are set at 50, 55 and 60 mph. Operational impacts of reduced speed limits on the intercity bus industry are also discussed and potential changes in maintenance procedures, resulting from lower engine-operating speeds, are briefly reviewed. For the purpose of this report, the overall study is divided into 2 parts: (1) a 2-day test series, performed using 8 buses to demonstrate fuel usage variation between 50 and 60 mph speed limits over a round trip course between Washington DC and Norfolk, Virginia (the "Virginia" tests); and (2) a 2-week test series performed using 4 buses to demonstrate fuel usage variation among speed limits of 50, 55, and 60 mph over a round trip course between Boston and Lee, Massachusetts (the "Massachusetts" tests). The Virginia tests were performed on November 23 and 24, 1973; the Massachusetts tests were carried out between December 5 and 19 of the same year.

1.2 DESCRIPTION OF WORK

The Virginia tests were necessarily of short duration, performed on a "quick-response" basis. The buses were driven between Washington, DC and Norfolk, Virginia, a one-way distance of approximately 200 miles, with the major portion of this route traveled on Interstate Highway 95. Each bus travelled at 60 mph one way and 50 mph on the return leg of the trip. Of the four buses making the round trip each day, two observed a 50 mph speed limit going south and 60 mph going north; the remaining two buses reversed this procedure. Fuel consumption was determined by measuring the amount of fuel required to top off the tank at the end of each leg of the trip. (Fuel consumption measurement devices were unavailable for this study.) Thus, 16 data points were obtained using 8 buses, each bus providing a measure of fuel consumption for one leg of the round trip at 50 mph and the other leg at 60 mph over relatively flat terrain.

The Massachusetts tests were designed to gather a large amount of data over relatively hilly terrain. Four buses were used for a period of 2 weeks, and each provided data for operation at speed limits of 50, 55 and 60 mph. The route followed the Massachusetts Turnpike, and in contrast to the Virginia tests, each "leg" of the test actually consisted of a round trip at a single speed. Half of the data was gathered for a round trip distance of approximately 250 miles (Boston to Lee and return). The remainder was gathered over the same route shortened by one turnpike exit (Boston to Westfield and return) resulting in a 190-mile distance. These first of these routes includes a long crossing of the Berkshire mountains, which is eliminated by using the shorter run.

The Massachusetts series of tests was designed to provide 72 data points, 24 each at speed limits of 50, 55 and 60 mph. Unforeseen mechanical problems with one of the buses resulted in less data, and only 54 valid data points were actually obtained.

1.2.1 Dynamometer Tests

In addition to road testing, each bus used in the Massachusetts tests was tested for fuel consumption on a chassis dynamometer. For each bus, rolling resistance and wind loads to be simulated were estimated and used to obtain fuel consumption at 50, 55 and 60 mph for zero road-grade. Grade-loads for 1, 2 and 3% road-grades were added to the wind and rolling loads to obtain data on fuel consumption under simulated hill-climbing conditions at a constant speed. This type of simplified "laboratory" testing is extremely helpful in interpreting road-test data and can act as a bridge between computer-simulation and field testing. With more sophisticated equipment than was available for these tests, virtually complete simulation of an arbitrary route can be obtained.

1.2.2 Modeling

In conjunction with the dynamometer testing of the buses used on the road tests, analyses were conducted using simple computer-simulation of certain operating conditions. Using typical specifications for a bus system, the analysis predicts fuel consumption values under various speeds and road-grades. Due to the number of simplifying assumptions made in these calculations, little emphasis should be placed on the absolute value of the fuel consumption predictions. Rather, changes in the predicted values with various speeds should be qualitatively compared with the dynamometer and road test values.

1.2.3 Maintenance

To address the question of possible increases in engine maintenance which might arise due to low-speed operation, empirical data were unobtainable in the time allowed for this study. Instead, bus industry suppliers and others were contacted for expert opinions, and a summary of information obtained is presented.

1.2.4 Operational Impact

The effect of a reduced nationwide speed limit upon intercity bus company operating expenses resulting from revised driver and equipment utilization patterns was studied by selecting a subset of the industry for a detailed investigation. The operation selected presents a mix of various types of regular-route operation, including both high-speed express routes over interstate and other limited access highways on which the impact of a reduced speed limit would be markedly noticeable and also lower speed routes over the primary highway network that would only be marginally affected by a reduced maximum speed. Charter operations, either in volume or variety were not considered as a factor for selection of the operation to be studied. The runs of the company selected are such that both "straightaway" runs, where the driver makes only a one-way trip during the course of his day's work, and "turn-arounds", where the driver makes a round trip during the day, are included. Although initial industry reaction was that no "truly" representative segment of the industry could be defined, agreement was reached that the company selected (Continental Trailways of New England, Inc.) could be considered to be typical of regular route carriers for the purposes of the study.

2. FUEL CONSUMPTION STUDIES

Roughly 23,000 intercity buses are currently being operated by 1,000 companies and cover over 1 billion miles per year. Though generalizations are impractical, the following specifications (for an Eagle coach, operated by Continental Trailways) typify today's intercity bus:

<u>Coach</u>

Length:	over bumpers	49'0"
Width:	over fenders	96"
Height:	overall, unloaded	133 1/2"
Wheelbase:	front to drive axle	285 1/2"
	front overhang	85 1/2"
	rear overhand	109"
Wheels:	all, steel	22.5" x 8.25"
Weight:	max. loaded (approx.)	36,000 lb

<u>Engine</u>

General Motors Detroit Diesel V-type Model 8VA-71 N-series, 8 cylinder, 2-stroke cycle.

Displacement:	567.4 cu. in.
Compression Ratio:	18.7:1
Bore/Stroke:	4 1/4"/5"
Injectors:	N-60
BHP @ 2100 RPM:	290

<u>Transmission</u>

Spicer No. 8844A constant mesh, four forward speeds. First gear, 4.30:1; second, 2.28:1; third, 1.44:1; fourth, direct.

<u>Differential</u>

Hypoid full-floating type, Rockwell Standard R162, 3.7:1 ratio.

2.1 ANALYSIS

2.1.1 Fuel Economy Strategies

It is a well-accepted fact that fuel expenses are a large portion of the direct operating cost of bus companies. As a result, simple economics has demanded that engineering departments optimize fuel economy as one part of minimizing overall direct operating costs. Recent months, however, have seen a drastic change in the fuel situation: costs have skyrocketed, availability is uncertain and speed limits have been changed. It is not surprising, then, that the fuel economy of buses has become a more important factor than in the past. Even today, though, fuel costs will be minimized only to the point at which additional fuel economy would result in higher direct operating costs, and hence become unprofitable. Thus, the current fuel shortage and attendant new operating parameters raise three questions: (1) What is the effect of reduced speed limits on fuel usage with existing equipment? (2) How can existing equipment be modified to provide cost-effective fuel savings? (3) How should new equipment be specified to maximize fuel economy while minimizing direct operating cost? The following paragraphs treat only the first question, in summary form.

The parameters pertinent to a mathematical analysis of an assumed "typical" bus are listed below:

Weight	36,000 lb
Frontal Cross-sectional area	89 ft
Engine Displacement	567.4 in
Piston Stroke	5"
Engine	8 cyl
1st Gear	4.3:1
2nd Gear	2.28:1
3rd Gear	1.44:1
4th Gear	1:1
Differential	3.7:1
Rolling Circumference	10.6
Drag Coefficient	0.7
Accessories Power	25 HP (at 1000 rpm)

Using a program previously developed at TSC, computer simulations of bus fuel consumption were carried out at assumed steady speeds of between 50 and 65 mph for road-grades between ± 3%. Detailed results of the calculations are included in Appendix A and summarized in Table 2-1. It is easy to see that under level road conditions (zero grade) fuel consumption is predicted to increase as speed increases. It is also obvious that the same holds true with a modest grade in the road. Figure 2-1 shows the predicted savings in fuel which might be realized as the speed is decreased from a constant cruise of 60 mph over roads with zero, +1% and-1% grade. For this simulation, it is predicted that slower speeds should realize additive fuel economies in the range of 1.5 to 2% per mile-per-hour of speed reduction.

2.1.2 Limitations of Modeling

All analytical models, like the one discussed above, have shortcomings. Some of the shortcomings of such models pertinent to this effort are discussed in the following subsections.

2.1.2.1 Driver Model - The model employed in this study, like any vehicle simulation, contains assumptions about the driver. In this case, the simulated "driver" diligently tries to keep the vehicle at a constant speed. This results in some "hunting" -if he is going too fast, he applies a small amount of braking; if he is going too slow, he applies a little more throttle. The computer is quite good at this, probably much better than the average driver whose attention may wander or be distracted. As a result, one might not expect to achieve actual fuel economies as high as those predicted under constant speed conditions. As better data on actual drivers are obtained, models will be able to take more realistic characterization of throttle control into account.

2.1.2.2 Engine Fuel Consumption - Data on engine fuel consumption as a function of BMEP (brake mean effective pressure) and piston speed - sometimes called a "fuel-island map," in graphical form - are contained in the computer memory as an array of specific data points. Since data are not readily available for every point

TABLE 2-1. SUMMARY OF ANALYTICAL RESULTS

Speed(MPH)	Grade (%)	MPG	Speed(MPH)	Grade(%)	MPG
50	0	6.47	50	-1	9.48
55	0	5.87	55	-1	8.38
60	0	5.29	60	-1	7.37
65	0	4.83	65	-1	6.57
50	+1	4.61	50	-2	19.44
55	+1	4.24	55	-2	15.11
60	+1	3.97	60	-2	12.01
65	+1	IP	65	-2	9.89
50	+2	3.51	50	-3	BRAKES
55	+2	IP	55	-3	93.52
60	+2	IP	60	-3	43.09
65	+2	IP	65	-3	24.63
50-65	+3	IP			

IP = Insufficient Power to Maintain Speed

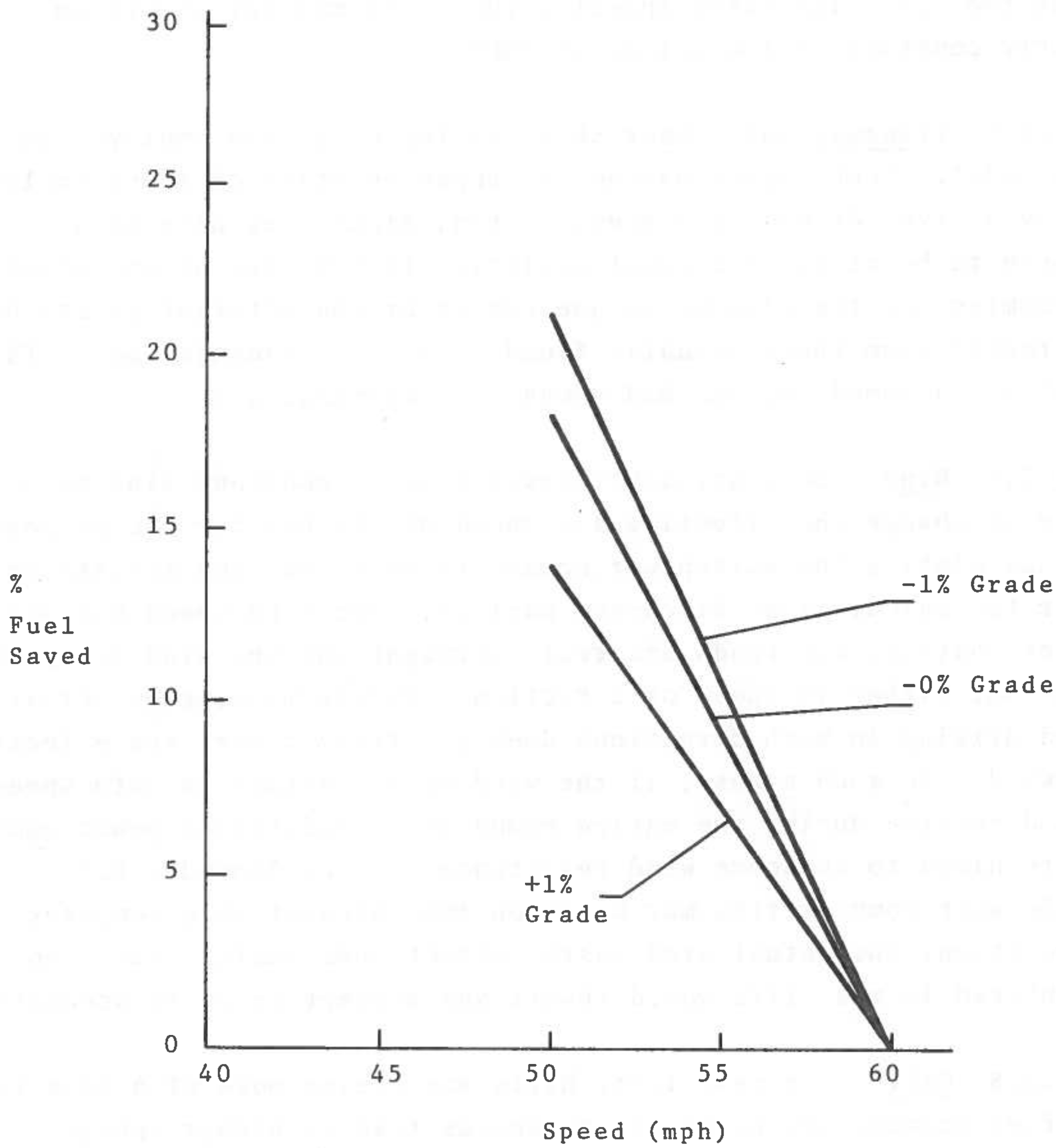


Figure 2-1. Fuel Savings vs. Speed Limits at Different Grades (Fourth Gear)

within the operating envelope of the engine, some errors of interpolation are bound to occur. At BMEP values below the lowest for which data are available (typically 30 psi), the BSFC (brake specific fuel consumption) is estimated according to the principle that the ISFC (indicated specific fuel consumption) should be fairly constant at low values of BMEP.

2.1.2.3 Transmission - Gear shifting logic is also employed in the model. Such shifts may not be representative of those employed by a given driver on a specific run, since they have been chosen to be of general applicability. In the case of an automatic transmission, the assumed torque converter characteristics may be different from those actually found in a real transmission. (This analysis assumed the bus had a manual transmission.)

2.1.2.4 Wind - On a straight, level road, a constant wind acts only to change the effective air-speed of the bus for the purposes of calculating the horsepower needed to overcome wind resistance. (For the calculations discussed earlier, zero wind speed was used.) Unfortunately, few roads are truly straight and the wind is rarely constant either in speed or direction. Furthermore, even actual road driving in both directions does not truly cancel the effects of wind. In such a case, if the wind were constant in both speed and direction during the entire round trip, additional power would be required to overcome wind resistance. (See Appendix B.) While such complexities may be taken into account in a computer simulation, the actual wind gusts, directional shifts, etc., encountered in real life would thwart any attempt to do so accurately.

2.1.2.5 Hills - In real life, hills may create more of a penalty in fuel economy for buses at low speeds than at higher speeds. (Appendix C discusses this point in more detail.) In addition, the Massachusetts tests were run on a very hilly route, with grades up to ± 3.5%, in contrast to the Virginia tests, run over relatively flat terrain. Thus, the computer simulation summarized in Table 2-1 more closely approximates the results obtained in the Virginia tests.

2.2 EXPERIMENTAL DATA

2.2.1 Virginia Tests

Appendix D contains a detailed report on the Virginia test series, which will be only briefly summarized here. This two-day test was performed using a total of 8 buses to demonstrate fuel usage variation between speeds of 50 and 60 mph. The test buses, with a simulated load of 4000 pounds of sand ballast (about 60% load), were each driven on one round trip between Washington, DC and Norfolk, Virginia at a speed of 60 mph in one direction and 50 mph in the other. From the data obtained, it can be stated that, with a 90% level of statistical confidence, fuel economy at 50 mph was better than that achieved at 60 mph. On a straight-average basis, the 8 buses driven at 50 mph showed a fuel consumption of 8.8 mpg with a standard deviation of 0.998 mpg (i.e., 8.8 ± 0.998 mpg); the same buses, when driven over the same route (in the opposite direction) at 60 mph showed a fuel consumption of 8.1 ± 0.64 mpg. Thus, one can infer from these data an average gain in fuel economy of 0.9% per mile-per-hour speed decrease for these buses on this route.

2.2.2 Massachusetts Tests

This series of tests was conducted on the Massachusetts Turnpike over two routes. From Boston to Exit 3 and return, the 190-mile round trip covered rolling hills with short grades up to 3.5%; from Boston to Exit 2 and return, the 250-mile round trip included a long, steep crossing of the Berkshire mountains. Using a total of four buses, the tests were designed to collect fuel economy data at 50, 55 and 60 mph speed limits for the two routes with each bus travelling both routes at each speed, yielding a total of 72 data points. Unforeseen mechanical problems with one of the buses resulted in obtaining only 54 valid test points. A complete description of the tests and data obtained may be found in Appendix E.

A summary of the test results is given in Figure 2-2. Statistical tests performed on the data indicated the following:

- Differences in fuel economy as a function of type of bus were not significant.
- Differences in fuel economy for the two different types of run were significant at the 95% confidence level; i.e., there is only a 5% probability that the observed differences due to the differing routes were due to chance.

It is, therefore, valid to summarize the data as is done in Figure 2-2, which shows the mean fuel consumption for all buses at each speed and for each run. Additional statistical tests performed on the data indicate, moreover, that the slight differences between the mean values at 50 and 55 mph during the short runs and the mean values at 50, 55 and 60 during the long runs are <u>not</u> statistically significant; i.e., the observed differences are much less than the overall experimental uncertainty of approximately ± 3%.

Therefore, the following conclusions can be drawn from data obtained in the Massachusetts tests:

- Bus fuel consumption is approximately the same for 50, 55 and 60 mph when driving on Interstate highways that include both "rolling" hills with grades of up to 3.5% and lengths less than 2 miles, and a mountain crossing with a long, steep grade of approximately 7 miles in length.
- Bus fuel consumption at 60 mph is actually less than that at 50 and 55 mph (i.e., better fuel economy at 60 mph) when this mountain crossing is eliminated and the route includes only rolling hills.

This latter effect, which may be unexpected to some readers, is examined in more detail in Appendix C.

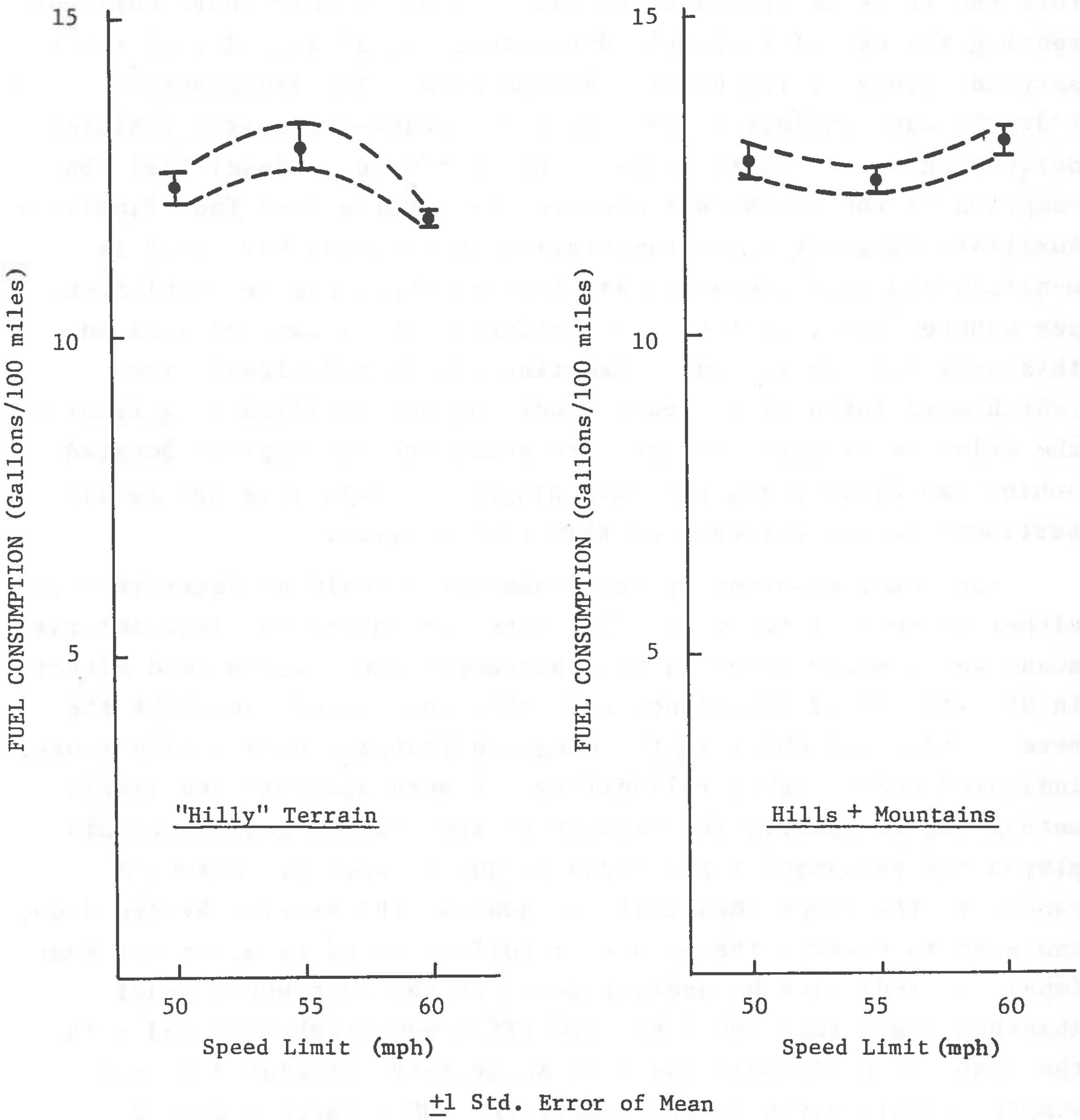


Figure 2-2. Fuel Consumption vs. Speed Limit for Massachusetts Tests

2.2.3 Chassis Dynamometer Tests

2.2.3.1 Test Facility - The heavy-duty facility required to perform the tests described below was secured on very short notice by renting the use of a chassis dynamometer at a large diesel truck service agency in the Greater Boston area. The dynamometer ("dyno") was configured for single-or tandem-drive-axle vehicles delivering up to 400 horsepower (HP) per axle. Diesel fuel consumption of the engine was measured by a three-port fuel flowmeter. Auxiliary diagnostic instrumentation in the test bay, such as manifold and fuel pressures and temperatures, engine revolutions per minute (rpm), combustion efficiency, etc., was not used in this work for two reasons: Existing sample and signal lines (which were intended to reach truck engines positioned in front of the drive axle) were too short to reach the bus engines located behind the drive axle; and such diagnostic data were not really pertinent to the purposes of this test program.

The power absorbed by the dynamometer could be determined in either or both of two ways. The more convenient but less accurate means was a power meter on the instrument panel which read directly in HP; very brief experience with this instrument, in which the meter needle was observed to swing continuously over a wide range, indicated questionable reliability. A more accurate and stable method was to observe the reading of the "Force" gage which displayed the resistive force (dyno torque divided by lever arm radius to the force load cell) in pounds (lb) exerted by the dyno, and also to observe the dyno roll surface speed in miles per hour (mph), as indicated by another meter in the instrument panel. Absorbed power then could be read off a nomograph supplied with the dyno, or preferably and more accurately calculated from a simple formula given on the nomograph: HP = Force x mph/72.5. This latter technique was used throughout the dyno tests, except for the very first series of data recorded in the beginning of the initial days' testing.

2.2.3.2 Dynamometer Load Selection - Dynamometer loads intended to be representative of typical road loads for these buses were selected on the basis of data provided by the Power and Propulsion Branch (TMP) of TSC. These data comprised the three major types of power loads which a vehicle's engine must overcome: aerodynamic drag, rolling friction and (uphill) grade load. Standard industry relationships were used to estimate aerodynamic drag and rolling friction; the grade load is a simple function of potential energy increase due to gain in altitude. These component losses were calculated for road grades of 0 to 3 percent at 5 mph speed increments from 40 to 65 mph, for a single hypothetical bus with constant weight of 36,000 lb, constant frontal area of 89 square feet (sq ft), and constant drag coefficient of 0.7. The resultant data used in these tests are summarized in Table 2-2.

For each bus to be tested, the rolling friction and grade load values were corrected for the actual weight of the bus by multiplying each number by the ratio of actual to hypothetical weight. The aerodynamic drag is independent of vehicle weight and in the absence of precise drag data for the individual vehicles was assumed constant for all buses tested. The three component losses then were summed for each speed and grade combination to provide "target" dyno load HP settings for the various conditions. Appendix C gives details of the test procedure.

2.2.4 Results

The results of these tests are summarized graphically in Figure 2-3. The results predict a savings in fuel consumption of approximately 1.7% per-mile per-hour reduction in speed from 60 to 50 mph over level terrain. As might be expected, these predictions lie between the more optimistic figures based on simplified computer models and those actually encountered in the field experiments.

TABLE 2-2. BUS ROAD LOAD VALUES

speed	40 MPH				45 MPH				50 MPH				55 MPH				60 MPH				65 MPH			
grade (%)	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
load aero (HP)	27				38				52				69				90				114			
load roll (HP)	33				38				44				50				56				62			
load grade (HP)	0	38	77	115	0	43	86	130	0	48	96	144	0	53	106	158	0	58	115	173	0	62	125	187
load total (HP)	60	98	137	175	76	119	162	206	96	144	192	240	119	172	225	277	146	204	261	319	176	238	301	363
best gear	4	4	4	3	4	4	4	3	4	4	3	3	4	4	3	*	4	4	*	*	4	4	*	*

*insufficient power

Bus parameters: weight 36,000 lb
cross section 89 sq ft
drag coefficient 0.7
engine 8V 71
differential ratio 3.7

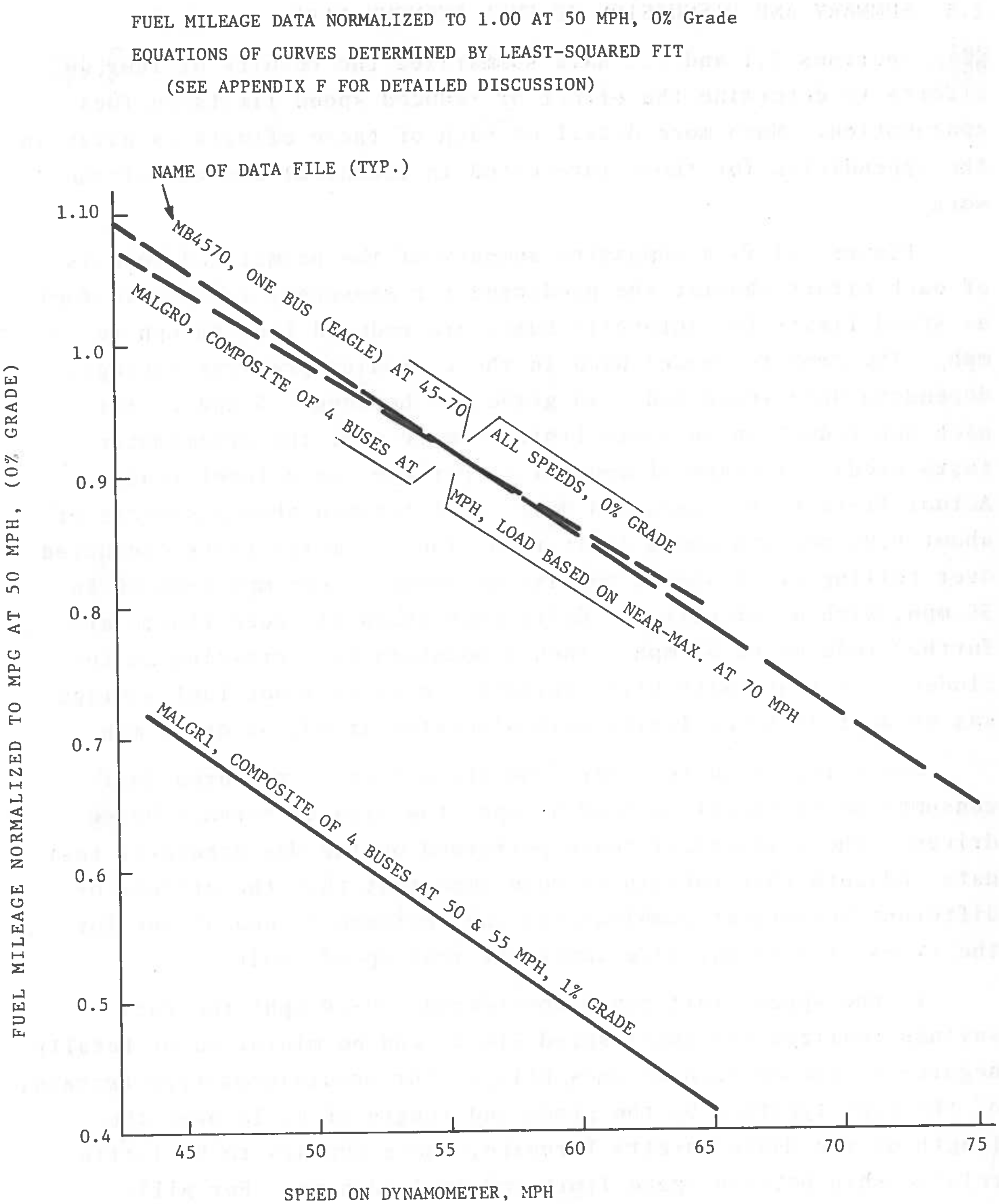


Figure 2-3. Dynamometer Tests of Buses

2.3 SUMMARY AND DISCUSSION OF FUEL ECONOMY DATA

Sections 2.1 and 2.2 have summarized the results of four efforts to determine the effect of reduced speed limits on fuel consumption. Much more detail on each of these efforts is given in the appendicies for those interested in technical aspects of the work.

Figure 2-4 is a composite summary of the normalized results of each effort showing the predicted (or measured) savings in fuel as speed limits for intercity buses are reduced from 60 mph to 50 mph. The computer model used in these studies predicts savings, depending upon speed and road grade, of between 1.5 and 2% for each mph reduction in speed limit from 60 mph; the dynamometer tests predict savings of about 1.7% per mph for a level road. Actual field tests conducted over level terrain show a savings of about 0.9% per mph speed limit reduction. Similar tests conducted over rolling hills show a penalty of about 1% per mph from 60 to 55 mph, with no significant difference shown if speed limits are further reduced to 50 mph. When a mountain-type crossing is included in a route with hilly terrain, no significant fuel savings was evident as speed limits were simulated at 60, 55 or 50 mph.

One thing is quite clear from these tests: measured fuel consumption is heavily dependent upon the type of terrain being driven. The statistical tests performed on the Massachusetts test data indicate that terrain is more important than the effects of different bus-driver combinations and, between 50 and 55 mph for the types of terrain, more important than speed limit.

In the speed limit range considered (50-60 mph) the fuel savings realized for lower speed limits can be minimized or totally negated as the terrain becomes hilly. For mountainous-type terrain, of the type typified by the grade and length of hills over the length of the Massachusetts Turnpike, there appears to be little relationship between speed <u>limit</u> and fuel economy. For hilly terrain, of the type typified by traveling only the eastern half of the Massachusetts Turnpike, speed limits of 50 and 55 mph actually give <u>worse</u> fuel economy than a 60 mph speed limit.

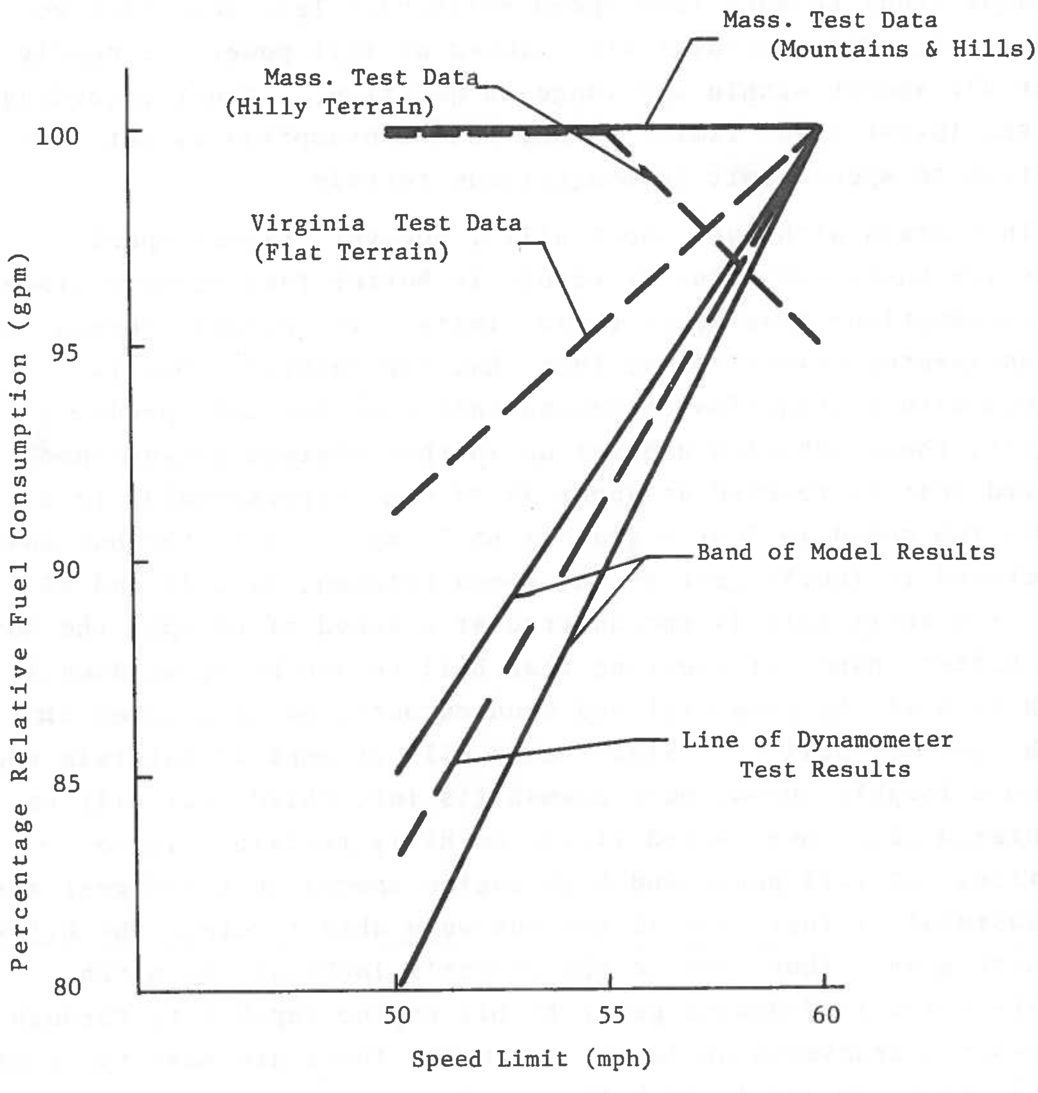


Figure 2-4. Composite Summary - Relative Fuel Consumption vs. Speed Limit

Qualitatively, the effect of the mountains is easy to explain. Normally, one would expect increased fuel consumption with higher speed limits. In mountainous regions, buses have difficulty maintaining speeds above 50 mph on grade. Thus, the presence of mountains tends to make road speed relatively less sensitive to speed limit. The mountains are climbed at full power (or nearly so) at all speeds within the range in question, without exceeding even the lowest speed limit. Thus, fuel consumption is not very sensitive to speed limit in mountainous terrain.

In terrain with many short hills, however, higher speed limits for buses can actually result in better fuel economy (lower fuel consumption) than lower speed limits. The primary reason for this unexpected effect is the fact that the intercity bus is equipped with a transmission having only four forward speeds. Normally, these vehicles are set up so that maximum engine speed in third gear is reached at about 45-48 mph, corresponding to a maximum top speed in fourth gear of 65-70 mph. Thus, the bus must be operated in fourth gear at any speed between, say, 45 and 65 mph. If a short hill is encountered at a speed of 60 mph, the bus has a better chance of cresting that hill before he slows down to 45 mph than if the same hill had benn encountered at a speed of 50 mph (see Appendix C). Since buses will attempt to maintain the maximum allowable speed, more downshifts into third gear will be encountered with lower speed limits on hilly terrain. These operations (at full power and high engine speed) in third gear are more wasteful of fuel than if the bus were able to crest the hills in fourth gear. Thus, due to the driver's inability to match accurately the road-demand power to his engine capability through a many-speed transmission (as in a truck), there are some types of terrain which can result in better fuel economy for buses at higher speeds than at lower speeds (Appendix C discusses this in more detail.)

The net result of these efforts, then, may be summarized as follows: Intercity buses should realize a measureable fuel saving, if speed limits are reduced from 60 to 55 mph over "level" terrain In "mountainous" areas, these fuel savings become neglibible. If the terrain consists primarily of rolling hills, reducing the speed limit from 60 mph to 55 mph should show a measurable increase in fuel consumption (i.e., worse fuel economy). Reducing speed limits from 55 to 50 mph should result in no change in fuel economy in either mountainous or rolling terrain, but will show a savings in fuel consumption over level terrain. These data were summarized graphically in Figure S-1 of the Summary.

3. MAINTENANCE CONSIDERATIONS

The length of time available for this work precluded actual testing to define additional maintenance problems, since the useful life of a typical intercity bus diesel engine is in the vicinity of 7500 hours. Unfortunately, contacting industry suppliers, maintenance personnel, etc., also proved of limited usefulness, inasmuch as few of them have had any actual experience with operating engines under lowered speed limits. The question, then, had to be approached from a more "theoretical" viewpoint by seeking expert opinions in answer to a general question, such as "what effect on maintenance would you expect from operating engines at lower speeds?"

The answers to this type of question were almost universally favorable toward low-speed operation in every area, with two exceptions. Engine maintenance at lower speeds should be reduced in the areas of ring wear, valve wear, bearing wear and fuel-injector wear. For any given engine, the stress on these components is proportional to the engine speed; lower speeds (within reason) result in longer life. Lower speeds also increase tire life, since tire wear is proportional to the square of the velocity. Cummins Engine Company, Inc., for example, states in a December 1973 Automotive Marketing Bulletin that "any Cummins engine will operate indefinitely at wide-open-throttle (a worst-case situation) anywhere between governed RPM and peak torque RPM. It is neither necessary nor desirable to keep the engine 'wound-up.' Better breathing characteristics...have improved low speed performance, and cooling-system improvements have eliminated the life problems once associated with low engine speed operation." They take no position on the desirability of reduced speed limits, but their technical information clearly points out the reduced maintenance problems associated with such low-speed operation.

A large Florida-based trucking company has spent considerable effort in trying to minimize fuel consumption in order to decrease direct operating costs and increase profits. Their experience indicates that derating the maximum engine power and operating at reduced speeds significantly improves fuel economy. At the same time, maintenance problems have decreased and engine life has dramatically increased. Other automotive engineers also agree that driving at reduced speeds will reduce all aspects of engine maintenance.

Two vehicle components might be adversely affected by reduced speed limits. There is a small chance of increased transmission problems, since more driving will presumably be done in third gear, resulting in a higher countershaft speed. This effect, however, is almost surely negligible in intercity buses. (It is a little more pronounced in the case of long-haul trucks with many-speed (10, 13 or more) transmissions, but the added wear should be negligible here, too.) The clutch, however, will more probably incur additional wear, especially on routes with short, rolling hills (as in New England, on a New York-Boston trip). Since well-synchronized shifts result in little clutch slippage in comparison to starting from a stop, it is difficult to see how this could be significant. However, maintenance personnel at Continental Trailways report a sudden, dramatic increase in clutch problems since the speed limits were lowered. On the New York-Boston run in one 2-week period (December 6-20, 1973), they report replacing 3 clutches and adjusting 3 more. This is approximately a factor of 10 higher incidence of clutch problems over "normal," and may in fact be anomalous.

In summary, lowered speed limits are generally expected to result in reduced expenditures for maintenance and longer engine life. There is a possibility of increased transmission wear, and it is expected that clutch life will decrease somewhat. Only several years of maintenance data will be able to determine these affects more precisely.

4. OPERATIONAL IMPACT OF REDUCED SPEED LIMITS

4.1 SUMMARY OF CURRENT OPERATING RULES

Intercity bus company operating costs are in part a function of driver utilization efficiency, as reflected in the company's assignment of drivers to the many trips it schedules during the course of the day. Two sets of constraints operate to affect the company's freedom to make such assignments. The first is the limitation on hours of service of motor coach operators found in the Motor Carrier Highway Safety Regulations of the Federal Highway Administration of the Department of Transportation. These are uniform for all bus lines operating in interstate commerce. The second is the labor-management agreement in effect between any particular company and the union that represents that company's drivers. The terms of such agreements vary among companies.

4.1.1 Federal Regulations Affecting Hours of Service

Federal regulations affecting the hours of service of motor coach operators may be found in Part 395 of the Motor Carrier Safety Regulations of the Federal Highway Administration of the U.S. Department of Transportation. The regulations first define several terms. "On duty time" is defined in Section 395.2(a) as all time from when a driver begins to work or is required to be in readiness to work until he is relieved from work and all responsibility from performing work. Thus, on duty time would include time spend, for example, waiting to be assigned a run, loading passengers and express, inspecting equipment, fueling equipment, as well as time spent actually driving. "Driving time" is defined in Section 395.2(b) as all time spent at the driving controls of a motor vehicle in operation. Section 395.3(a) restricts the amount of time a person employed as a driver may spend actually driving to not more than 10 hours following 8 consecutive hours off duty, and prohibits him from driving for any period after having been on duty 15 hours following 8 consecutive hours off duty. Section 395.3(b) further restricts the total on duty time of a driver employed by a company that operates vehicles every day of the week to not more than 70 hours in any period of 8 consecutive days. That period is defined in Section 395.2(d) to be the period of 8 consective days beginning at 12:01 a.m. on any day.

Furthermore, Section 395.7 provides that a driver traveling from one point to another at the direction of his employer, but not driving or assuming any other responsibility to the carrier, is considered on duty while traveling — unless he is given at least 8 consecutive off duty hours after he arrives at his destination, in which case he shall be considered off duty for the entire period. Section 395.10 permits an additional 2 hours of driving time when necessary for a driver to complete his run during adverse driving conditions, if the highways are snow- or ice-covered, or in the presence of unusual road and traffic conditions, provided that the total of 12 hours of driving time will be completed within 15 hours of on duty time following 8 consecutive hours off duty. Section 395.11 provides that, in case of emergency, a driver may complete his run without being in violation of the provisions of the hours of service regulations, if, without any emergency, the run could have been completed without being in violation. Section 395.12 exempts carriers from hours of service regulations when providing service to or from any section of the country suffering from a calamitous visitation or disaster. The restrictions on driving hours and on duty hours are less stringent for drivers operating buses solely in the state of Alaska.

4.1.2 Provisions in Labor-Management Agreements Affecting the Assignment of Drivers

Many provisions contained in the labor-management agreement between a company and the union representing its drivers restrict the freedom of the company in assigning drivers to runs. The constraints imposed are not absolute prohibitions in the same sense as the hours of service regulations delineated in 4.1.1, but rather impose economic penalties upon the company in the form of wages required to be paid for work not actually performed, i.e., miles not driven. Provisions in such union contracts tend to vary between companies. Appendix G contains the provisions of the current agreement between Continental Trailways of New England (CTNE) and the Amalgamated Transit Union, Division 1318 (effective November 1, 1971, for a 3 year period) relevant to this study.

In reviewing these provisions, it will be noted that operators of motor coaches in intercity service may be divided into "regular-run" operators and "spare" operators. The provisions providing for utilization and compensation of the two types of operators differ. An operator becomes a regular-run operator in the following manner: The company sets up schedules which it prints in its timetables and advertises to the public. It then divides the scheduled trips into pieces of work, or "runs." Each run may require driving one schedule, driving two or more schedules, driving just part of a scheduled trip, or possibly some combination of these options. Furthermore, the requirements of a run may differ from day to day. The number of days off interspersed with the number of working days in a run also vary. Some runs, for example, are "four on, two off" (i.e., work four days, take two days off); others might be "six on, one off." Appendix H contains six representative runs from a recent "bid book." A "bid book" contains a description of each run. Drivers pick runs from the bid book on the basis of their seniority in the company. The drivers without enough seniority to pick a regular run or those who for some personal reason do not chose to do so become "spare drivers" or "extra drivers." They are available to operate extra sections of regular schedules, charters, and other special movements. Spare drivers may exercise their seniority to pick a home terminal to the extent of the number of drivers the company wishes to be assigned to that terminal. Thus, CTNE has three home terminal spare "boards" at New York, Boston and Springfield.

Intercity motor coach drivers' pay has traditionally been computed on the basis of miles driven, and all time spent in the company's service is equated to miles for pay purposes. Thus, a minimum day's pay of 160 miles for work performed within 8 consecutive on duty hours is based on the minimum of 20 miles pay per hour. (Reference to Appendix H will verify that scheduled or regular runs almost invariably pay more than the minimum pay.) On the other hand, a charter or any move involving long layovers could require payment for many hours at the basic 20 miles per hour rate. For example, a driver assigned to stand-by at a terminal in the anticipation that he will be needed to drive an extra section of a regularly scheduled run would be paid 20 miles per hour for this so-called "protection" work, in addition to being paid for any trip he is eventually ordered to make. Similarly, an extra driver, riding as a passenger to another point from which he will drive a bus, will be paid 20 miles per hour for this so called "cushioning." If a driver is on duty for more than 8 consecutive hours, he is entitled to more than a minimum day's pay, regardless of whether he does any driving at all, and if on duty for more than 12 hours, he will be entitled to penalty pay or overtime pay. Also, if a spare driver is off duty at any point away from his home terminal due to lack of work for more than 16 hours, he becomes entitled to layover pay.

The mileage rate paid a driver is a function of the driver's length of service with the company. As of December 1973 a driver with CTNE more than 2 years is entitled to the maximum rate of $0.199 per mile. A spare operator is guaranteed 800 miles pay per week, provided he is available for work 6 days during the week. An operator furloughed due to lack of work is required to be given one week's notice of furlough and, at the effective date of the furlough, pay for 6 minimum days (960 miles).

4.2 SUMMARY OF NATIONAL STATISTICS

The statistics in this section were compiled either by the National Association of Motor Bus Operators (NAMBO), the national trade association for the motor bus industry, or by the Interstate Commerce Commission (ICC) Bureau of Accounts. The availability of statistics for an individual intercity bus operator depends upon the geographical extent and financial magnitude of the operation. For example, a bus company that does not operate across state lines in its regular route services and has no interstate charter or special operations rights would not be subject to the jurisdiction of the Interstate Commerce Commission and thus would not file any reports with that agency. It would only file reports with the appropriate state regulatory agency.

On the other hand, every company with interstate operating rights, be they regular route or charter or special operations, is subject to the jurisdiction of the ICC and must file reports with it. Such carriers are divided into classes I, II and III on the basis of average annual gross operating revenue. If the average annual gross operating revenue of a carrier is $1 million or more, it is a Class I carrier and more detail is required in its reports. Class I carriers, however, may provide not only "intercity" regular route service, but also "local and suburban" regular route service as well as "charter or special" service. The ICC has defined the term "intercity carrier" to include any Class I carrier reporting revenues from both intercity service and local and suburban service "if the revenues received from intercity traffic equal or exceed 50 percent of the total revenues received from intercity and local or suburban traffic." Thus, 72 of the 95 Class I carriers in 1972 were classified as intercity carriers by the ICC. Note, however, that local and suburban passengers may be carried on intercity schedules, and the ICC statistics provide no way to differentiate between passengers on intercity schedules on the basis of the length of their trips. This impacts the distribution of data on both passenger revenue and number of revenue passengers between the two classifications to an unknown extent.

The total magnitude of the intercity bus industry may thus be ascertained only by recourse to the NAMBO statistics presented in Section 4.2.1.

However, it is the Class I carriers meeting the ICC definition of "intercity carrier" that are most likely to be impacted by a reduced speed limit, because they cover greater distances on express highways in the course of their regular route operations. The operational impact portion of this study, it will be recalled, is explicitly limited to the effect of reduced speed limits on regular route operations. Statistics pertaining to these Class I carriers are presented in Section 4.2.2. Where possible, final ICC figures for 1972 are used. Where it was necessary to use preliminary NAMBO figures, they are indicated as such. In this connection, it should be noted that the NAMBO figures were based on 74 (not 72) intercity bus companies operating in 1972. An immediate reconciliation of the discrepancy is not available. Comparable statistics for Continental Trailways of New England are presented, and the percent of the industry total represented by CTNE in each major category of interest is shown.

In reviewing these statistics it should be borne in mind that the same motor coaches and drivers may be, and typically are, used in regular route and charter services. On the other hand, the physical characteristics of the regular route operation may not be the same as those of the charter operations, i.e., there may be more low speed stop-and-go running on regular routes and more sustained high-speed running in charter operations. Similarly, the labor cost component of the operating expenses may differ markedly between regular route operations and charter operations, due to the provisions in union-management contracts covering the two types of operations, especially those pertaining to meal expenses, over-night lodging expenses, layover pay and overtime pay. Furthermore, passenger load factors (percent of seats occupied) differ between the two types of services. Thus, it is not accurate to attempt to assign operating or other expenses to regular route or charter operations by pro rata computations based either on passenger revenues, bus miles, or number of passengers carried.

4.2.1 The Intercity Bus Industry in the United States

The statistics below include operations of Class I, II and III carriers reporting to the ICC, and intrastate carriers. They were compiled by NAMBO from ICC data, including published materials and reports filed by individual carriers, supplemented by estimates to cover unavailable segments.

	1972
Number of Operating Companies	1,000
Number of Buses	22,700
Miles of Highway Served[a]	267,000

	1972
Number of Employees[b]	48,600
Total Bus-Miles (millions)	1,181
Revenue Passengers (millions)	387
Revenue Passenger-Miles (millions)	25,600
Operating Revenues, all services ($ millions)	971.6
Operating Expenses ($ millions)	879.9
Net Operating Revenue, before income taxes ($ millions)	91.7
Taxes Assignable to Operations ($ millions)[c]	82.9

[a]Includes duplication between carriers.

[b]Operating companies only.

[c]Excludes income taxes.

4.2.2 Revenues, Expenses, Other Income and Statistics of Intercity Class I Motor Carriers of Passengers - 1972

Statistics of the bus company (CTNE) used for this study are compared to national statistics in Table 4-1. Data were compiled from ICC and NAMBO statistics.

4.3 DETAILED STATISTICS-REPRESENTATIVE STUDY REGION

The statistics presented in this section augment the statistics already presented about CTNE in Section 4.2.2 for comparison with national figures. The descriptive materials in this section will aid in an understanding of certain analytic aspects of the problem of optimum driver assignment and coach utilization.

4.3.1 Routes and Service

The route structure of CTNE is schematically depicted in Figure 4-1. The schedules operated during November 1973, appear in Appendix I. Table 4-2 shows the number of trips operated during this time period between each pair of route end-points and the resulting daily and weekly bus revenue mileage. Actual bus mileage is greater than revenue bus mileage because it includes

TABLE 4-1. COMPARISON OF CTNE STATISTICS AND INTERCITY CLASS I NATIONAL BUS STATISTICS

	United States-All Regions Total of All Intercity Carriers Reported	Continental Trailway of New England (CTNE)	CTNE As a Percent of Total
Operating Revenue			
Passenger Revenue			
Intercity Schedules	$534,611,714	$7,133,940	1.3%
Local and Suburban			.0%
Schedules	$ 11,652,843	$ 0	.0%
Charter or Special			
Service	$ 93,953,690	$ 636,798	.7%
Total Passenger Revenue[a]	$640,218,247	$7,770,738	1.2%
Total Operating Revenue*	$768,055,522	$8,753,523	1.1%
Expenses			
Operating and Maintenance	$585,749,524	$7,341,225	1.3%
Depreciation and Amortization	$ 29,545,243	$ 554,872	1.9%
Operating Taxes and Licenses	$ 53,844,894	$ 494,000	.9%
Operating Rents-Net	$ 13,318,340	$ 460,266	3.5%
Total Expenses	$682,458,001	$8,850,363	1.3%
Net Operating Revenue	$ 85,597,521	$ −96,840	-
Operating Ratio-Percent	88.9	101.1	-

The operating ratio is the percent of operating revenues needed to pay operating expenses.

*Includes Other Operating Revenue, i.e., package express and mail.

TABLE 4-1. COMPARISON OF CTNE STATISTICS AND INTERCITY CLASS I NATIONAL BUS STATISTICS (Continued)

	United States-All Regions Total of All Intercity Carriers Reported	Continental Trailway of New England (CTNE)	CTNE As a Percent of Total
Expenses (Cont'd)			
Other Income	$ 18,033,112	$ 0	-
Other Deductions	$ 9,689,879	$ 229,999	-
Ordinary Income			
Before Income Taxes	$ 93,940,754	$ -326,839	-
After Income Taxes*	$ 59,267,793	$ — 83,877	-
Net Income **	$ 59,323,675	$ — 83,877	-
Bus Miles Operated:			
Intercity Schedules	698,920,436	8,260,821	1.2%
Local and Suburban Schedules	14,499,911	0	.0%
Charter or Special Services	121,363,601	732,828	.6%
Total Bus Miles[a]	834,783,948	8,993,649	1.17%

*Includes Other Operating Revenue, i.e., package express and mail.

**Includes the net of extraordinary and prior period items.

TABLE 4-1. COMPARISON OF CTNE STATISTICS AND INTERCITY CLASS I NATIONAL BUS STATISTICS (Continued)

	United States-All Regions Total of All Intercity Carriers Reported	Continental Trailway of New England (CTNE)	CTNE As a Percent of Total
Number of Revenue Passengers Carried:			
Intercity Schedules	120,899,734	1,212,338	1.0%
Local and Suburban Schedules	15,500,788	0	.0%
Charter or Special Services	20,389,118	47,459	.2%
Total Revenue Passengers[a]	156,789,640	1,259,797	.8%
Percent of Total Revenue Passengers Carried on Regular Route Intercity Schedules[a]	77.1%	96.2%	-
Percent of Total Bus Miles Operated on Regular Route Intercity Schedules[a]	83.7%	91.9%	-
Percent of Total Passenger Revenues from Regular Route Intercity Schedules[a]	83.5%	91.8%	-

TABLE 4-1. COMPARISON OF CTNE STATISTICS AND INTERCITY CLASS I NATIONAL BUS STATISTICS (Continued)

	United States-All Regions Total of All Intercity Carriers Reported	Continental Trailway of New England (CTNE)	CTNE As a Percent of Total
Route Miles Served[b]	195,000	891	0.5%
Buses Owned[b]	9,900	99	1.0%
Drivers[b]	15,680	164	1.0%

[a]Denotes figure computed from ICC data.

[b]Denotes preliminary figure from NAMBO _Bus Facts_, 1972. All other figures from ICC Statement No. 750, _Revenues, Expenses, Other Income, and Statistics of Class I Motor Carriers of Passengers_.

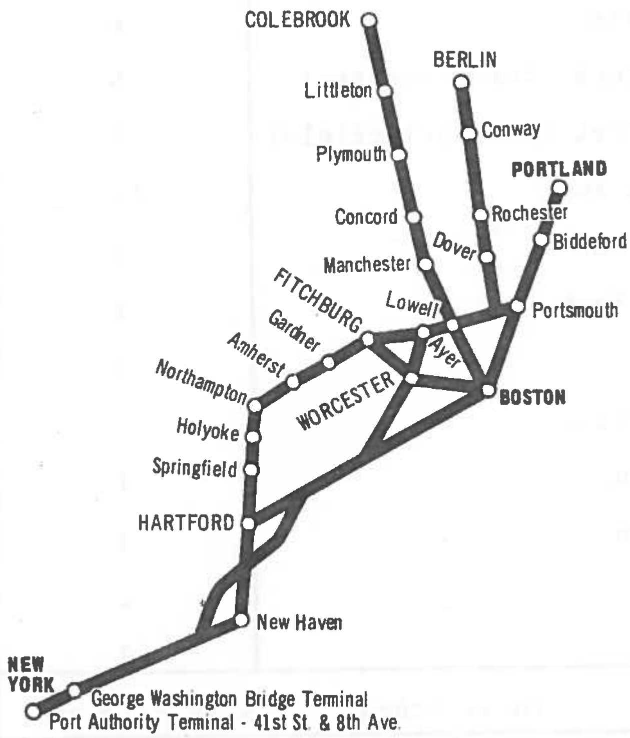


Figure 4-1. Continental Trailways of New England (CTNE) Route Structure (November 1973)

TABLE 4-2. SUMMARY OF SERVICE PROVIDED BY CTNE DURING NOVEMBER 1973

DAILY SERVICE

Route	Number of Round Trips	Total Scheduled Bus Revenue Mileage
Boston-New York	9	3,943
Portland-New York	6	3,930
Haverhill-New York (via Worcester)	5	2,560
Haverhill-New York (via Springfield)	1	559
Springfield-New York	14	4,059
Fitchburg-New York	1	402
Manchester-New York	1	533
Berlin-Boston	1	368
North Conway-Boston	1	298
Rochester-Boston	1	158
Colebrook-Boston	1	470
Plymouth-Boston	2	606
Laconia-Boston	2	480
Total Scheduled Daily Mileage		18,366

NON-DAILY SERVICE

Route	Frequency	Weekly Bus Mileage
Concord-Boston	1 Round Trip Mon-Fri.	870
New York-Boston	1 1/2 Round Trips Fri.& Sun	656
New York-Amherst	1 Round Trip Sun	340
Total Scheduled Weekly Mileage		130,428

garage-terminal movements before and/or after almost every trip. No conclusions should be drawn from this table as to the frequency of service at any particular point. That information, although readily available from the Schedules in Appendix I, was determined to be too complex for facile summarization and of only marginal utility for the purposes of this study. It should also be remembered that the mileage between two end points is a function of the location of the intermediate stops. For example, the distance from Springfield to New York is 144 miles via Hartford only, or via Hartford and New Haven, but increases to 147 miles if the trip also operates via Middletown.

Primary input to the scheduling procedure comes from the Assistant Traffic Manager. Schedules are manually configured to reflect the latest available information about the demand for service, i.e., riding and revenue data. Schedules must be designed to maximize revenue by affording the greatest possible convenience to potential passengers, not only with regard to on-line originations and terminations, but also with respect to connecting passengers, both on-line and off-line, at the selected frequency of service for any particular route. The Traffic Department is necessarily required to interface with the Operating Department in order that the impact of schedule changes upon operating costs (i.e., operator assignments and coach utilization) be fully understood. When it is impossible to reconcile desired schedule changes with increased operating costs by a compromise or agreement between the Traffic and Operating Departments, the final decision is made by CTNE's top management.

4.3.2 Equipment

CTNE owns 99 buses, 93 of which are Silver Eagles and six of which are Golden Eagles. Of these coaches, 55 are required to cover the daily schedules, including the Concord-Boston five-day commuter schedule. Three more buses are needed to cover the Friday and Sunday weekend runs. In addition, one bus from another Continental Trailways division is used each day.

4.3.3 Personnel

CTNE currently employs 164 drivers. The daily schedules and the Concord-Boston commuter run have been split into 91 pieces of work, or "runs," as shown in Table 4-3. These runs are selected by drivers on the basis of their seniority. Of the remaining 73 drivers, 13 selected the New York spare board, 9 selected the Springfield spare board, and the remaining 51 have been assigned to the Boston board. They are available for assignment to the weekend extra schedules, to extra sections, to charters, and to other special moves.

It is important to note that, of the 91 regular runs, 31 result in the driver returning to his starting point by the end of the day. Thus, the company does not incur hotel expenses for drivers on these runs. Furthermore, 8 runs incur penalty pay — that is, the additional pay of 20 miles for each hour on duty over 12 consecutive hours provided for in the union contract. It is the impact of reduced speed limits on hotel expenses and penalty pay that will be highlighted in the next section.

4.3.4 The Run-Cutting Procedure

CTNE, as is typical of the industry, employs no computerized "run-cutting" procedure to divide schedules into runs. Run-cutting on CTNE is performed manually. It is necessary to consider not only the constraints on driver utilization imposed by both the D.O.T. hours of service regulations as explained in Section 4.1.1 and the labor-management contract as discussed in Section 4.1.2, but also the general desire of the company to minimize hotel expenses and payments for miles not actually driven, such as penalty pay. Although it is occasionally impossible to include a particular schedule in some driver's run every day that it is operated, every effort is exerted to minimize this occurrence, because of the resultant administrative burden incurred by the necessity to assign a driver from the appropriate spare board in sufficient time to allow him to be at the starting point of the run when it is due to leave. It is generally considered impractical to change drivers

TABLE 4-3. SUMMARY OF DRIVER RUNS OF CTNE DURING NOVEMBER 1973 BY DAILY WORK ASSIGNMENTS

End Points	One-Way	Round Trip	Number of Runs	Note
Boston-New York	X		12	
Boston-New York		X	6	a
Boston-Laconia		X	2	
Boston-Berlin	X		2	
Boston-Plymouth		X	1	
Boston-North Conway		X	1	
Portland-New York	X		18	
Fitchburg-New York		X	2	b
Haverhill-New York	X		17	
Manchester-New York	X		3	
Manchester-Plymouth via Boston	X		2	
Manchester-Colebrook	X		2	
Concord-Boston		X	1	b
New York-Springfield		X	19	a
Rochester-Boston		X	1	b
Laconia Relief			1	c
Rochester Relief			1	d
Total			91	

Notes:
- a: Penalty Pay incurred on two runs only.
- b: Penalty Pay incurred.
- c: Covers days off of drivers on Laconia-Boston, Manchester-Plymouth via Boston and Manchester-Colebrook Runs.
- d: Covers days off of driver on Rochester-Boston run and one driver on a Boston-New York one way run.

on an isolated stretch of a highway, interstate or local, in order to reconstitute, say, two straightaway runs between New York and Portland into two turnaround runs.

There is no requirement in the union contract that any particular number of runs have any particular home terminal, or that any particular division of schedules into runs be followed. However, it is generally recognized in the transportation industry that operating employees frequently select their residences based on an expectancy of being able to earn a predictable amount of money by picking a run originating at or near their homes. Any attempt by a transportation company to restructure its runs by changing run patterns of long standing would probably engender employee resentment, which would become evident either at the next contract negotiation or even before, through possible informal and unofficial actions, e.g., massive sickouts or slowdowns. This could easily result in economic detriment to the company outweighing any gains accrued from reducing expenses by making major changes in the run structure.

4.4 IMPACT OF REDUCED SPEED LIMITS ON OPERATIONS OF CTNE

This section will discuss the increased operating expenses that will be incurred by CTNE as a result of the decrease in speed limits. These expenses will be considered from two viewpoints. First, the impact on expenses incurred in regular run operations will be projected on an annual basis. Then, an attempt will be made to suggest the increase in expenses incurred in operating extra sections of scheduled trips to accommodate holiday travel, the volume of which is frequently several times greater than that on normal weekdays.

4.4.1 Scheduled Running Times

Table 4-4 shows comparative running times based on present speed limits, a 55 mph national limit and a 50 mph limit. Where the number of location of intermediate stops differed from schedule to schedule, the running times are shown for several representative trips, and run numbers are provided to permit the trip to be

TABLE 4-4. COMPARATIVE RUNNING TIMES FOR REPRESENTATIVE CTNE SCHEDULED TRIPS

Between	At Current Speeds	At 55 mph Maximum	At 50 mph Maximum	Run Number
Boston and New York, Express	4:25	4:50	5:10	(17 trips)
Boston and New York, Local	4:52	5:17	5:29	205
	4:37	4:58	5:22	213
	4:35	5:00	5:23	217
	5:00	5:20	5:40	104
	4:40	5:05	5:20	216
Portland and New York	7:25	7:50*	8:10*	151
	7:55	8:20*	8:40*	117
	7:40	8:05*	8:40*	101
Portland and Boston	2:15	2:25	2:35	151
	2:45	2:50	3:00	101
Boston and Plymouth	3:50	4:00	4:00	1404
	3:35	3:45	3:48	1401
Boston and Berlin	4:30	4:35	4:45	1304
	4:45	4:50	5:00	1305
New York and Haverhill	7:05	7:20	7:30	402
	5:55	6:05*	6:12*	414
	7:35	7:35*	7:55*	408
	6:47	7:07	7:17	401
	7:52	8:12	8:18	403
Fitchburg and New York	5:00	5:17	5:33	2301
	5:00	5:05*	5:15*	2300
Manchester and New York	6:15	6:30*	6:50	602
New York and Springfield				
via Hartford	3:12	3:24	3:34	(8 trips)
via Htfd and New Haven	3:22	3:39	3:49	(13 trips)
via Htfd, Middletown and NH	3:47	3:54	4:04	(9 trips)

* Denotes rest stop duration reduced

<u>Source</u>: Current CTNE timetable (Oct. 28, 1973) and proposed timetables (informal company documents)

located in the timetable in Appendix I, if detailed information about its characteristics is desired. As might be expected, the incremental running time is a function of the proportion of the distance traveled on local roads and city streets (where the speed limits have always been below 50 mph) to the distance travelled over express highways. Because all trips operating through Boston, Worcester, and Springfield make rest stops at these points (except for New York-Boston trips stopping at Worcester), some of the impact on overall running times on longer trips was offset by reducing the length of the rest stop. In Table 4-4, an asterisk denotes those trips affected by this strategy. These running times were extracted from schedules proposed to be operated by CTNE during January 1974.

As an example, the Boston-New York express running time was recomputed in this manner to obtain the running time at a 50 mph maximum speed:

(a) Current running time: 4:25 = 265 minutes

(b) Estimated current running time from the Port Authority Bus Terminal, New York City to the New York City limits, currently at speeds under 50 mph: 45 minutes. No increase in this figure takes place at the reduced speed limits.

(c) Estimated current running time from New York City limits to Union, Connecticut, at the Connecticut/Massachusetts state line: 130 minutes. Speed limit for buses in Connecticut is currently 55 mph. (Speed limit in New York State is 60 mph for a very short stretch, about 12 miles, so this difference is ignored as a simplifying assumption.)

$130 \times (55/50) = 143$ minutes: round to 145 minutes.

(d) Estimated current running time from Union, Connecticut to Boston is 90 minutes at maximum speed of 65 mph.

$90 \times (65/50) = 117$ minutes; round to 120 minutes.

(e) $45 + 145 + 120 = 310$ minutes = 5:10.

Note that current running times include stops at toll plazas, etc., and thus include an allowance for acceleration and deceleration.

When reviewing Table 4-4, it might be useful to bear in mind that schedule making, insofar as it requires estimating running times, is as much an art as it is a science. Mathematical computations must be augmented by experience based on road profiles, volumes of traffic handled at local stops, driver propensities, psychological factors such as the tendency of most persons to remember times to the nearest 5 minutes, the amount of other traffic on roads at various times of the day, and the non-desirability of advertising different running times for different days of the week even though road traffic density may vary greatly. It is occasionally necessary to revise running times in an iterative procedure based on inputs from the Operating Department.

4.4.2 <u>Revised Driver Assignments and Related Incremental Costs</u>

The new running times make it impossible for a driver to operate a round trip between Fitchburg and New York or between Boston and New York in one day as is done presently, because the total driving hours would be in excess of the federally prescribed limit of 10 hours. Hence, it was necessary to reconfigure these "turnaround," or round trip, runs as one-way runs. Some minor changes in departure times were made and the combinations of one-way trips used in the currently existing Boston-New York one-way runs were revised so that it was not necessary to increase the number of runs to cover all Boston-New York scheduled trips on a one-way basis. The driver on the Fitchburg-New York turnaround currently starts his day's work in Fitchburg in the morning. The new runs cover the same schedule with the same number of drivers by changing the home terminal to New York City; a driver will now leave New York in the afternoon, go to Fitchburg, spend the night there, and return to New York the next morning. In the present run structure, the drivers on the Boston-New York turnarounds worked 2 days and took 2 days off; drivers of the New York-Fitchburg turnaround worked on alternate days. In the new run structure, drivers on all the restructured runs will work 6 consecutive days and take 1 day off. On that one day, a driver will be assigned from the spare board to cover the run.

Although no additional runs are created and no additional miles are driven under these restructured runs, the company will incur additional hotel expenses as follows:

Two additional hotel rooms in Boston each night	@ $9.00 =	$18.00
One additional hotel room in New York each night	@ $9.50 =	9.50
One hotel room in Fitchburg each night	@ $15.75 =	15.75

This will result in an additional annual expense of $15,786.25.

Although the increased running times on the New York-Springfield runs will still allow a driver to make a round trip within a single working day, the runs must be reconfigured because later arrivals at destination terminals make it impossible for drivers to continue to return to their home terminals on the same trips as formerly and also because one trip in each direction will no longer operate daily. Additional penalty pay will be incurred on five New York-Springfield turnabound runs in a total amount of 70 miles per day or 490 miles per week.

The commuter trips from Boston to Rochester and Concord will arrive at their home terminals later; the Rochester trip will also leave Rochester earlier in the morning. The on-duty time of the driver on the Boston-Concord commuter run will be 12 minutes or 4 pay miles longer each day for a total of 20 miles per week. The on-duty time of the driver on the daily Boston-Rochester commuter run will be 18 minutes or 6 pay miles longer for a total of 42 miles per week. Against the additional 552 penalty pay miles per week must be applied the savings of 455 penalty pay miles accured by eliminating the Boston-New York and Fitchburg-New York turnaround, resulting in a net gain of 97 penalty miles per week. The current maximum pay for a CTNE driver is $0.199 per mile, subject to cost of living increases every quarter during the life of the contract.

Assuming a rate of $0.20 per mile, this will result in additional weekly expenses of $19.40 or $1008.80 per year.

The total increased annual expense to the company from the impact of reduced speed limits on their driver assignments is thus seen to be $16,795.05.

4.4.3 Other Expenses

Continental Trailways operates certain designated express schedules as "Five Star Limited Service," with a hostess on board to serve light meals and beverages, and distribute pillows and magazines. These women are paid by the hour. As a result of increased running times, in recent weeks each of the 7 hostesses has been receiving overtime pay for 4 hours and 20 minutes per week. This pay is computed at the rate of $5.25 per hour, one and one-half times the regular earning rate. This will result in a disbursement of $22.75 per woman per day, or, since all Five Star trips run daily, $8281 per year.

4.4.4 Equipment Requirements

The increased running times will have a minimal impact on the number of new coaches used to cover the scheduled trips. Although the exact number of buses has not been computed, the company has resorted to self-help in adjusting certain departure times to reflect the later arrival of equipment at points where CTNE does not maintain standby equipment. Furthermore, the company will have three additional coaches in service by the end of 1973, for a total of 102 buses.

4.4.5 Effect of Reduced Speed Limits on Holiday Operations

The impact of increased running times on holiday operations will be markedly greater than the impact of increased running times on CTNE's daily operations. On major holidays, the company runs many extra schedules and every driver on their roster and every bus in their fleet is utilized to the fullest. In fact, during the 1973 Thanksgiving Day weekend, when the impact of reduced speed limits was only starting to be felt — that is, reduced speeds were not yet being uniformly enforced — CTNE was forced to hire buses (with drivers) from other companies to enable it to carry all prospective passengers. In particular, two such coaches were used on Wednesday, November 21, and four coaches were hired on Sunday, November 25, primarily to service points in New Hampshire.

It must be recognized that extra-section operation is "demand-activated" and that reservations are typically not taken for passengers originating or transferring at New York and Boston (although reservations are made for the Five Star Limited Service and for all passengers boarding at the suburban station at Framingham-Natick and at the George Washington Bridge Station). Therefore, the advance notice to the company that potential business requires an extra section is of the order of magnitude of 5 to 15 minutes before the scheduled departure time. The company must project the number of extra sections on the basis of previous years' requirements, hope that no substantial extra loads will occur as a result of airport closings or other extra-ordinary factors, and arrange for standby drivers and equipment on the basis of these projections.

As might be expected, the major problem arises from the fact that drivers will no longer be able to make a Boston-New York round trip within 10 driving hours. On Thanksgiving Sunday, November 27, 1972, traditionally the heaviest single travel day in the entire year, 46 extra sections were operated between Boston and New York by 23 spare drivers making Boston-New York round trips, 16 of which originated in New York, and seven in Boston, in addition to other Boston-New York one-way trips made by drivers who were given other assignments in their remaining driving hours.

If we assume that all drivers were earning the maximum rate of pay of $0.20 per mile, and that each one-way trip between Boston and New York paid 220 miles, thus allowing for some terminal-garage movements, the total cost to CTNE for these 46 sections was $2024.00.

Under the new speed limits, these drivers could not have completed a trip back to their point of origin within 10 driving hours. We shall consider three possible alternatives.

4.4.5.1 Alternative A - Let us assume that other drivers were available to make all trips other than New York-Boston, and, in terms of the union contract, had priority to drive those runs so that there was no other work to which these men could be assigned that could be performed during their remaining driving hours.

Let us assume that it is decided that each of these men will be given 8 hours rest so that he will be available to drive a trip back to his home terminal (Boston or New York): but, after his rest period is over, there is, in fact, no trip for him to drive, and he is told to ride a bus to his home terminal, rather than drive it, thus incurring deadheading (cushioning) pay of a minimum day rather than layover pay. On these assumptions, costs would be incurred by CTNE as follows:

Hotel expenses:	16 rooms in Boston	@ $9.00	=	$144.00
	7 rooms in New York	@ $9.50	=	66.50
Cushioning pay:	23 drivers @160 miles	@ $0.20/		
		miles (maximum)	=	736.00
				$946.50

The 23 trips that would have been driven by these men are covered by hiring coaches from other companies at a cost of $0.75 per "live" miles and $0.50 per "deadhead" mile. A "live" mile is a mile driven with revenue passengers in the coach, a "deadhead" mile is a mile intentionally driven without passengers. The company is prevented from hiring drivers from other companies to drive CTNE buses by the union contract requirement that CTNE equipment be operated by members of Union Division 1318 only; another relevant consideration is the differences between the Silver Eagle model coaches used by Continental Trailways and the various other types of coaches used in intercity service. It is therefore not possible to assume that the coaches that were used for the 23 trips in 1972 could be used to run the same trips after delays corresponding to the increase in running time on the going portion of the round trip.

Assume that each hired coach is used for a one-way line trip followed by a one-way deadhead trip. The cost to CTNE would thus be $275 per bus or a total of $6325.

Costs to CTNE of this alternative are thus:

23 one-way trips by CTNE drivers	$1012.00
Hotel expenses	210.50
Cushioning pay for 23 CTNE drivers	736.00
23 Hired coaches	6325.00
	$8283.50

This represents an incremental expense of $6259.50.

As against this total cost must be balanced the factor that, for each driver that can be used after his rest period to drive a bus back to his point of origination, a saving to the company would accrue of $32 cushioning pay plus $125 hired coach expense less $44 driving pay, or a net saving of $113. The Thanksgiving Sunday peak travel period is long enough so that some drivers might actually be used in this manner. For example, a driver arriving in Boston at 2 PM would become available for a return trip at 10 PM when demand might reasonably be expected to be at a high enough level to require additional extra sections.

The availability of sufficient hired coaches from other carriers is also problematic. Although there are many bus companies whose scheduled operations are trivial by comparison with their charter work (or even nonexistent), and who therefore are not impacted by increased travel demand on a holiday period to the extent that CTNE is, this report must not be construed to suggest that the requisite number of vehicles will be available on short notice.

4.4.5.2 Alternative B - If two drivers, each with, say, 4 driving hours left, are put on a single bus to drive it from New York to Boston, each driver is paid as if he had driven the entire trip.

As a matter of fact, the company did just this on five trips on Thanksgiving Sunday 1973.

By putting two drivers on each of eight buses, the 16 New York drivers would have been able to return home at a maximum cost to the company of $704.00 (2 drivers x 220 miles per driver x $0.20 per mile x 8 buses); six of the seven Boston drivers would have been able to drive three trips back at a maximum cost of $264.00. It still would have been necessary to pay hotel expenses and cushioning pay for one driver of $9.50 + $32.00 = $41.50. Total expense to the company for this procedure would have been $968.00 to cover 11 of the 23 return trips. The 12 remaining trips would be covered by hired coaches at a cost of 12 x $275 = $3300.00

Costs to CTNE of this alternative are thus:

23 one-way trips by CTNE drivers, solo	=	$1012.00
11 one-way trips by CTNE drivers, tandem	=	968.00
Hotel expense and cushioning pay for one driver	=	41.50
12 hired coaches	=	3300.00
		$5321.00

This represents an incremental cost of $3297.50

4.4.5.3 Alternative C - Another possibility might be to assign each of the 23 drivers to drive three-quarters of the way back to his point of origination. For example, a driver originating in Boston might drive as far back as, say, Sturbridge or Worcester, Massachusetts. A driver originating in New York might return to Stamford, Connecticut. Another driver would then be assigned in Boston to cushion to Worcester or Sturbridge, relieve the driver returning from New York, and drive the bus to Boston. Analogously, a driver would be assigned in New York to cushion to Stamford, relieve the driver returning from Boston, and drive the bus to New York. The estimated cost of such a procedure would be:

First Driver:	Driving from origin, one-way	220 miles
	Driving back, 3/4 of the way	165 miles
	Cushioning 1/4 of the way, 1-1/2 hours @ 20 miles per hour	30 miles
Second Driver:	Three hours from assignment to relief of first driver @ 20 miles pay per hour	60 miles
	Driving 1/4 of the way	55 miles
		530 miles

This would cost the company $106 per round trip, or $2438. However, the administrative burden inherent in insuring that sufficient relief drivers are available and dispatched to the relay points so that they will arrive in time to meet their buses would probably be intolerable on a holiday weekend, given the already vastly increased workload on supervisory personnel. This alternative also makes the rather unrealistic assumption that enough drivers would be available at the appropriate places with sufficient on-duty and driving hours to perform such an assignment. Against this must be weighed the intangible factor of negative good will that would be incurred if passengers are "stranded" at relay points due to failure to make timely assignments of relief drivers. On Thanksgiving Sunday 1973, four drivers were, in fact, relieved in Worcester; three of the relief drivers had to come from Boston to perform this work, and the fourth had previously driven a one-way trip from New York to Worcester.

The limited time available for this study makes it impossible to do much more than suggest the above alternatives and hint at the shortcomings of each. All have been used by the company at different times and in different mixes during the same holiday period.

The possibility of hiring additional drivers to handle peak period loads also exists. The question then arises: would management hire additional drivers at a training cost of $2000 per man and to whom they are obligated under the union contract to pay a minimum guarantee of 800 miles pay ($160) per week regardless of how many miles they actually drive? It is not advantageous to furlough drivers between holiday periods both because of the requirement of notice and layoff pay and because irregular employment will not attract the mature, responsible individuals needed for this type of work. Assuming that the company decides to hire some additional drivers, over how many years should the $2000 training cost be depreciated? Although a precise statistical computation of the average tenure of employment of a CTNE driver has, as far as is known to this writer, never been attempted, it is known that, of the 17 drivers completing training in 1972, 10 are still with the company; of the 32 starting work in 1969, 16 are still with the company; of the 17 starting in 1964, 4 remain; of the 14 starting in 1962, 4 still drive for CTNE.

Management decisions in this area must necessarily consider other factors that are not readily quantifiable. These include the desirability of keeping passengers waiting at bus stations in terms of the impact of extremely long delays upon potential repeat business, the feasibility of establishing a category of part-time drivers for use in peak holiday periods and the possible union reaction to such action, and the company's responsibility to provide service to the general public under its Interstate Commerce Commission operating rights certificate and its inherent duty as a regulated public utility.

The time constraints imposed upon this study make it impossible to do more than suggest the problems faced by management in attempting to handle peak period loads under the constraints newly imposed by the reduced speed limits.

4.5 GENERAL DISCUSSION

The limited time available for this study necessarily restricted the subject material analyzed. Furthermore, the total impact of reduced speed limits on intercity motor bus operation can only be measured over a period of time and in interaction with other variables that are primarily sensitive to other aspects of the total energy conservation program. Thus, it may be necessary to expand on the work already done in order to present a comprehensive picture of the resultant changes in the bus business, since there may well be other long standing characteristics of the intercity bus business that should be reviewed in light of the current need for energy conservation.

4.5.1 Generalization from the Results of this Study

A quick review of the statistical comparison of CTNE with the intercity motor coach industry in Section 4.2.2 shows that CTNE represents about one percent of the industry. However, further study is necessary before it may be definitively stated that it is a representative sample in terms of the parameters of interest for this study.

In particular, it has been noted that CTNE's route structure includes both one-way and round trip runs and that, while all the one-way runs and some of the round trip runs will still be operationally feasible under the new speed limits, other round trip runs will be required to be split into one-way runs. Thus, hotel expenses and penalty rule pay will increase. However, there are divisions of other bus companies that will not be affected at all by the reduced speed limits. For example, drivers on the New York-Pittsburgh division of American Bus Lines (another division of Continental Trailways) will continue to be able to run between New York and Pittsburgh. The run structure of the Boston-Albany, Boston-Bangor, Bangor-Calais, and Providence-New York City divisions of Greyhound Lines East will not be affected at all by the reduced speed limits, according to Greyhound's Regional Manager in Boston.

On the other hand, Greyhound has 16 turnaround runs between Boston and New York City, to which 32 drivers are assigned. These runs will no longer be able to be operated as such; thus the impact on the Boston-New York Division of Greyhound Lines East will be far greater than on CTNE.

Thus, to measure accurately the total impact on bus company expenditures, it is necessary to analyze separately every division of every company; the analysis must take into account not only the various run structures but also the differing provisions in the several union contracts.

4.5.2 Impact on Driver Earnings

Although the total expenditure of CTNE for driver wages for regular route schedule operation will only increase by $1008 per year, that figure can be misleading. The long range impact of the change in driver earnings resulting from differing run structures due to increased running times may well manifest itself in demands for changes in both the manner and magnitude of compensation when the union contract is next renegotiated.

Of CTNE's 91 regular runs, 7 will pay slightly more for slightly increased on-duty times, due to the requirement for penalty pay, as discussed in Sections 4.1.2 and 4.4.2; these 7 drivers will gross an average of $2.29 more per working day. The pay for 76 regular drivers will remain the same, although on-duty times will increase slightly; i.e., a driver from Portland to New York will be on duty 45 minutes longer, but since his mileage would still average out to more than the contractual guarantee of 20 miles per hour, he will not receive any incremental pay.

The six drivers currently assigned to Boston-New York round trip runs and the two drivers currently assigned to Fitchburg-New York round trip runs will be seriously affected. In particular, a driver on a Boston-New York turnaround run now works 14 out of 28 days (two days on, two day off) and is paid for 442 miles for each working day. Assuming the maximum rate of $0.20 per mile, this man's gross pay is $1237.60 for that time period. Under the revised run structure, assuming that the same driver picked a Boston-New York one way run, he would work 24 out of 28 days (6 days on, 1 day off) and be paid for 221 miles for each working day. Thus, his gross pay would be $1060.80, or a reduction of 14.3% for working 71.4% more days and spending 12 nights away from home during the 28 day period. Whether the same driver would, in fact, exercise his seniority to pick a Boston-New York one-way run is, of course, open to question and further study, but he would, regardless of what run he picked, be forced to choose between being home every night, working more days, earning less money, and traveling a greater distance at his own expense to the point where his run originated. A 4 days on, 2 days off Portland-New York one-way run will pay almost as much as a 2 days on, 2 days off Boston-New York turnaround, but the driver's personal deadhead mileage and travel time will increase and he will be away from home two nights out of six.

The effect on the drivers on the spare board is harder to estimate. During peak periods they will probably earn somewhat less money; during slack periods, there will be slightly more work for them due to the creation of several more 6 days on, 1 day off runs that will be covered by spare drivers on the regular driver's day off. The greatest impact on the earnings of the spare drivers will be a function of factors not yet studied, i.e., the impact of fuel allocation programs on the charter business of the company; the impact of gasoline scarcity upon the volume of business on regular schedules and hence the number of extra sections operated; the possible loss of business to other modes due to increased running times. Since the company is required under the union contract to guarantee every spare driver 800 miles pay per week (running from Sunday through Saturday) it occasionally happens during slack periods that drivers are paid under this provision for miles not actually driven. Any increase in work for spare drivers will mean a decrease in the amount of pay they will receive for miles not driven.

5. CONCLUSIONS

The nature of the specific terrain traveled (e.g., level, hills, mountains) must be carefully considered when assessing the inpact of reduced speed limits on fuel consumption for intercity buses.

A measurable fuel savings is to be expected for intercity buses if speed limits are reduced from 60 to 50 mph on level terrain (e.g., Washington DC to Norfolk VA). Smaller but still noticeable fuel savings should also be achieved if speed limits are reduced from 60 to 55 mph or 55 to 50 mph over level terrain.

A measurable increase in fuel consumption is to be expected for intercity buses if speed limits are reduced from 60 to 55 mph over "hilly" terrain (e.g., eastern Massachusetts).

No significant fuel savings are expected for intercity bus operations if speed limits are reduced from 60 to 55 mph or 55 to 50 mph over "mountainous" terrain (as, for example, would be encountered in a Boston-Albany crossing of the Berkshires).

Reduced speed limits should result in reduced maintenance costs overall, especially for buses with automatic transmissions (clutch wear may be increased with lower speed limit due to increased shfiting).

Reduced speed limits may result in significantly increased direct operating costs for intercity bus companies, having a adverse effect on profitability and, by extension, service.

The above are the principal conclusions reached during this brief, intensive study of the effect of reduced speed limits on intercity buses and operating companies. Due to the limited number of buses tested during the project, it is not prudent to put much weight on the quantitative sensitivity of fuel consumption to speed limit. The trends of fuel consumption with speed limit changes on different types of terrain were, however, established by a detail statistical analysis of the data.

It is important to note that the fuel consumption values reported herein <u>do not reflect</u> typical values in intercity bus operations. City driving, with its inherently higher fuel consumption, tends to increase typical intercity bus fuel consumption by about 30 - 40% over the figures reported herein. (A typical intercity bus will average on the order of 16 - 17 gallons/100 miles - a fuel economy of about six miles per gallon.)

The effect of reduced speed limits on carrier operations, however, is not so readily measured. The analysis presented in Section 4 shows that the total annual increase in operating exsenses for the company studied would be in the neighborhood of $25,000, or 1/3 of 1% of its 1972 expenditure for operations and maintenance. This figure does not include the annual increase in expenses for the ten holiday operations, however. If we assume that this further increase amounts to $5,000 per holiday (based on Section 4.4.5), the estimated increase triples to $75,000 per year. If the company operated at 10% gross profit margin, this increased expense would reduce profits by 10% annually. If our case study is truly representative (a weak assumption), the total dollar cost, represented by a 1% increase in expenses for Class I intercity bus companies, amounts to $7.5 million per year. This represents a decrease of about 9% in total industry net operating revenues.

These figures are only estimates of a preliminary nature. The effects of new union demands, possible shifts of passengers to other, more rapid, modes of transportation, etc., cannot now be quantified. It is clear, however, that the effect of reduced speed limits will be to increase operating expenses significantly.

APPENDIX A
COMPUTER MODELING

Two tasks undertaken in support of the bus fuel economy program were 1) analysis through computer simulation of the fuel economy of a modern intercity bus on various grades; and 2) assessment of the effect of reduced speeds on maintenance. Table A-1 shows data on the buses used in this study.

The detailed computer output of a nominal Eagle bus is shown in Figure A-1. Results are shown for the bus at 0, ±1, ±2, and ±3 percent grade. Because of limitations in time and personnel for this project, there is some uncertainty in the absolute accuracy of these results. This deficiency, however, is not likely to affect the characteristic dependence of fuel economy on speed. These characteristics are:

1. As bus speed increases above 40 mph, bus fuel economy decreases, i.e., the miles per gallon rate decreases.
2. The effect of improved fuel economy at reduced speeds is increased by negative grades and decreased by positive grades.

TABLE A-1. INTERCITY BUS DATA

BUS	GREYHOUND	TRAILWAYS SILVER EAGLE
BUS MANUFACTURER	MOTOR COACH INDUSTRIES NORTH DAKOTA	
MODEL NUMBER	6046-6047 (1972) MC-7	
WEIGHT W/PASSENGERS (LBS)	36,000	36,000*
FRONTAL CROSS-SECTIONAL AREA (SQ FT)	89* 8 feet wide	89
ENGINE DISPLACEMENT (CU INCH)	568	567.4
ENGINE STROKE (INCHES)	5	5
OTHER ENGINE INFORMATION	8V71N DDA 2 CYCLE 8 CYL	8 CYL
1ST GEAR	4.3 : 1	4.3
2ND GEAR	2.33 : 1	2.28
3RD GEAR	1.36 : 1	1.44
4TH GEAR	1 : 1	1
DIFFERENTIAL GEAR RATIO	3.7 : 1	3.7*
ROLLING CIRCUMFERENCE (FT)	10.6	10.6
DRAF (CD)	.7*	.7*
ACCESSORIES POWER (HP)	25*	25*
OTHER BUS INFORMATION		

*ASSUMED VALUE

0% grade

SPEED = 50.0 — MILES/GALLON = 6.47

	HP-HR	%	CONSMP, GPM	HP
TOTAL	2.41714	100.037	.154549	145.03
ACCESS	0.64827	26.820	.041450	38.90
TRANS	0.17689	7.318	.011310	10.61
ROLLING	0.72836	30.133	.046570	43.70
AERO	0.86272	35.692	.055161	51.76
ACCEL	0.00090	0.037	.000058	0.05

SPEED = 55.0 — MILES/GALLON = 5.87

	HP-HR	%	CONSMP, GPM	HP
TOTAL	2.90633	100.063	.170325	174.38
ACCESS	0.71197	24.497	.041725	42.72
TRANS	0.21944	7.550	.012860	13.17
ROLLING	0.82689	28.451	.048460	49.61
AERO	1.14619	39.438	.067172	68.77
ACCEL	0.00184	0.063	.000108	0.11

SPEED = 60.0 — MILES/GALLON = 5.29

	HP-HR	%	CONSMP, GPM	HP
TOTAL	3.45920	100.023	.189025	207.55
ACCESS	0.77590	22.430	.042398	46.55
TRANS	0.26833	7.757	.014663	16.10
ROLLING	0.92974	26.877	.050805	55.78
AERO	1.48442	42.912	.081115	89.07
ACCEL	0.00081	0.023	.000044	0.05

SPEED = 65.0 — MILES/GALLON = 4.83

	HP-HR	%	CONSMP, GPM	HP
TOTAL	4.07495	99.992	.207151	244.50
ACCESS	0.83825	20.571	.042612	50.29
TRANS	0.32367	7.943	.016454	19.42
ROLLING	1.03579	25.418	.052655	62.15
AERO	1.97757	46.076	.095446	112.65
ACCEL	[illegible]	-0.008	.000016	[illegible]

Figure A-1. Detailed Computer Output of Trailways Silver Eagle Bus

1% grade

SPEED = 50.0 MILES/GALLON = 4.61

	HP-HR	%	CONSMP, GPM	HP
TOTAL	3.31019	99.904	.216806	198.61
ACCESS	0.67552	20.407	.044245	40.53
TRANS	0.26347	7.959	.017256	15.81
ROLLING	0.72439	21.884	.047445	43.46
AERO	0.85236	25.750	.055827	51.14
ACCEL	-0.00318	-0.096	-.000209	-0.19
GRADE	0.79763	24.096	.001729	47.86

SPEED = 55.0 MILES/GALLON = 4.24

	HP-HR	%	CONSMP, GPM	HP
TOTAL	3.87799	100.015	.235735	232.68
ACCESS	0.74826	19.295	.045485	44.90
TRANS	0.31297	8.071	.019025	18.78
ROLLING	0.81910	21.122	.049791	49.15
AERO	1.12275	28.952	.068250	67.37
ACCEL	0.00059	0.015	.000036	0.04
GRADE	0.87431	22.546	.002061	52.46

SPEED = 60.0 MILES/GALLON = 3.97

	HP-HR	%	CONSMP, GPM	HP
TOTAL	4.39119	99.478	.251702	263.47
ACCESS	0.81525	18.565	.046730	48.91
TRANS	0.35759	8.143	.020497	21.46
ROLLING	0.90421	20.591	.051829	54.25
AERO	1.39679	31.809	.080064	83.81
ACCEL	-0.02303	-0.524	.001320	-1.38
GRADE	0.94038	21.415	.002367	56.42

SPEED = 65.0 INSUFFICEINT POWER TO MAINTAIN SPEED

Figure A-1. Detailed Computer Output of Trailways Silver Eagle Bus (Continued)

2% grade

SPEED = 50.0 MILES/GALLON = 3.51

	HP-HR	%	CONSMP,GPM	HP
TOTAL	4.11515	99.039	.284796	246.91
ACCESS	0.76148	18.504	.052699	45.69
TRANS	0.33537	8.150	.023210	20.12
ROLLING	0.70282	17.079	.048640	42.17
AERO	0.79612	19.346	.055097	47.77
ACCEL	-0.03992	-0.970	-.002763	-2.40
GRADE	1.55929	37.891	.004441	93.56

SPEED = 55.0 INSUFFICEINT POWER TO MAINTAIN SPEED

SPEED = 60.0 INSUFFICEINT POWER TO MAINTAIN SPEED

SPEED = 65.0 INSUFFICEINT POWER TO MAINTAIN SPEED

3% grade

SPEED = 50.0 INSUFFICEINT POWER TO MAINTAIN SPEED

SPEED = 55.0 INSUFFICEINT POWER TO MAINTAIN SPEED

SPEED = 60.0 INSUFFICEINT POWER TO MAINTAIN SPEED

SPEED = 65.0 INSUFFICEINT POWER TO MAINTAIN SPEED

Figure A-1. Detailed Computer Output of Trailways Silver Eagle Bus (Continued)

-1% grade

SPEED = 50.0	MILES/GALLON =		9.48	
	HP-HR	%	CONSMP, GPM	HP
TOTAL	1.52261	99.835	.105539	91.36
ACCESS	0.64324	42.246	.044586	38.59
TRANS	0.08794	5.775	.006095	5.28
ROLLING	0.72970	47.925	.050579	43.78
AERO	0.86631	56.896	.060048	51.98
ACCEL	-0.00252	-0.165	-.000174	-0.15
GRADE	-0.80206	-52.677	-.000846	-48.12

SPEED = 55.0	MILES/GALLON =		8.38	
	HP-HR	%	CONSMP, GPM	HP
TOTAL	1.92331	99.923	.119311	115.40
ACCESS	0.70689	36.754	.043851	42.41
TRANS	0.12164	6.325	.007546	7.30
ROLLING	0.82801	43.052	.051365	49.68
AERO	1.14963	59.774	.071317	68.98
ACCEL	-0.00148	-0.077	-.000092	-0.09
GRADE	-0.88139	-45.827	-.001052	-52.88

SPEED = 60.0	MILES/GALLON =		7.37	
	HP-HR	%	CONSMP, GPM	HP
TOTAL	2.39116	99.976	.135685	143.47
ACCESS	0.77054	32.224	.043724	46.23
TRANS	0.16206	6.778	.009196	9.72
ROLLING	0.93102	38.936	.052830	55.86
AERO	1.48883	62.264	.084483	89.33
ACCEL	-0.00058	-0.024	-.000033	-0.03
GRADE	-0.96072	-40.178	-.001304	-57.64

SPEED = 65.0	MILES/GALLON =		6.57	
	HP-HR	%	CONSMP, GPM	HP
TOTAL	2.92965	100.006	.152185	175.79
ACCESS	0.83342	28.448	.043293	50.01
TRANS	0.20962	7.155	.010889	12.58
ROLLING	1.03844	35.446	.053943	62.31
AERO	1.88783	64.439	.098066	113.27
ACCEL	0.00017	0.006	.000009	0.01
GRADE	-1.03983	-35.493	-.001582	-62.39

Figure A-1. Detailed Computer Output of Trailways Silver Eagle Bus (Continued)

-2% grade

SPEED = 50.0 MILES/GALLON = 19.44

	HP-HR	%	CONSMP,GPM	HP
TOTAL	0.63595	100.418	.051430	38.16
ACCESS	0.64132	100.845	.051865	38.48
TRANS	-0.00054	-0.085	-.000043	-0.03
ROLLING	0.72760	114.412	.058842	43.66
AERO	0.86425	135.899	.069893	51.85
ACCEL	0.00264	0.416	.000214	0.16
GRADE	-1.59933	-251.488	-.000823	-95.96

SPEED = 55.0 MILES/GALLON = 15.11

	HP-HR	%	CONSMP,GPM	HP
TOTAL	0.94646	99.951	.066193	56.79
ACCESS	0.70664	74.662	.049421	42.40
TRANS	0.02398	2.534	.001677	1.44
ROLLING	0.82860	87.547	.057950	49.72
AERO	1.15141	121.654	.080527	69.08
ACCEL	-0.00046	-0.049	-.000032	-0.03
GRADE	-1.76371	-186.348	-.001167	-105.82

SPEED = 60.0 MILES/GALLON = 12.01

	HP-HR	%	CONSMP,GPM	HP
TOTAL	1.32288	99.977	.083254	79.37
ACCESS	0.76932	58.155	.048416	46.16
TRANS	0.05536	4.185	.003484	3.32
ROLLING	0.93105	70.381	.058594	55.86
AERO	1.48894	112.553	.093704	89.34
ACCEL	-0.00030	-0.023	-.000019	-0.02
GRADE	-1.92148	-145.250	-.001600	-115.29

SPEED = 65.0 MILES/GALLON = 9.89

	HP-HR	%	CONSMP,GPM	HP
TOTAL	1.77032	100.059	.101133	106.22
ACCESS	0.83167	46.978	.047510	49.90
TRANS	0.09387	5.302	.005362	5.63
ROLLING	1.03760	58.611	.059275	62.26
AERO	1.88458	106.455	.107660	113.07
ACCEL	0.00104	0.059	.000059	0.06
GRADE	-2.07843	-117.405	-.002102	-124.71

Figure A-1. Detailed Computer Output of Trailways Silver Eagle Bus (Continued)

-3% grade

SPEED = 50.0 BRAKES CONTINUOUSLY APPLIED

SPEED = 55.0 MILES/GALLON = 93.52

	HP-HR	%	CONSMP,GPM	HP
TOTAL	0.12370	-1349.456	.010693	7.42
ACCESS	0.59978	484.851	.051843	35.99
TRANS	-0.04761	-38.485	-.004115	-2.86
ROLLING	0.70347	568.665	.060805	42.21
AERO	0.98001	792.215	.084709	58.80
ACCEL	0.13287	107.410	.011485	7.97
GRADE	-2.24482	-1814.656	-.000240	-134.69

SPEED = 60.0 MILES/GALLON = 43.09

	HP-HR	%	CONSMP,GPM	HP
TOTAL	0.31496	121.715	.023208	18.90
ACCESS	0.72574	230.421	.053477	43.54
TRANS	-0.04108	-13.042	-.003027	-2.46
ROLLING	0.87931	279.181	.064793	52.76
AERO	1.41358	448.811	.104162	84.81
ACCEL	0.05619	17.841	.004141	3.37
GRADE	-2.71878	-863.212	-.000631	-163.13

SPEED = 65.0 MILES/GALLON = 24.63

	HP-HR	%	CONSMP,GPM	HP
TOTAL	0.64642	102.899	.040593	38.79
ACCESS	0.82138	127.066	.051580	49.28
TRANS	-0.01750	-2.707	-.001099	-1.05
ROLLING	1.02645	158.790	.064458	61.59
AERO	1.87695	290.361	.117866	112.62
ACCEL	0.01821	2.817	.001144	1.09
GRADE	-3.07908	-476.328	-.001250	-184.74

Figure A-1. Detailed Computer Output of Trailways Silver Eagle Bus (Concluded)

APPENDIX B

EFFECT OF WIND ON FUEL CONSUMPTION

Most discussions of on-road fuel consumption implicity assume, for the sake of simplicity, that the wind velocity is zero. To minimize the effects of wind during road tests, it is best to make each individual test consist of a round trip over the prescribed course. In the tests reported in this document, round trips were employed for each test in the Massachusetts series; logistics prevented this procedure in the Washington, D.C. series. (This may be part of the reason for the slightly increased data scatter in the Washington tests.) Even though round trips are employed to minimize wind effects, the error due to wind gusts, directional changes, etc., is not fully compensated and there remains a residual error in the measurement due to differences in wind velocity. To provide an idea of the magnitude of the expected effects, the following paragraphs will examine the effect of a constant-speed wind on fuel consumption.

The power required to operate a vehicle is given approximately by the following relationship:

$$\underbrace{DWHP}_{\text{Total Power Required}} = \underbrace{\frac{GW \times V \times G}{37{,}500}}_{\text{Power Required to Climb Hills}} + \underbrace{\frac{GW \times V\ (.675 + .0074\ V^2)}{37{,}500}}_{\text{Power Required to Overcome Rolling Resistance}} + \underbrace{\frac{KAM^2V}{375}}_{\text{Power Required to Overcome Air Resistance}}$$

where:

DWHP = total demand wheel horsepower (horsepower)

GW = vehicle gross weight (lb)

V = road speed of vehicle (miles per hours)

G = grade of road (%)

K = vehicle drag coefficient (0.00182 assumed)

A = vehicle cross-sectional frontal area

M = vehicle air speed (road speed plus or minus headwind or tailwind)

On the right side of the equation, the three principal components of horsepower demand are noted. It is evident that the presence of wind only changes the value of the last term, which describes the power required to overcome air resistance.

For the sake of illustration, assume that a vehicle is to make a trip over a perfectly flat road, in which case the first term on the right side of the equation is zero (0% grade). Fuel consumption (FC) is then obtained by multiplying the horsepower required (DWHP) by the brake-specific fuel consumption (BSFC, gallons per horsepower hour) and dividing by the road speed (V). Under conditions of zero wind (V = M), fuel consumption is given by

$$FC = \underbrace{\frac{DEHP \times BSFC}{V}}_{\text{Total Fuel Consumption}}$$

$$= \underbrace{\frac{GW \times V\ (.675 + .0074\ V^2)}{37{,}500} \times \frac{BSFC}{V}}_{\text{Fuel Consumed to Overcome Rolling Resistance}} + \underbrace{\frac{KAV^3}{375} \times \frac{BSFC}{V} \quad \left(\frac{\text{gallons}}{\text{mile}}\right)}_{\text{Fuel Consumed to Overcome Air Resistance}}$$

The fuel consumed just to overcome air resistance is given by the last term on the right. In the presence of wind, the fuel consumed just to overcome air resistance (FC_A) is given by

$$FC_A = \frac{KAM^2V}{375} \times \frac{BSFC}{V}$$

where M = V + W, and W = headwind speed. If we travel a round trip to minimize the effects of wind, the average fuel consumed to overcome air resistance over the trip in the presence of a steady wind is given by

$$FC_{A(AVG)} = \frac{FC_{A1} + FC_{A2}}{2} = \frac{\left(M_1^{\ 2} + M_2^{\ 2}\right)\left(\frac{KAV}{375} \times \frac{BSFC}{V}\right)}{2}$$

where M_1 is the airspeed on the outbound leg of the trip $(V + W_1)$ and M_2 is the airspeed on the inbound leg of the trip $(V + W_2)$. Assuming a constant wind for the duration of the trip, $W_2 = - W_1$, and $M_1 = V + W_1$: $M_2 = V - W_1$. Therefore, we can expand the $\left(M_1^{\ 2} + M_2^{\ 2}\right)$ term as follows:

$$\left(M_1^{\ 2} + M_2^{\ 2}\right) = \left(V + W_1\right)^2 + \left(V - W_1^{\ 2}\right)$$

$$= \left(V^2 + 2VW_1 + W_1^{\ 2}\right) + \left(V^2 - 2VW_1 + W_1^{\ 2}\right)$$

$$\left(M_1^{\ 2} + M_2^{\ 2}\right) = 2V^2 + 2W_1^{\ 2}$$

The average fuel consumption just to overcome air resistance over a round trip on a flat road under constant wind is, therefore,

$$FA_{A(AVG)} = \left(V^2 + W_1^{\ 2}\right)\left(\frac{KAV}{375} \times \frac{BSFC}{V}\right)$$

As a rough guide to the magnitude of the errors which could be introduced by wind speed changes, assume that we are making fuel-consumption measurements on a round trip at 60 mph (V = 60 mph) over a level road. Assume further that the fuel consumed in overcoming air resistance represents about 50% of the total fuel consumption (a good approximation). In the case of zero wind, the fuel consumed in overcoming air resistance is proportional to the square of the road speed $(V^2 = 60^2 = 3600)$; for a 10 mph wind $(W_1 = 10)$ parallel to the road, the fuel consumed is proportional to $(V^2 + W_1^{\ 2} = 960^2 + 10^2 = 3600 + 100 = 3700)$. The difference in fuel consumed in overcoming air resistance is $\frac{100}{3600} = 2.8\%$. Since this represents about half of the total trip fuel consumption, the error is reduced to about 1.4% for a 10 mph wind compared to zero wind. For a 20 mph constant wind speed, the error compared to zero wind is about 5.6%.

APPENDIX C
INFLUENCE OF HILLS ON FUEL CONSUMPTION

It is well known that driving in hilly terrain results in poorer fuel economy than could be achieved if the terrain were flat. Sometimes situations can arise where hilly terrain causes a "peaking" effect in the fuel economy curve, i.e., the fuel economy at some speed in between a faster and slower speed could result in better fuel economy than either the faster or slower speed (though all three will be worse than would be obtained without hills). Since this seems to be in conflict with conventional understanding of the trend of fuel economy with speed, it is instructive to examine the situation in more detail. First, we will isolate the effect of hills from other factors to examine the nature of their effect on a vehicle. The second part of this appendix presents the results of some calculations designed to verify analytically that the observed data are not anomalous.

The effect of hills, as discussed below, has been isolated from other factors in an attempt to illustrate clearly their effect on fuel economy. Consideration is not given to reserve power ("more gas-pedal pressure") the driver may have at his command, nor do we consider the effect of such things as decreasing engine-power requirements with decreasing speed (due to wind- and rolling-resistance) or possible variation in engine specific-fuel-consumption with speed. Though these and other effects modify the actual numbers calculated herein, they do not modify the qualitative effect of hills on fuel consumption. It is stressed, however, that the following discussion is intended to be only illustrative in nature:

If a driver approaches a hill from level terrain, without using any additional power to climb the hill and in the absence of factors discussed in the preceding paragraph, his speed will decrease. This decrease is due to a dissipation of kinetic energy which can be approximated as follows:

$$1/2\ m\ \ V_1^{\ 2} - V_2^{\ 2} = \left(\frac{V_1 + V_2}{2}\right) (\%\ G)\ (m)\ (g)$$

where m = weight of bus

V_1 = initial speed at t = 0

V_2 = speed at time t

%G = percent grade

g = acceleration of gravity.

The formula can be rearranged to determine how long it takes the bus to slow down to V_2 if the driver does not change the throttle position:

$$\frac{1/2\ m\ \ V_1^{\ 2} - V_2^{\ 2}}{\left(\frac{V_1+V_2}{2}\right)(\%G)\ (m)\ (g)} = t_{V_1 \rightarrow V_2}$$

We can then determine the approximate distance the bus covers in this time, t, by multiplying by the average bus velocity:

$$\left(\frac{V_1+V_2}{2}\right) \frac{1/2\ m\ \ V_1^{\ 2} - V_2^{\ 2}}{\left(\frac{V_1+V_2}{2}\right)\ (\%G)\ (m)\ (g)} = \text{Distance covered}$$

Cancelling terms and substituting values for constants, the formula becomes

$$\frac{V_1^{\ 2} - V_2^{\ 2}}{157090(\%G)} = \text{distance miles}$$

and we can calculate how far up a hill of a given grade a bus will go before its speed drops below V_2. The results are plotted in Figure C-1. For example, if a bus encountered a hill of 1% grade at a speed of 60 mph, and the driver did not change his throttle setting, the bus could go about 1.06 miles up the hill before his speed dropped to 44 mph, but only about .57 miles (1.06 to .49) before his speed dropped below 52 mph. An identical bus approaching the hill at 50 mph would only get about 0.36 miles up the hill

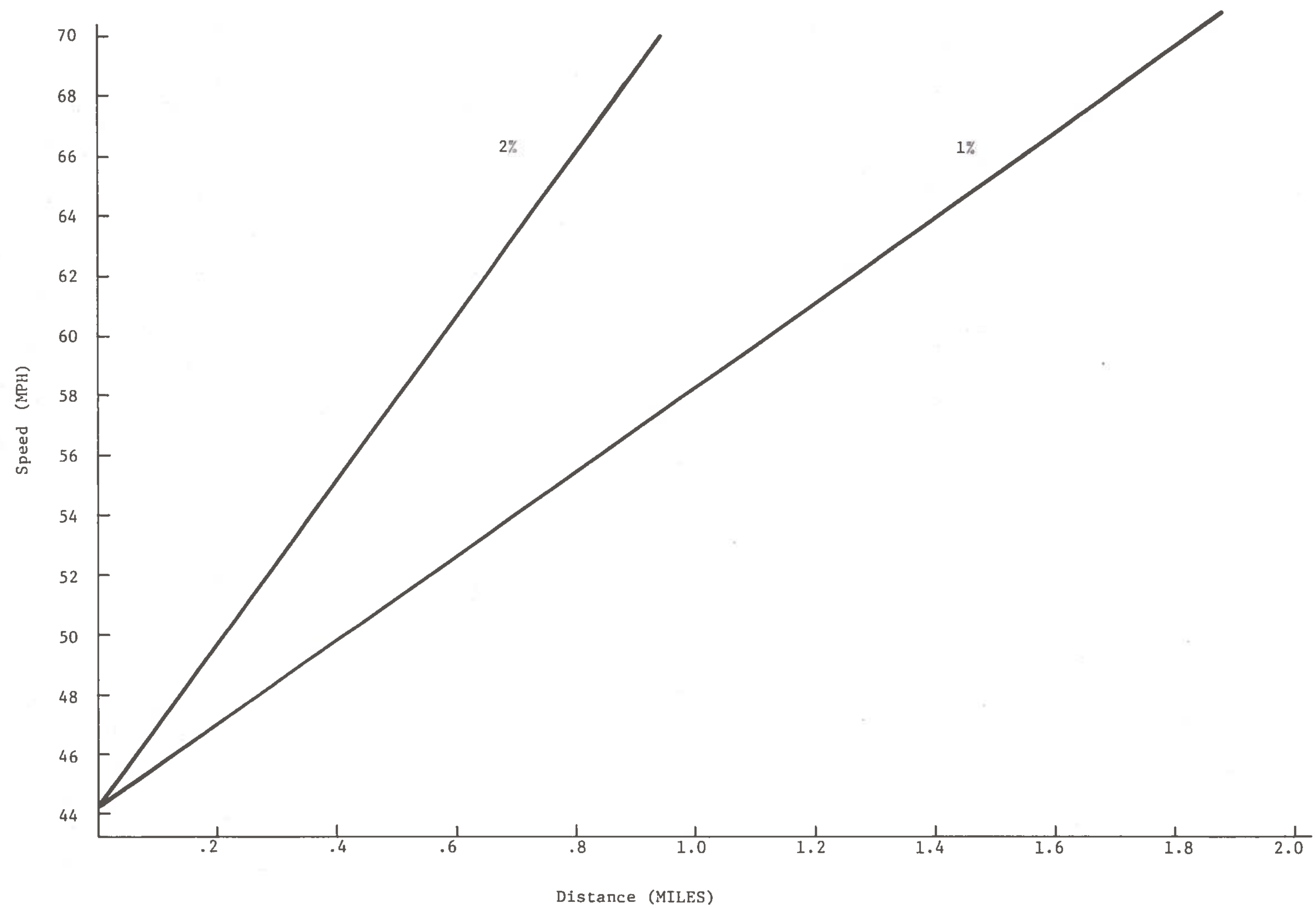


Figure C-1. Distance Covered When Climbing Hill at Constant Power and Decreasing Speed by a Given Increment before his speed dropped below 44 mph. Thus, if the hill happens to be 1 mile long, the first bus driver would be able to get over the crest in fourth gear without additional power, while the slower driver would be forced to either apply more power or downshift into third. One can easily imagine, then, a combination of speeds, hills of a certain length and grade, etc., where going slightly faster will cost more fuel (due to air drag) but going flower will also cost more fuel (due to the need to shift into third gear or use more power while in fourth gear).

This factor is difficult to simulate fully in a simple computer, since so much depends on the style of the driver and the manner in which he manipulates his throttle.

APPENDIX D
VIRGINIA TESTS

D.1 SUMMARY

A two day test was performed using 8 buses to demonstrate fuel usage variation between 50 and 60 mph. The test buses were run round trip between Washington, D.C. and Norfolk, Virginia (a one way distance of 200 miles). Excellent cooperation was received from both Greyhound Lines, Inc. and Continental Trailway both during and planning the test. An equal number of company buses were used. The results of the sampled buses show an increase in fuel consumption of ≈9% with the corresponding increase in speed from 50 to 60 mph. See Tables D-1 and D-2.

D.2 OBJECTIVE

The objective of this test was to determine the variation in fuel usage due to speed of travel in intercity buses.

D.3 APPROACH

The test was to emulate operating conditions along one intercity bus route. The route was selected by the transit company in cooperation with TSC. Qualified drivers were used in operational buses. A simulated load factor of 60% (approximately 4000 lb) was achieved by placing sand in the luggage compartments. The test was designed to eliminate as many variables as possible while minimizing the number of buses used and performing the test as soon as possible.

D.4 TEST DESCRIPTION

The test was run Friday and Saturday, November 23, 24, 1973. The first 4 buses left Washington for Norfolk, Virginia at 11:20 a.m. and returned at 11:30 p.m. On Saturday the second group of 4 buses left Washington for Norfolk, Virginia at 8:20 a.m. and returned at 7:05 p.m. The buses were driven as follows: 2 at 60 mph,

TABLE D-1. VIRGINIA TEST DATA (50 MPH)

Co.	Model	Dir. N/S	Obs.	Time of Start	Tire Type	Odo. Type	Inj. Type	Tran.	3rd Stops No. of Shift Town	No. of Shift Road	Road Stops	Distance Mi.	Fuel Gal.	Temp. °C	MPG	Tire Rad. F	Tire Rad. R	Press F	Press R	Press T	Was Wt.
G	MC-7	S	J.P.	11/23 10:50am	R	Hub	N60	M	-	-	-	234.7	22.5	21.5°	10.43	20	20.5	105	80	80	32,000
T	E	S	H.M.	11/23 11:02am	B	Tac	N60	M	18	8	4	230.9	29.0	21.5°	7.96	21	20.5	105	109 105 / 110 103	105/ 102	34,480
G	MC-7	N	A.L.	11/23 5:45pm	F-R R-B	Hub	N60	M	16	-	-	199.9	24.0	22°	8.33	20-	21	103	75	65	31,780
T	E	N	J.M.	11/23 5:45pm	B	Tac	N60	M	15	3	3	200.7	22.2	22°	9.04	20.5	20.5	100 105	103 / 100 104 / 100	103	32,800
T	E	S	A.L.	11/24 3:19am	B	Tac	N60	M	13	6	3	200.4	21.0	23.9°	9.54	20.5	21	95	95	95	32,800
T	E	N	J.M.	11/24 1:20pm	B	Tac	N60	M	12	6	4	200.1	22.8	20°	8.78	21	21	95	95	95	32,840
G	MC/8	S	H.M.	11/24 8:19pm	B	Hub	C60	A	18	1	4	199.1	27.6	23°	7.21	20.5	21	101	75	67	32,540
G	MC-8	N	J.P.	11/24 1:15pm	R	Hub	C60	A	-	-	-	200.5	21.5	20°	9.3	20	$20\frac{1}{4}$	100	75	75	31,920

TABLE D-2. VIRGINIA TEST DATA (60 MPH)

Co.	Model	Dir. N/S	Obs.	Time of Start	Tire Type	Odo. Type	Inj. Type	Tran.	Only 3rd Stops No. of Shift Town	No. of Shift Road	Distance Mi.	Fuel Gal.	Temp. °C	MPG	Tire Rad. F	Tire Rad. R	Press F	Press R	Press T	Was Wt.
G	MC-7	N	J.P.	11/23 6:20	R	Hub	N60	M	-	-	202.5	25.2	21	8.04	20	20.5	105	80	80	31,340
T	Exec	N	H.M.	11/23 6:25	B	Tac	N60	M	NOT TALLIED		199.4	25.4	21.5	7.85	21	20.5	105	109 105 110 103	105 102	34,320
G	MC-7	S	A.L.	11/23 11:20	F-R R-B	Hub	N60	M	NOT TALLIED		245.4	28.4	21	8.64	20	21	103	75	65	31,920
T	E	S	J.M.	11/23 11:20	B	Tac	N60	M	NOT TALLIED		246.3	30.6	21.5	8.05	20.5	20.5	100 105	103 100 106 100	103	32,960
T	E	N	A.L.	11/24 1:50p	B	Tac	N60	M	NOT TALLIED		199.9	22.0	21	9.09	20.5	21	95	95	95	-
T	E	S	J.M.	11/24 8:40	B	Tac	N60	M	NOT TALLIED		200.0	24.8	22	8.06	21	21	95	95	95	33,000
G	MC-8	N	H.M.	11/24 2:10p	B	Hub	C60	A	NOT TALLIED		198.7	25.1	20.5	7.91	20.5	21	101	75	67	-
G	MC-8	S	J.P.	11/24 8:37	R	Hub	C60	A	NOT TALLIED		200.8	29.1	22	6.9	20	$20\frac{1}{4}$	100	75	75	-

2 at 50 mph in one direction (except where posted speed limits prohibited). On the return the 50 mph buses were driven at 60 mph (except where posted speed limits prohibited). This procedure was repeated on the second day with different buses. A total of 8 different drivers and buses were used. A TSC observer was placed on each bus and was responsible for data sheet information. In addition to the data required on the data sheets, each observer counted the number of shifts required by the buses throughout the trip to determine if more shifting was required at 50 mph. Also, rolling radius and tire pressures were measured. Tire pressures differed for each bus company with Trailway maintaining ≈ 100 ± 5 lb on all tires and Greyhound using 75 to 80 on the drive wheels with 100 lb in the front. The only other deviation to the original test plan was weighing of buses at the start and end of each run. This was only performed on the first run from Washington to Norfolk.

After the fuel tanks were filled at each location the gas caps were sealed and initialed by the TSC observer. These seals were not removed until the tanks were to be filled at the end of the runs. The route selected was generally level with only a few grades. The buses used were as follows:

2 - MC-7 Greyhound (Manual Transmission)

2 - MC-8 Greyhound (Automatic Transmission)

3 - Eagles Trailway (Manual Transmission)

1 - Executive Trailway (Manual Transmission)

All buses used Detroit diesel engines. The MC-8 used C-60 injectors vice N60 for all others. No fuel optimization techniques were used by any driver. The weather was fair except for light rain on Saturday morning, November 24, 1973.

D.5 RESULTS

The "T" test shows the calculation for the test of the hypothesis that there is no difference in the fuel usage at 50 and 60 mph. From the data it can be stated with a 98% confidence that the fuel usage rates are different. From a straight average position the sample of 50 mph buses had a mean miles per gallon of

8.8 (with a standard deviation (σ) of .998) whereas the 60 mph bus sample had a mean of 8.1 (σ = .64). However, in two instances 60 mph buses had higher mpg than at 50. This discrepancy was eliminated when buses were paired to eliminate the effects of wind, etc. These calculations are shown in Table D-3. The results of these tests show that buses traveling at 60 mph used ≃ 9% more fuel than those traveling at 50 mph.

D.6 "T" TEST CALCULATIONS

The null hypothesis is:

$$Ho \quad \bar{X}_1 = \bar{X}_2$$

The means ($\bar{X}_1 + \bar{X}_2$) of two different samples (sample 1 is calculated miles/gal. for buses traveling at 50 mph and sample 2 for 60 mph) did, in fact, come from the same population with the same means.

$$SS_{X_1} = EX_1^2 - \bar{X}_1 EX_1$$

	50 MPH			60 MPH	
	X_1	X_1^2		X_2	X_2^2
	10.43	108.7849		8.04	64.6416
	7.96	63.3616		7.85	61.6225
	8.33	69.3889		8.64	74.6496
	9.04	81.7216		8.05	64.8025
	9.54	91.0116		9.09	82.6281
	8.78	77.0884		8.06	64.9636
	7.21	51.9841		7.91	62.5681
	9.3	86.4900		6.9	47.6100
EX_1	70.59	629.8311		64.54	523.486

$\bar{X}_1 =$ 8.8237 $\bar{X}_2 =$ 8.0675

$$SS_{X_1} = EX_1^2 - \bar{X}_1 EX_1$$

$$= 629.8311 - 8.8237 \times 70.59$$

$$SS_{X_2} = EX_2^2 - \bar{X}_2 EX_2$$

$$= 523.486 - 8.0675 \times 64.54$$

TABLE D-3. CALCULATION OF BUS PAIRS BY COMPANY

Bus #	50 MPH				60 MPH			
	Direction	Distance	Fuel	MPG	Direction	Distance	Fuel	MPG
1-G	S	234.7	22.5	-	N	202.5	25.2	-
3-G	N	199.9	24.0	-	S	245.4	28.4	-
Total		434.6	46.5			447.9	53.6	
AVE				9.34				8.36
% Increase					11.7%			
2-T	S	230.9	29.0	-	N	199.4	25.4	-
4-T	N	200.7	22.2	-	S	246.3	30.6	-
Total		431.6	51.2			445.7	56.0	
AVE				8.43				7.96
% Increase					5.9%			
5-T	S	200.4	21.0	-	N	199.9	22.0	-
6-T	N	200.1	22.8	-	S	200.0	24.8	-
Total		400.5	43.8			399.9	46.8	
AVE				9.14				8.55
% Increase					6.9%			
7-G	S	199.1	27.6	-	N	198.7	25.1	-
8-G	N	200.5	21.5	-	S	200.8	29.1	-
Total		399.6	49.1			399.5	54.2	
AVE				8.14				7.37
% Increase					10.4%			

Notes:
1. T - Continental Trailways bus.
2. G - Greyhound bus
3. Buses 7 & 8 are automatic shifts; all others are manual transmission.
4. The buses are paired to eliminate variables such as wind, hills, etc.
5. Buses 1, 2, 3 and 4 were run 11/23/73; buses 5, 6, 7 and 8 were run 11/24.

$= 629.8311 - 622.8649$ $\quad\quad$ $= 523.486 - 520.6764$

$SS_{X_1} = 6.9662$ $\quad\quad$ $SS_{X_2} = 2.81$

POOLED ESTIMATE OF $\sigma = \overline{S}(X) = \sqrt{\dfrac{SS_{X_1} + SS_{X_2}}{N_1 + N_2 - 2}}$

$$\overline{S(X)} = \sqrt{\frac{6.9662 - 2.81}{8 + 8 - 2}} = \sqrt{\frac{4.1562}{14}} = \sqrt{.2968}$$

$S(X) = \sqrt{.545}$ $\quad\quad$ $\overline{S(X)} = .545$

$$t = \frac{\left|\overline{X}_1 - \overline{X}_2\right|}{\overline{S}(X)\sqrt{\left(\frac{1}{\overline{N}_1}\right) + \left(\frac{1}{\overline{N}_2}\right)}}$$

$$t = \frac{|8.8237 - 8.0675|}{.545\sqrt{\frac{1}{8} + \frac{1}{8}}} = \frac{|.7562|}{.545\sqrt{.25}}$$

$$\frac{.7562}{.545x.5} = \underline{\underline{2.775}}$$

The tabular value of t with 14 degrees of freedom + an α of 0.05 is:

$$t_{0.05_1}\ 14 = 2.14$$

Comparing the tabular and calculated value of t, we reject the hypothesis of equality and conclude that there is a difference between the means.

D.7 BUS SPECIFICATIONS

<u>Bus # 3263-3285 (1973)</u>

1. Motor Coach Industries, North Dakota
2. 1973
3. MC-8
4. 280 BHP

5. #1 Diesel per GMC Spec.
6. Allison Automatic Model HT-740
7. 1st - 3.69
   2nd - 2.07
   3rd - 1.40
   4th - 1.00
   Rev - 5.73
8. Not supplied
9. Test Wt. ≈ 32,000
10. GMC Diesel Model 8V-71C
11. 43
12. Curb Weight 43 Pass. + Driver - Full
    Fuel & Lav. Serviced Total = 36,000
    12,000 Front
    18,000 Drive
    6,000 Tag

Bus # 6046-6047 (1972)

1. Motor Coach Industries, North Dakota
2. 1972
3. MC-7
4. 280 BHP
5. #1 Diesel Per GMC Spec.
6. Spicer Model 8844A
7. 1st - 4.30
   2nd - 2.33
   3rd - 1.36
   4th - 1.00
   Rev - 6.00
8. 3.70:1 Rockwell Std.
9. Test Wt. ≈ 32,000
10. GMC Diesel Model GMC 8V-71N
11. 43
12. Curb Wt. 43 Pass. + Driver - Full
    Fuel & Lav. Serviced Total = 36,000
    12,000 Front
    18,000 Drive
    6,000 Tag

APPENDIX E
MASSACHUSETTS TESTS

E.1 SUMMARY

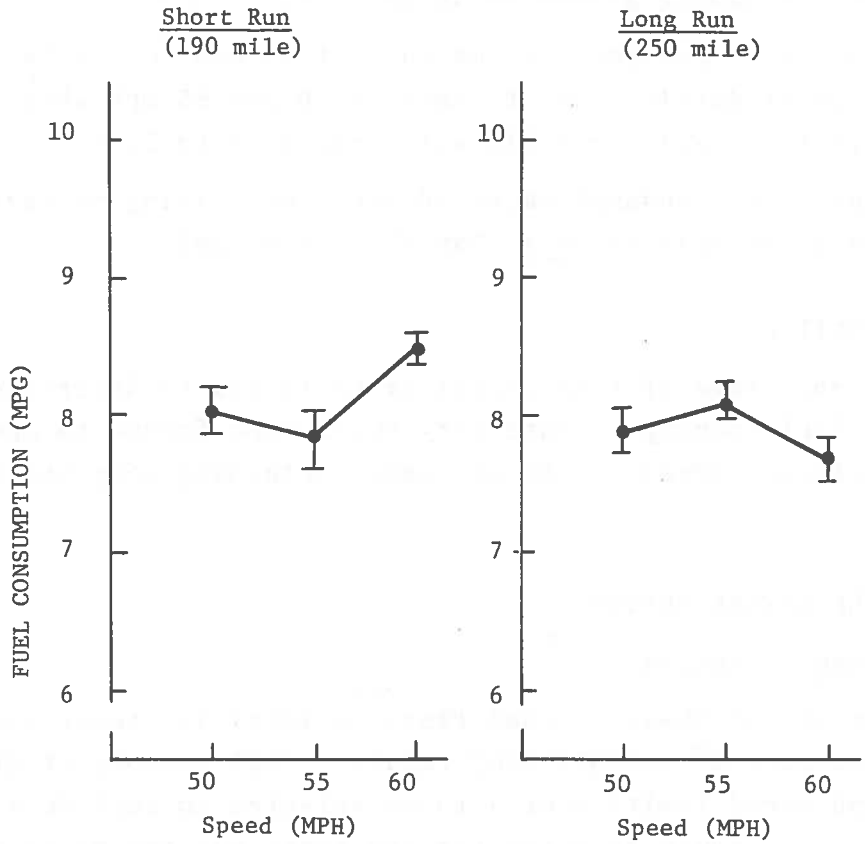
An experiment to determine the effect of speed limit on intercity bus fuel economy was conducted over two routes, a 190 mile round trip through rolling hills, and a 250 mile round trip which added a long grade of 7 miles length. Four different buses and drivers were provided for the tests by Vermont Transit, Bonanza Bus Lines, Continental Trailways and Greyhound. Each bus was driven over the two routes at three different speeds, 50, 55 and 60 mph, with multiple samples taken for each test condition. In order to minimize the effects of head and tailwinds, each constant speed run was a complete east-west round trip with refueling at a common terminus.

A summary of the test results is given in Figure E-1. Statistical tests performed on the data indicated the following:

- differences in fuel economy as a function of type of bus were not significant;
- differences in fuel economy for the two runs were significant at the .05 level; i.e., there is only a give percent probability that the observed differences were due to chance;

The results can therefore be summarized, as shown in Figure E-1, as the mean fuel consumption for all buses at each speed and for each run. Additional statistical tests performed on the data indicate, moreover, that the slight differences between the mean values at 50 and 55 mph during the short runs and the mean values at 50, 55 and 60 during the long runs are not statistically significant; i.e., the observed differences are much less than the experimental error of approximately ± 3%. Therefore the following conclusions can be reached:

- Bus fuel consumption is the same at 50 and 55 mph, and approximately 7.5% less at 60 mph (relative to the 50 mph



SPEED (MPH)	FUEL CONSUMPTION	(MPG)
50	8.02 ± 0.16	7.86 ± 0.16
55	7.84 ± 0.20	8.08 ± 0.12
60	8.47 ± 0.10	7.68 ± 0.15

Figure E-1. Summary of Calculated Fuel Consumption (Massachusetts Test) figure) when driving on Interstate highways with rolling hills having grades of up to 3.5%.

- Bus fuel consumption increase at 60 mph to a value approximately equal to that at 50 and 55 mph when the road includes rolling hills with grades up to 3.5%.
- Bus fuel consumption at 50 mph when driving on relatively flat terrain is less than that at 60 mph.

E.2 OBJECTIVE

The objective of this series of tests was to determine the relative fuel economy of intercity buses when forced to operate at three different speed limits on roads containing long and short grades.

E.3 EXPERIMENTAL DESIGN

E.3.1 General Approach

This second phase of road tests on intercity buses was run for the purpose of establishing relative fuel economy at 50, 55 and 60 mph speed limits over a route selected to include a number of hills. The route selected for the tests was the Massachusetts Turnpike between Boston and Pittsfield, a road that passes through 100 miles of rolling hills and then through the Berkshire mountains. The maximum grade on this road, 3.5%, is reached many times over the run, thus providing many potential opportunities for the buses to downshift at the lower speeds.

Additional differences between these and the first series of tests were that a common fueling point was selected in Boston, each test run was a complete round trip at a single speed to reduce the effects of wind loading, and three speeds were used instead of two.

Four buses were used: a Silver Eagle from Continental Trailways, an MC-7 from Vermont Transit, an MC-8 from Greyhound and a GMC 4905 from Bonanza Bus Lines. Each bus was driven by a experienced driver provided by the transit companies while carrying a simulated load of approximately 6000 lb.

E.3.2 Test Variables

Three primary variables were selected for examination during this series of tests:

- speed: 50 mph, 55 mph, 60 mph
- bus type: Eagle, MC-7, MC-8, GMC 4905
- terrain characteristics: 190 mile run through rolling hills, 250 mile run to add Berkshire mountain crossing.

The experiment was structured to minimize the effect of variables such as weather, wind and errors on the fuel reading, so that relative differences between fuel economy at the various speeds could be accurately detected. The highly unpredictable effect of changing traffic conditions on fuel consumption was not treated separately due to the relatively small sample size; however, it was included in the statistical error term. The effect of head or tailwinds on the measurement, although partially compensated for by the use of a complete round trip, cannot be completely eliminated since the force on the bus will be proportional to the square of the wind velocity. The magnitude of this error can be calculated, however, from a knowledge of wind conditions during the run.

To summarize, the following are the known contributers to the experimental error term:

- changing traffic conditions
- residual wind effects
- road conditions due to weather (wet, dry)
- bus transmission type (manual, automatic)
- tire type (radial, bias ply).

E.3.3 Test Description

A total of 18 test runs were made by each bus during the period from December 5, 1973 to December 19, 1973. Each bus made two complete roundtrips per day, each run being a different speed and length. Table E-1 gives the complete schedule for each bus

TABLE E-1. TEST SCHEDULE (MASSACHUSETTS TEST)

DATE	DAY	RUN #	PLANNED NOMINAL DISTANCE (miles)	EAGLE CONT. TRAILWAYS	SPEED (mph) MC-7 VT. TRANSIT	MC-8 GREYHOUND	GMC 4905 BONANZA
12/5/73	WED	1	250	60	60	60	60
		2	190	50	50	50	50
12/6	THUR	3	190	55	55	55	55
		4	250	50	50	50	50
12/7	FRI	5	190	50	50	50	50
		6	250	55	55	55	55
12/10	MON	7	190	DYNO	60	60	60
		8	250	DYNO	55	55	55
12/11	TUE	9	250	50	DYNO	50	50
		10	190	60	DYNO	60	60
12/12	WED	11	190	55	55	DYNO	55
		12	250	60	60	DYNO	60
12/13	THUR	13	190	60	60	60	DYNO
		14	250	50	50	50	DYNO
12/14	FRI	15	250	55	55	55	55
		16	190	50	50	50	50
12/18	TUE	17	250	60	60	60	60
		18	190	55	55	55	55
12/19	WED	19	190/250/190/190	60	50	55	60
		20	250/190/250/250	55	60	60	50
12/20	THUR	-	-	DYNO	-	-	-

including the day scheduled by dynomometer testing. All runs were made on weekdays, with only one cancellation due to weather, that being on Monday December 17, 1973, when a severe ice storm covered the entire route. Each bus was weighed twice, once on the first day of testing and once on the last day.

A Department of Transportation observer was assigned to each bus for the purpose of monitoring the fueling, observing and collecting environmental data, and performing spot checks of bus speed while enroute. In addition, the observer was instructed to record the total number of downshifts due to traffic, hills and road conditions.

Except for the one cancellation due to the ice storm, weather was generally good, with seven fair days and two rainy days. Wind conditions were obtained from the weather bureau three times daily at 0800, 1200 and 2000 hr for three locations along the route. Wind speed were generally in the 8-15 knot range, with the direction remaining relatively constant over the route throughout the day. Detailed tables of wind speed, direction and air temperature are contained in Table E-2.

The one serious problem encountered during the conduct of the tests was a fueling problem with the GMC 4905 bus. After the second run, it was discovered that the fuel tank vent line was restricting the free air flow prior to the tank being filled to the filler lip (the reference point used during the tests). As a result, there was an uncertainty in the measurement of fuel consumed during individual runs; i.e., during some runs the tank was underfilled, resulting in a spuriously low fuel consumption. Although numerous attempts were made to eliminate this problem, the uncertainty remained to the end; therefore the results from this bus were not included in the statistical analysis. The individual data for the GMC are presented for information purposes. It should be noted that this problem affected only the road tests and not the dynomometer tests, since in those tests fuel flow was the dependent variable.

TABLE E-2 WEATHER DATA (MASSACHUSETTS TEST)

DATE	TEMP	TIME	ALBANY °F	ALBANY DIR (DEG)	ALBANY SPD (KNOTS)	WORCESTER °F	WORCESTER DIR (DEG)	WORCESTER SPD (KNOTS)	BOSTON °F	BOSTON DIR (DEG)	BOSTON SPD (KNOTS)	WEATHER
12/5		0800	53	170°	12	49	200	8	51	150	5	RAIN
		1200	56	180°	13	55	200	11	57	180	10	
		2000	61	170	10	58	200	15-31	58	. 190	13	
12/6		0800	43	290	12	49	270	8	57	290	11	FAIR
		1200	43	290	15-23	43	290	12	59	260	11	
		2000	31	calm	0	27	270	9	45	290	12	
12/7		0800	37	290	10	30	280	9	41	300	9	FAIR
		1200	36	020	9	39	310	11	44	330	11	
		2000	30	320	7	32	360	8	3[illegible]	340	10	
12/10		0800	38	180	4	39	250	8	49	210	14	FAIR
		1200	42	170	6	41	250	10	49	260	12	
		2000	32	140	5	35	270	5	44	180	11	
12/11		0800	32	310	10	34	360	11	41	040	9	FAIR
		1200	32	300	13	37	020	10	34	330	10	
		2000	31	290	13	30	330	8	3[illegible]	320	12	

TABLE E-2. WEATHER DATA (MASSACHUSETTS TEST) (Continued)

DATE	TEMP	TIME	ALBANY °F	ALBANY DIR (DEG)	ALBANY SPD (KNOTS)	WORCESTER	WORCESTER DIR (DEG)	WORCESTER SPD (KNOTS)	BOSTON	BOSTON DIR (DEG)	BOSTON SPD (KNOTS)	WEATHER
12/12		0800	29	280	11	27	290	8	36	310	11	FAIR
		1200	35	310	11	32	310	10	39	330	10	
		2000	24	290	3	25	310	7	34	320	9	
12/13		0800	14	calm	0	23	220	5	30	240	2	FAIR
		1200	36	180	11	33	170	11	38	150	8	
		2000	40	170	14-22	33	120	7	39	180	8	
12/14		0800	40	360	9	41	080	9	50	130	16	RAIN
		1200	41	310	9	49	230	5	52	130	20	
		2000	28	300	20-31	40	310	20-28	46	290	16	
12/18		0800	06	300	14	08	290	15	18	280	16	FAIR
		1200	13	300	19	15	290	14	22	300	17	
		2000	09	320	15	09	300	11	22	310	11	
12/19		0800	10	360	4	05	300	2	11	330	10	FAIR
		1200	9	070	4	16	280	2	19	340	7	
		2000	11	calm	0	15	230	2	24	200	4	

E.3.4 Statistical Analysis

In order to determine which of the observed effects were "statistically significant," that is, which ones have a very low probability of being due to chance, an Analysis of Variance (ANOVA) was performed on the experimental data. Details of the analysis are contained at the end of this appendix. This analysis, which allowed a determination of the contribution of each of the main variables to the observed effects, was followed by two post hoc tests to establish specifically which of the individual differences were due to chance and which were real. These last tests yield results which are comparable to the "t-test" used on the simpler Washington to Norfolk experiment.

E.4 EXPERIMENTAL RESULTS

During the conduct of this experiment two things occured which altered the original experimental design. First, the GMC bus exhibited a fuel tank filling problem which necessitated separate consideration of the resultant data and removal of the data from the statistical tests. An examination of the fuel consumption graphs for this bus show, however, that even with this problem the results are qualitatively similar to the other buses. The second departure from the original design was caused by a scheduling error on the last day of tests resulting in the interchange of the long and short runs for the MC-7 bus. Although this created unequal sample sizes in the 50 mph and 60 mph data cells for this bus requiring a minor change in the statistical procedures the total effect on the test results was minimal.

Detailed data sheets for each bus are contained in Tables E-3 through E-6, and the primary results have been summarized in Table E-7. The temperatures listed in this table were those measured at the fueling point in South Boston (Continental Trailways maintenance garage, 55 Fargo Street). The additional weather information gathered for the entire route indicated that the assumption of relatively constant wind speed and direction was valid for seven of the nine test days. Two of the days were rainy, but visual

TABLE E-3. RAW DATA (CONTINENTAL TRAILWAYS)

BUS: EAGLE

OWNER: CONT. TRAILWAYS

NO.: 34566

DRIVER: George Fitzgerald RUN 1,2
R. Stark 3,4
R. Whitehouse 5-20

ROLLING RADIUS: 20.75"

PRESSURE: FRONT 100 psi
BOGIE 100 psi
DRIVE 100 psi

ENGINE:

TRANSMISSION: MANUAL

INJECTOR: C-60

TIRES: 12.5 x 22.5 BIAS (GOODYEAR)

WEIGHT #1: 33,870 12/7/73
(1b) #2: 33,490 12/19/73

DATE	RUN	DISTANCE (MILES)	FUEL USED (GAL)	FUEL CONSUMPTION (MPG)	NO. OF SHIFTS			SPOT SPEED CHECKS (avg $\pm \frac{\sigma}{\sqrt{n}}$)		OBSERV.
					TRAFFIC	ROAD	HILLS	TARGET SPEED		
12/5/73	1	248.5	33.9	7.33	5	4	7	60	59.96± 0.43	A.I.
12/5	2	190.0	24.7	7.69	3	4	9	50	50.13±0.26	
12/6	3	190.4	22.8	8.35	5	5	2	55	55.34± .37	
12/6	4	248.8	30.9	8.05	5	7	7	50	51.44± .44	
12/7	5	189.5	22.1	8.57	7	5	3	50	49.54± .32	
12/7	6	251.8	29.7	8.48	6	5	1	55	56.72± .59	
	7	-	-							
	8	-	-							
12/11	9	249.2	29.0	8.59	3	7	4	50	50.26± .19	
12/11	10	189.6	22.2	8.54	3	5	0	60	61.10± .44	
12/12	11	193.7	23.0	8.42	3	5	1	55	55.55± .27	
12/12	12	249.9	28.0	8.92	3	5	3	60	61.55± .72	
12/13	13	190.1	21.6	8.80	3	4	0	60	60.80± .34	
12/13	14	250.2	33.4	7.49	5	6	2	50	50.34± .43	
12/14	15	250.3	30.7	8.15	4	6	2	55	55.80± .39	
12/14	16	190.2	23.0	8.27	2	5	3	50	50.17± .16	
12/18	17	250.2	31.7	7.89	3	6	2	60	60.80± .35	
12/18	18	190.4	26.3	7.24	0	2	0	55	55.00± .22	A.I.
12/19	19	190.2	21.8	8.72	0	4	1	60	60.80± .30	A.S.
12/19	20	253.5	32.3	7.85	2	3	4	55	54.54± .18	A.S.

TABLE E-4. RAW DATA (VERMONT TRANSIT)

BUS: MC-7

OWNER: VT. TRANSIT

NO.: 930

DRIVER: C. Blaisdell

ENGINE:

TRANSMISSION: MANUAL

INJECTOR: C-60

TIRES: 12.5 x 22.5 BIAS

ROLLING RADIUS: 20.75"

PRESSURE:	(1-2)	(3-6)	(7-20)
FRONT	95	90	90
BOGIE	90	85	90
DRIVE	90	85	90

WEIGHT #1: 34,280 12/7/73

(1b) #2: 34,330 12/19/73

DATE	RUN	DISTANCE (MILES)	FUEL USED (GAL)	FUEL CONSUMPTION (MPG)	NO. OF SHIFTS			SPOT SPEED CHECKS		OBSERV.
					TRAFFIC	ROAD	HILLS	TARGET SPEED	(avg. $\pm \frac{\sigma}{\sqrt{n}}$)	
12/5/73	1	252	35.1	7.18	7	1	3	60		M.D.
12/5	2	193	26.15	7.39	3	8	4	50		
12/6	3	192	24.4	7.86	0	8	0	55		
12/6	4	252	31.2	8.07	0	8	3	50		
12/7	5	194	22.5	8.62	0	8	1	50		
12/7	6	255	33.7	7.56	0	8	1	55		
12/10	7	193	23.3	8.28	0	8	0	60		
12/10	8	251	31.9	7.87	1	8	5	55		
	9	-								
	10	-								
12/12	11	192	22.9	8.38	0	8	0	55		
12/12	12	252	33.4	7.54	1	8	2	60		
12/13	13	192	23.3	8.24	0	8	0	60		
12/13	14	252	31.1	8.10	0	8	2	50		
12/14	15	252	30.1	8.28	3	8	5	55		
12/14	16	192	23.4	8.20	0	8	0	50		
12/18	17	252	33.7	7.47	0	8	3	60		
12/18	18	192	25.3	7.58	0	8	0	55		
12/19	19	196	22.8	8.64	0	8	0	50		
12/19	20	252	33.6	7.40	0	8	0	60		

TABLE E-5. RAW DATA (GREYHOUND LINES)

BUS: MC-8
OWNER: GREYHOUND
NO.: 3204
DRIVER: San Stephens

ENGINE:
TRANSMISSION: AUTO
INJECTOR: C-60
TIRES: RADIAL

ROLLING RADIUS: 20.0"
PRESSURE: FRONT 105
BOGIE 80
DRIVE 80

WEIGHT #1: 34,120 12/7/73
(lb) #2: 34,060 12/19/73

DATE	RUN	DISTANCE (MILES)	FUEL USED (GAL)	FUEL CONSUMPTION (MPG)	NO. OF SHIFTS			SPOT SPEED CHECKS		OBSERV.
					TRAFFIC	ROAD	HILLS	TARGET SPEED	(avg. $\pm \frac{\sigma}{\sqrt{n}}$)	
12/5/73	1	255	33.7	7.56	0	5	19	60	60.91	A.S.
12/5	2	193	26.4	7.31	1	4	37	50	46.20	A.S.
12/6	3	194	23.8	8.15	2	2	8	55	51.11	A.S.
12/6	4	253	33.9	7.48	0	4	40	50	48.76	A.S.
12/7	5	194	24.5	7.92	1	0	16	50	49.35	J.T.
12/7	6	257	29.7	8.65	0	0	5	55	52.98	J.T.
12/10	7	194	22.5	8.62	0	0	1	60	58.13	J.T.
12/10	8	254	33.1	7.67	0	2	6	55	53.19	J.T.
12/11	9	254	31.9	7.96	1	1	16	50	49.26	A.S.
12/11	10	193	24.2	7.98	0	1	2	60	59.18	A.S.
	11	-	-	-	-	-	-	55		
	12	-	-	-	-	-	-	60		
12/13	13	194	22.6	8.58	0	1	2	60	59.04	A.S.
12/13	14	254	35.6	7.13	0	1	19	50	49.59	A.S.
12/14	15	255	31	8.23	0	2	8	55	53.71	J.T.
12/14	16	193	25.4	7.60	2	0	17	50	49.08	J.T.
12/18	17	255.1	33.1	7.70	0	0	7	60	56.92	J.T.
12/18	18	193.9	29.1	6.66	0	0	1	55	54.27	J.T.
12/19	19	194	24.5	7.92	1	0	2	55	54.26	J.T.
12/19	20	255	32.5	7.85	0	0	1	60	59.47	J.T.

TABLE E-6. RAW DATA (BONANZA LINES)

BUS: GMC 4905

OWNER: BONANZA

NO.: 7214

DRIVER: Gerry Schiano

ROLLING RADIUS: 20.75"

PRESSURE:	(1-2)	(3-4)	(5-6)	(7-20)
FRONT	100	100	105	105
BOGIE	-	-	-	
DRIVE	90	100	90	95

ENGINE:

TRANSMISSION: STD

INJECTOR: N-60

TIRES: RADIAL - FRONT/BIAS - REAR

WEIGHT #1: 30,120 12/7/73

(lb) #2: 30,340 12/19/73

DATE	RUN	DISTANCE (MILES)	FUEL USED (GAL)	FUEL CONSUMPTION (MPG)	NO. OF SHIFTS			SPOT SPEED CHECKS		OBSERV.
					TRAFFIC	ROAD	HILLS	TARGET SPEED	(avg. $\pm \frac{\sigma}{\sqrt{n}}$)	
12/5/73	1	253	33.3	7.6		3	1	60	61.55± .42	D.R.
12/5	2	192	22.0	8.7			8	50	51.55± .40	D.R.
12/6	3	192	26.1	7.3				55	55.09± .32	C.H.
12/6	4	253	29.2	8.6				50	51.15± .31	C.H.
12/7	5	192.7	24.2	7.96		-0-		50	48.35±1.85	D.R.
12/7	6	257.4	32.4	7.94		-0-		55	56.42± .27	D.R.
12/10	7	192.3	26.4	7.27		-0-		60	62.31± .14	T.K.
12/10	8	252.4	28.4	8.9		-0-		55	57.60± .41	T.K.
12/11	9	253.3	29.9	8.5		-0-		50	49.49± .29	T.K.
12/11	10	192.4	22.6	8.5		-0-		60	61.55± .32	T.K.
12/12	11	192.6	20.3	9.45		-0-		55	57.72± .21	T.K.
12/12	12	253.0	35.1	7.2		-0-		60	62.65± .56	T.K.
	13	-								
	14	-								
12/14	15	250.1	27.5	9.0	6	1		55	55.80± .41	T.K.
12/14	16	190.2	22.9	8.3		-0-		50	49.93± .29	T.K.
12/18	17	250.2	33.2	7.05		1		60	60.80± .36	A.S.
12/18	18	190.5	22.3	8.54		-0-		55	55.42± .15	A.S.
12/19	19	190	22.4	8.4				60	60.65± .17	C.H.
12/19	20	253	29.2	8.6				50	48.92± .26	C.H.

TABLE E-7. SUMMARY OF INDIVIDUAL FUEL CONSUMPTION(MASSACHUSETTS TESTS)

DATE	RUN #	DISTANCE (MILES)	AIR TEMP (°C) START/END	BUS SPEED LIMIT	WEATHER	FUEL CONSUMPTION (MPG)			
						EAGLE	MC-7	MC-8	GMC 4905
12/5/73	1	250	15.5/17.5	60	RAIN	7.33	7.18	7.56	7.60
	2	190	17.8/18.5	50	RAIN	7.69	7.39	7.31	8.72
12/6	3	190	14.0/16.0	55	FAIR	8.35	7.86	8.15	7.36
	4	250	16.0/ 7.0	50	FAIR	8.05	8.07	7.48	8.66
12/7	5	190	6.0/11.0	50	FAIR	8.57	8.62	7.92	7.96
	6	250	11.0/ 4.0	55	FAIR	8.47	7.56	8.65	7.94
12/10	7	190	9.0/ 9.5	60	FAIR	-	8.28	8.62	7.27
	8	250	9.5/ 8.0	55	FAIR	-	7.87	7.67	8.90
12/11	9	250	6.0/ 6.0	50	FAIR	8.60	-	7.96	8.50
	10	190	6.0/ 4.0	60	FAIR	8.54	-	7.98	8.50
12/12	11	190	3.0/ 5.0	55	FAIR	8.42	8.38	-	9.45
	12	250	5.0/ 1.0	60	FAIR	8.92	7.54	-	7.20
12/13	13	190	1.0/ 6.0	60	FAIR	8.80	8.24	8.58	-
	14	250	6.0/ 3.0	50	FAIR	7.49	8.10	7.13	-
12/14	15	250	10.0/11.0	55	RAIN	8.15	8.28	8.23	9.00
	16	190	11.0/ 7.0	50	RAIN	8.27	8.20	7.60	8.30
12/18	17	250	-8.0/-3.0	60	FAIR	7.89	7.47	7.70	7.05
	18	190	-3.0/-8.0	55	FAIR	7.20	7.58	6.66	8.54
12/19	19	190	-10/-2	60/50/55/60	FAIR	8.72	8.64	7.92	8.40
	20	250	-2/-6	55/60/60/50	FAIR	7.84	7.40	7.85	8.60

examination of the data indicates no consistent effect on fuel consumption.

Table E-8 gives the calculated fuel consumption for each of the experimental data cells. The numbers presented are the mean and standard error of the mean for each set of three repeated samples. Figure E-2 presents these same data graphically with the short and long runs plotted separately.

From the statistical analysis of variance it was determined that the differences in fuel economy between the different buses were not statistically significant. However, the difference due to change in terrain was significant to the .05 level, a fact borne out by a visual examination of the two sets of graphs.

Subsequent to the analysis of variance, two additional tests were performed to establish the level of significance for individual points within the two runs and for the pairs of points at each speed. The results were that, within the experimental error of approximately ± 3%, the only significant differences were between 50 and 60 mph and between 55 and 60 mph during the short run, the run that excluded the long hill. Differences between means of all other pairs were not significant.

In essence, these results indicate that, within the experimental error, there is no significant difference in fuel consumption when driving over a road that has many rolling hills with grades up to 3.5% and some long hills. Furthermore, on roads that exclude the long hills, fuel consumption remains the same for 50 and 55 mph, but is slightly reduced at 60 mph. The effects of all the other variables – wind, tire type, transmission type, etc. – were contained within the 3% experimental error for this experiment.

Table E-9 shows the number of shifts due to hills, while Figure E-3 shows the graphic representation of the fuel consumption and shift data.

TABLE E-8. SUMMARY OF CALCULATED FUEL CONSUMPTION (MASSACHUSETTS TESTS)

BUS	FUEL CONSUMPTION (mpg)					
	50 mph		55 mph		60 mph	
	S	L	S	L	S	L
EAGLE	8.18 ±.45	8.05 ±.56	7.99 ±.68	8.15 ±.32	8.69 ±.13	8.05 ±.81
MC-7	8.21 ±.58	8.09 ±.02	7.94 ±.41	7.90 ±.36	8.26 ±.03	7.40 ±.16
MC-8	7.61 ±.30	7.52 ±.42	7.58 ±.80	8.18 ±.49	8.39 ±.36	7.70 ±.14
GMC 4905	8.33 ±.38	8.59 ±.08	8.45 ±1.05	8.61 ±.59	8.06 ±.68	7.28 ±.28
TOTAL SAMPLE (-GMC)	8.02 ±.16	7.86 ±.16	7.84 ±.20	8.08 ±.12	8.47 ±.10	7.68 ±.15

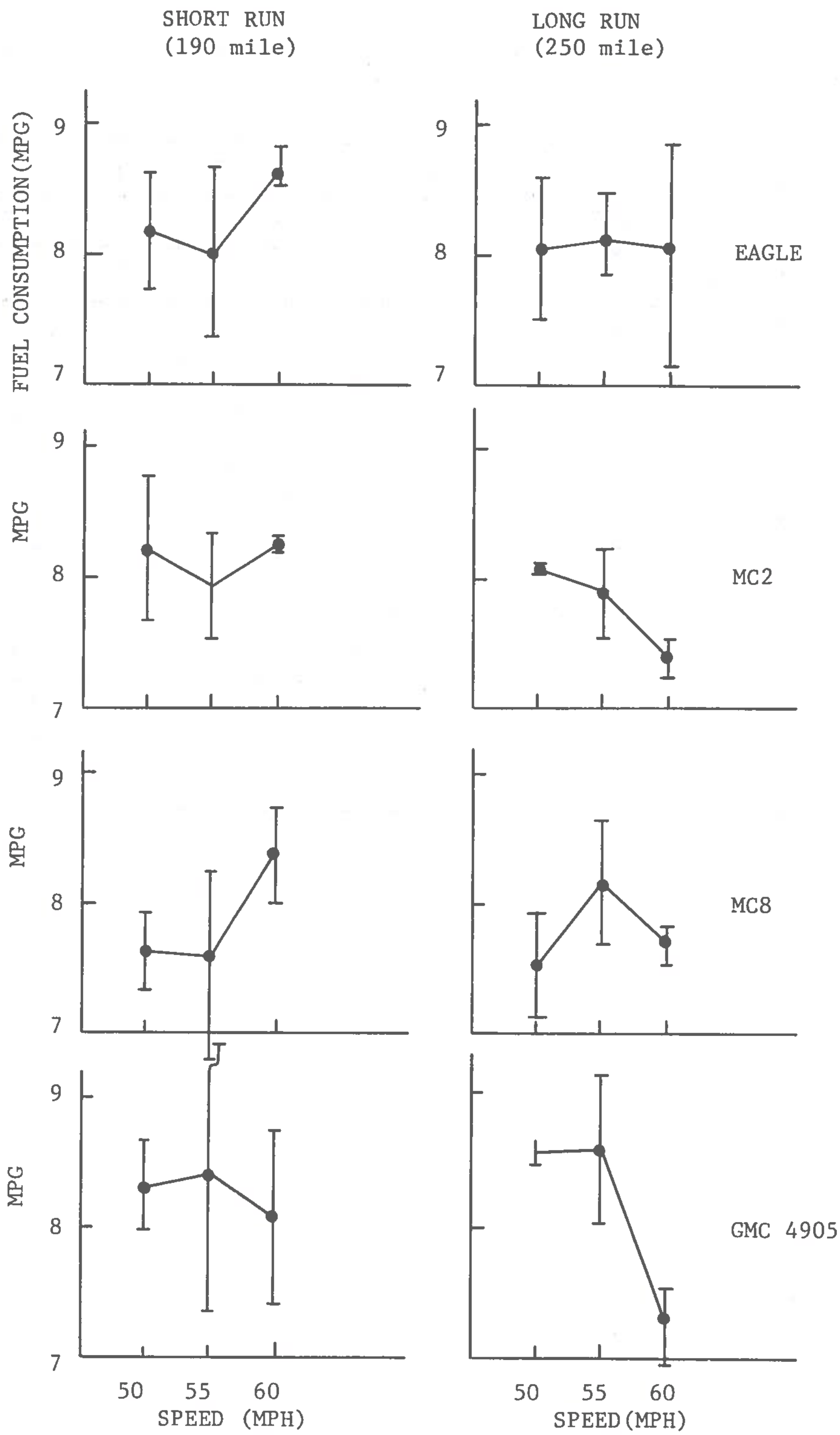
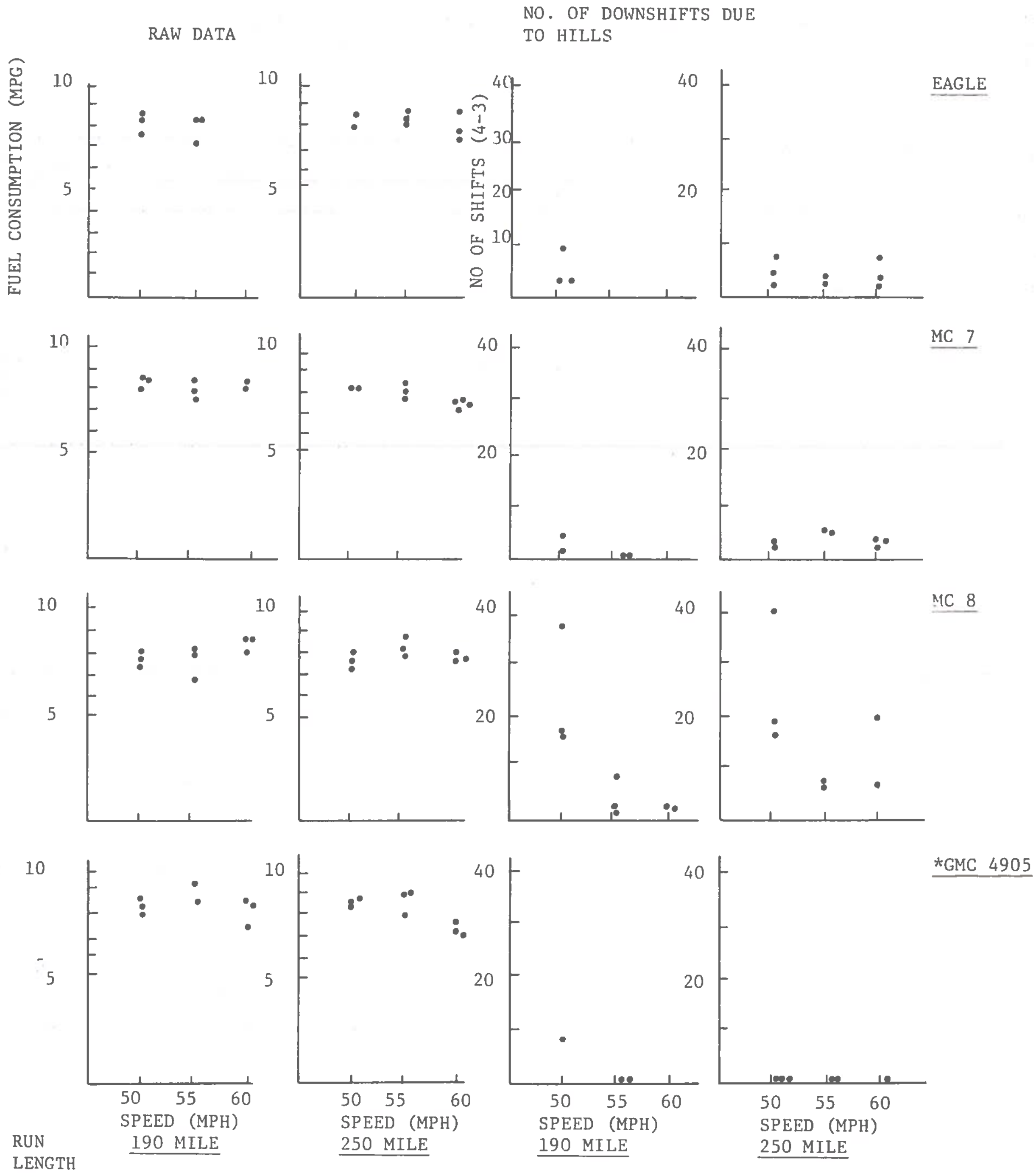


Figure E-2. Individual Fuel Consumption Curves
(Massachusetts Tests)

TABLE E-9. NUMBER OF SHIFTS DUE TO HILLS (MASSACHUSETTS TESTS)

BUS			50 S	50 L	55 S	55 L	60 S	60 L	AVE/RUN (S+L)
EAGLE									
SHIFT FROM	SPEED		9	7	2	1	0	7	
1-2 (UP)	15		3	4	1	2	0	3	50 = 4.7
2-3 (UP)	30		3	2	0	4	1	2	55 = 1.7
3-4 (UP)	45								
4-3 (DOWN)	46	TOTAL	15	13	3	7	1	12	60 = 2.2
MC-7			4	3	0	1	0	3	50 = 1.7
			1	2	0	5	0	2	55 = 1.8
			0		0	5		3	60 = 1.3
			0					0	
		TOTAL	5	5	0	11	0	8	
MC-8			37	40	8	5	1	19	50 = 25.8
			16	16	1	8	2	7	55 = 5.0
			17	19	2	6	2	1	60 = 5.3
		TOTAL	70	75	11	19	5	27	
GMC			8	—	—	—	—	1	50 = 1.3
4905			—	—	—	—	—	—	55 = 0
			—	—	—	—	—	—	60 = 0.2



*Note: GMC 4905 data is presented for information only due to the fuel tank filling problem (gal p ---). This data is not included in the statistical analysis

Figure E-3. Fuel Consumption and Shift Data

E.5 STATISTICAL ANALYSIS

The data were subjected to an analysis of variance to determine if any of the main factors — bus type, speed, trip type or any of the interacting: bus x speed, bus x trip, speed x trip, bus x speed x trip — had a significant effect on gas mileage. Because the "cell frequencies" — i.e., the number of observations with experimental factors fixed — were unequal, a special form of the analysis of variance, known as "unweighted means" analysis, was employed. The analysis of variance is summarized in Tables E-10 through E-12.

TABLE E-10. ANALYSIS OF VARIANCE SUMMARY

SOURCE OF VARIANCE	df	Mean Square	F	Significance Level
Buses (b)	2	.5511	2.55	N.S.
Speeds (s)	2	.1015	0.47	N.S.
Trips (t)	1	.5274	2.44	N.S.
bxs	4	.2775	1.28	N.S.
bxt	2	.0893	0.41	N.S.
sxt	2	1.07	4.93	.05
bxsxt	4	.045	0.21	N.S.
Error	36	.2169		———

For each factor the variance estimate equals sum of squares X2.198 degrees of freedom. The within sample variance estimate is the sum of squares divided by the degrees of freedom. The fraction is the ratio of the variance estimate to the within sample variance estimate. It is seen that the SxT interaction is the only factor significant at the 95% level.

TABLE E-11. "MAIN EFFECTS TEST" SUMMARY

SOURCE OF VARIANCE	C/f	F	SIGNIFICANCE LEVEL
Short trip	2	4.33	.05
Long trip	2	2.90	NS
50	1	0.828	NS
55	1	1.64	NS
60	1	12.76	.01
error (MS=.2169)	36	-	-

TABLE E-12. "NEWMAN - KEULS TEST" SUMMARY

SOURCE OF VARIANCE	C/f	F	SIGNIFICANCE LEVEL
Short trip			
50 - 60			.05
55 - 60			.05
50 - 55			NS
Long trip			
50 - 60			NS
55 - 60			NS
50 - 55			NS

APPENDIX F
DYNAMOMETER TEST PROCEDURE

F.1 STARTUP

The bus was backed into the test bay until the drive wheels dropped between the rollers of the dyno; the bus wheels then were briefly spun up at zero load to align the bus drive axle parallel to the dyno roller axles. The bus engine was stopped and the fuel flowmeter hoses were connected into the engine fuel line system. The engine was restarted and idled if necessary to bring it to operating temperature. The transmission was engaged, the drive wheels brought up to approximately 50 mph in fourth gear, and operation continued at modest dyno load for at least 5 minutes to get the drive tires into operating condition. The system was now ready to begin testing.

F.2 TEST SEQUENCE

The dyno load was increased to produce the force gage reading corresponding to the estimated HP for 50 mph, 0% grade. The bus driver was instructed to hold his speed as precisely as possible at 50 mph on his speedometer. When he had stabilized bus speed at this point, the dyno roll surface speed was read off the dyno speedometer. Using the dyno equation given above, the force required to absorb the desired HP at this indicated dyno speed was calculated. The dyno load was readjusted as necessary while the bus driver manipulated his throttle to maintain speed at "bus 50" mph.

When satisfactory stability had been achieved, operation was continued at this condition for 5 minutes. The dyno force gage and the fuel flowmeter were observed continuously by two people, with periodic checks being made of the dyno speedometer. At approximately 1-minute intervals, the range of dyno force indications and estimated mean fuel rate for that interval were recorded, along with mean dyno speedometer indication, until 5 sets of data had been logged. This completed the test at this particular condition.

Dyno force then was increased to the next calculated value at the same speed, in this case 1% grade at 50 mph, while the driver maintained speed, and the above procedure was repeated. This routine was followed throughout as much of the speed and grade schedule shown in Table 2-3 as the particular bus was able to perform. When the bus was unable to maintain the desired speed upon increasing load to the next higher grade, testing at that speed was discontinued, dyno force was reduced, speed was increased to the next level, and the sequence of increasing grades at constant speed resumed.

When maximum grade at 60 mph had been achieved, bus speed was decreased to 50 mph and the transmission downshifted to third gear (except for the GMC 4905, which could not exceed about 46 mph in third gear; for this bus, the following test was not performed). Dyno force was increased to the value corresponding to 50 mph, 1% grade, and a 5-minute series of observations was recorded. Without changing dyno force setting, the bus transmission was upshifted to fourth gear and another 5-minutes series was recorded. The transmission then was downshifted to third gear again without changing dyno settings and a third 5-minute series at 50 mph was logged. This completed one test sequence on that bus.

Usually a break in testing was taken at this point to allow the tires and engine to cool and to refresh the test personnel. The above test sequence then was repeated in full (except as noted below) to provide two test sequences on each bus.

Occasionally, the bus drive wheels were stopped and approximate tire tread temperature was observed both by touch and by inserting a thermistor bead into a center tread groove. Thermistor resistance was measured with an ohmmeter and temperature was read from a calibration chart of resistance vs. temperature.

F.3 EXCEPTIONAL CASES

In two of the buses (the MC-7 and MC-8), the driver's speedometer was driven by a front wheel of the bus, which was stationary for dyno tests; thus in these cases, the driver's speedometer could not be used to set speeds on the dyno. The baggage compartments of both these buses contained speedometer-odometers which were associated with rear-wheel motion. Although no precise correlation between this rear-wheel speedometer and the driver's front-wheel speedometer was known, it was necessary for this test to assume that the two would read identically.

When this situation was first encountered (on the MC-7), no means for giving the driver a visual indication of his speed was available. The bus was driven (on the dyno) to indicate steady speeds of 50, 55 and 60 mph on the rear-wheel speedometer while corresponding dyno speedometer readings were noted. During the speed-grade test sequences, an observer would station himself in the bus where he could see the dyno speedometer and orally coach the driver to the desired dyno speed at each load condition. The driver then maintained a steady-state condition by judging accelerator feel and engine sound, with continued guidance if necessary. A remarkable degree of stability in speed was achieved throughout both test sequences on this bus.

For the MC-8 the following day, a special speedometer drive cable extension was made up which ran from the baggage compartment through a window of the bus to the driver's position. The baggage compartment speedometer was attached to this extension cable where it would be conveniently visible to the driver, thus providing a speed-control reference.

In two cases (the MC-7 and the GMC 4905), incipient drive tire tread failure was observed before the midpoint of the second test sequence had been reached. In both instances, the failure was on a center tread rib of the inner tire on the left side of the bus. The best sequence was terminated at this point for both buses, and no attempt was made to repeat the tests on either bus.

F.4 COMMENTS

To facilitate numerical processing and analysis of the experimental results, all data were assembled in a file in computer memory. From this main file, entries were selectively extracted to form subfiles containing desired groupings of related data which then were transformed and combined to yield quantities of interest, such as miles per gallon (mpg), etc.

The names of these files are acronyms which suggest the contents: MALGR0: mileage, all buses, grade 0%; MALGR1: mileage, all buses 1%; MB4570: mileage, one bus, 45-70 mph (arbitrary "grade"). DYNMPH signifies test speed in mph, as indicated by the speedometer of the dyno; in all cases, this corresponded to the nominal 5-mph speedometer reading of the bus speedometer (e.g., 50, 55, 60, 70, etc.). DYNMPG is the fuel economy, or mileage, in miles per gallon (mpg) calculated from fuel flow rate in lb/hr and DYNMPH. NRMMPG is the normalized DYNMPG calculated using the average value of DYNMPG at 50 (bus) mph, 0% grade, as the normalizing value. Thus normalization to 1.000 at precisely 50 DYNMPH was not necessarily realized.

Once these files had been prepared, various mathematical and statistical operations were performed to aid interpretation of the results. One computer program provided constants for the equations of six different types of curves, fitted as well as possible to the experimental data by a least-squares technique; a measure of the "degree of fit" of each equation also was given. Another program fitted polynomial equations of any desired degree to the data and produced a standard error of estimate (another measure of "fit") for each curve. Single- and multiple-regression analyses with various sophisticated statistical test parameters were evaluated.

From all of this analysis, it became very evident that a simple equation of the form $y = A + Bx$ described the relationship between NRMMPG (y) and DYNMPH (x) at least as well as any of the more complicated functions and probably was a more valid description of the physical world than some complex polynomial. The standard error of estimate (analagous to the standard deviation of a group of numbers) of any one experimental value of NRMMPG at a given speed ranged from about 3 to 5% of the calculated value of the curve at that point. This was considered to be a quite satisfactory type of error for the limited dyno test effort on each bus, particularly in view of the generally excessive dyno load pattern. The general pattern of the data, together with this magnitude of error, indicated that conclusions of relative effects of speed changes based on the calculated composite NRMMPG/DYNMPH curves should be quite reliable.

The equations selected as best representations of the experimental data in the files discussed above are given in Table F-1; also included are the ranges of experimental dyno speeds applicable to each, and the standard error of estimate which applies over the entire speed range.

TABLE F-1. EXPERIMENTAL EQUATIONS DATA

FILE NAME	BEST-FIT EQUATION	DYNO SPEED RANGE, MPH	STANDARD ERROR OF ESTIMATE
MALGR0	NRMMPG = 1.59949 - 0.0123221 (DYNMPH)	48 - 63	±0.038
MALGR1	NRMMPG = 1.30906 - 0.0110302 (DYNMPH)	47 - 57	±0.034
MB4570	NRMMPG = 1.67866 - 0.0137587 (DYNMPH)	44 - 72	

To aid interpretation of the data tabulated in the three named files, the computer was used to generate a plot of the calculated individual values of NRMMPG vs. DYNMPH; these plots are shown in Figures F-1 through F-3. Note that the accuracy of plotting is limited by the resolution of the printer character spacing, and these plots should be used for general assessment only. Superimposed on each plot has been drawn the calculated best-fit straight line, together with associated error bars for ± one standard error of estimate (should include approximately 65-70% of all points). The accuracy of plotting the lines also is somewhat limited on these printouts. Should the reader desire a more precise presentation of the data, he is welcome to the task of point-by-point plotting.

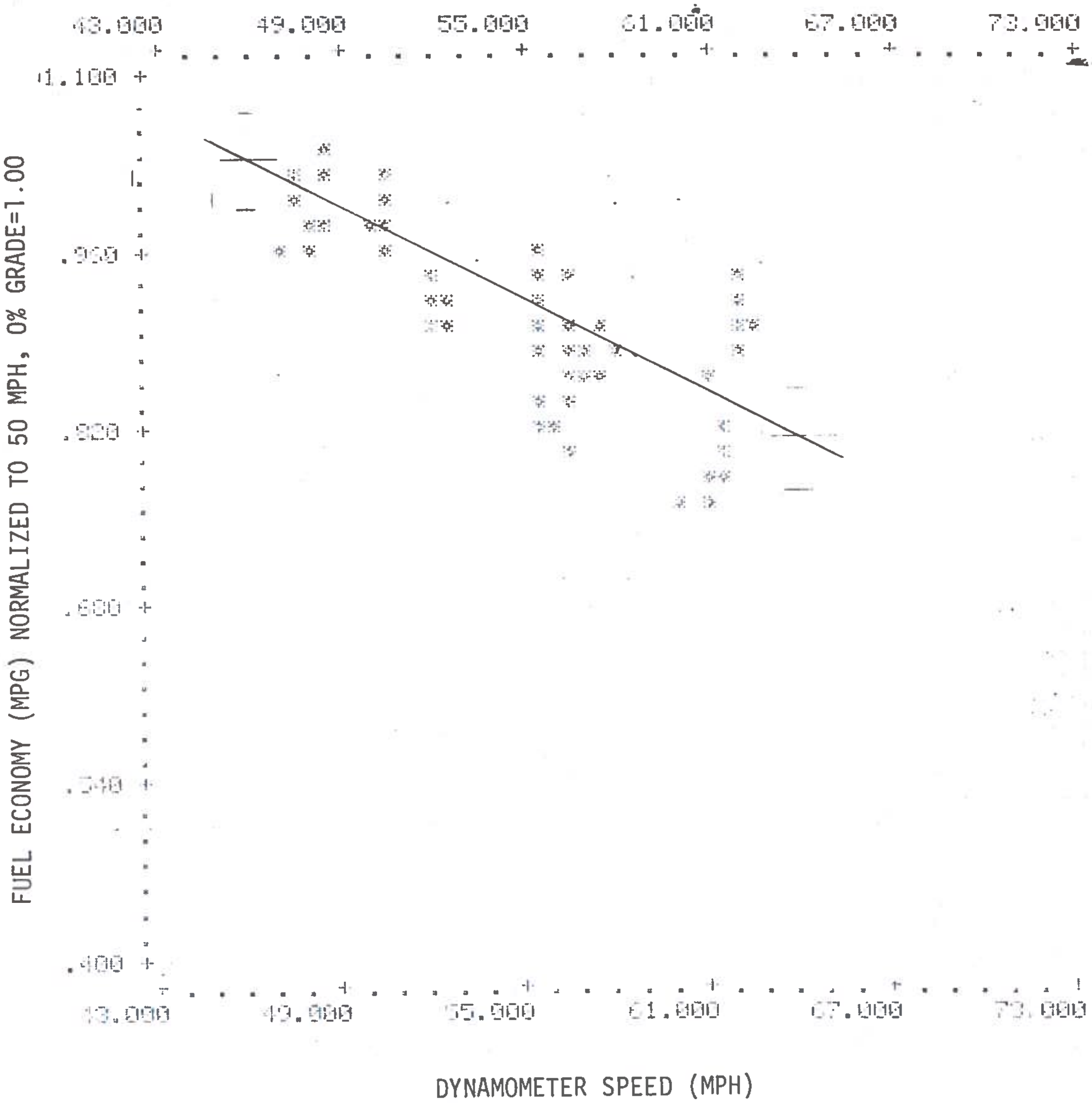


Figure F-1. Normalized Fuel Economy (NRMMPG) Vs. Dynamometer Test Speed (DYNMPH) MALGRO File

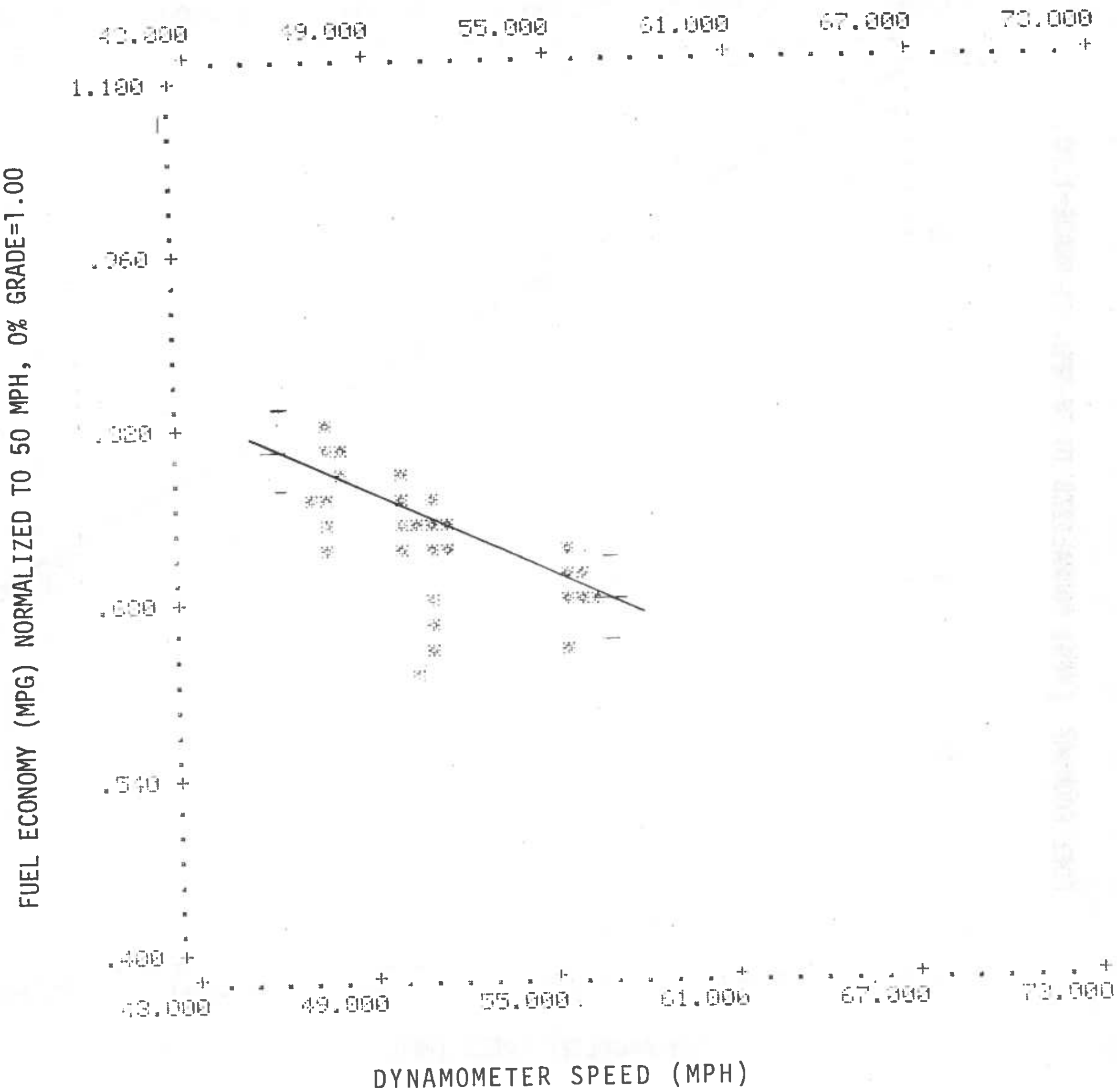


Figure F-2. Normalized Fuel Economy (NRMMPG) Vs. Dynamometer Test Speed (DYNMPH) MALGR1 File

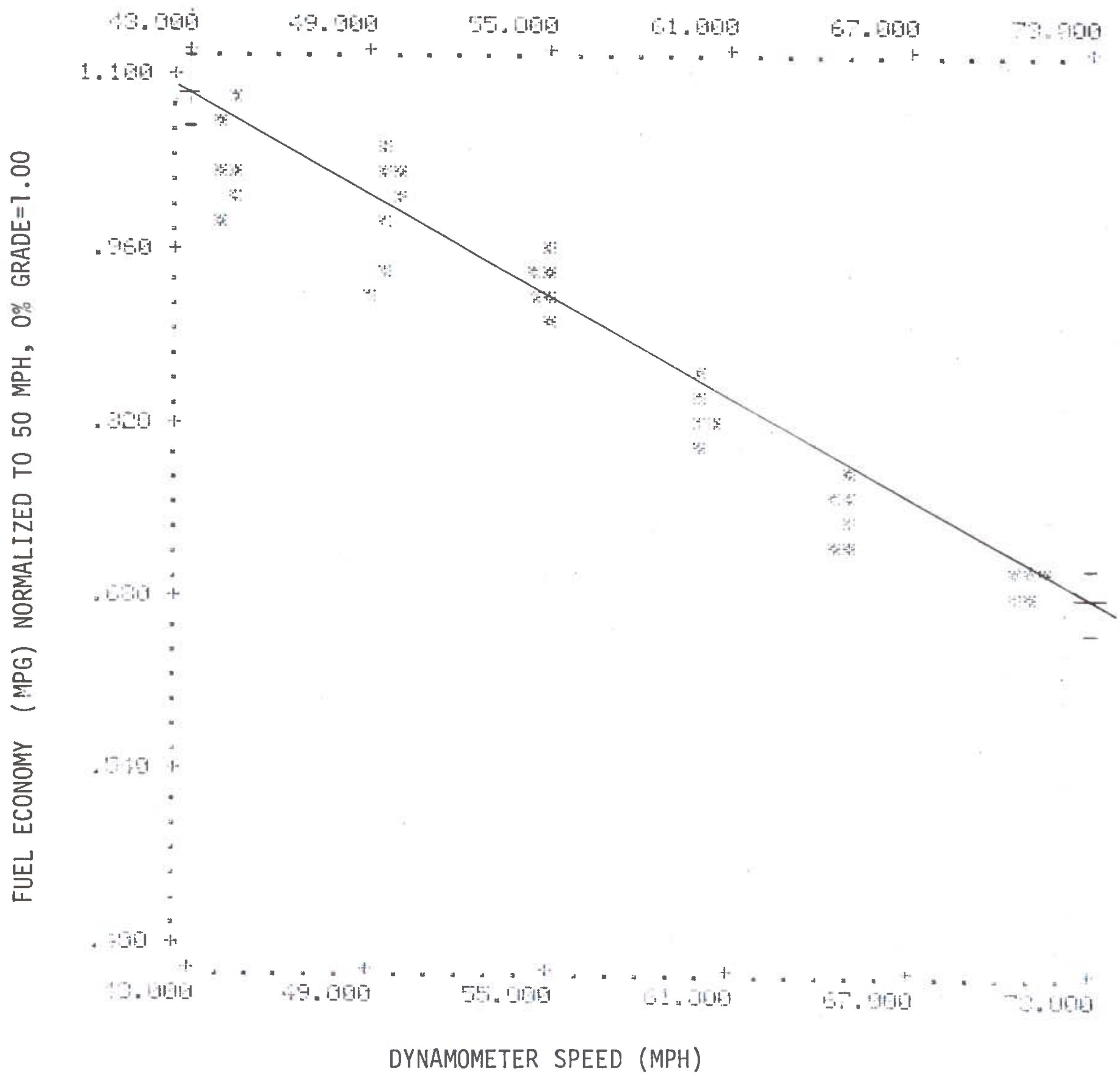


Figure F-3. Normalized Fuel Economy (NRMMPG) Vs.
Dynamometer Test Speed (DYNMPH)
MB4570 File

APPENDIX G

EXTRACTS FROM CURRENT CTNE LABOR MANAGEMENT CONTRACT RELEVANT TO DRIVER UTILIZATION

PART II

OPERATORS' AND HOSTESSES' WORKING CONDITIONS

Section 1. BID ASSIGNMENTS

The right to preference to work (bid assignments) will be governed by seniority.

Section 2. REPORTING ON DUTY

All bid assignments shall have a designated point and time for Employees to go on duty and a designated point and time for Employees to go off duty, and shall designate Employees' days off.

Section 3. GENERAL BIDS

A. A general shake-up to include all runs shall be posted to become effective on the last Sunday in April, the last Sunday in October, and during the month of January of each year at which time bids will be accepted by the COMPANY and runs will be assigned. Assignments shall be bid according to seniority with each Employee bidding in rotation and bidding only one assignment. Such assignment shall be held for not less than thirty (30) days, after which time, if the operator so desires, he may vacate the assignment by notifying, in writing, the proper supervisor at least twenty-four (24) hours before departure time of assignment, whereupon the assignment will be filled in accordance with Section 23 hereto. An Operator having vacated an assignment may not bid a hold-down within thirty (30) days after vacating.

B. All runs of the COMPANY that operate three (3) days or more per week, and accrue an average of nine hundred sixty (960) miles or more per week, will be advertised for bid as a regular assignment. Operators holding such regular assignments will not be allowed to work the extra board for the remainder of the week unless the extra board is exhausted.

C. Bid books shall be placed in terminals at least seven (7) days before bidding starts, and a copy shall be furnished the UNION at the same time. Each Op-

erator will be assigned a specific date and hour to place his bid. Operators who fail to bid at their designated time will be passed up. Operators who are passed will forfeit their right to bid except on vacant runs open at the time they become available to bid. Bidding will start at least seven (7) days prior to effective date of schedule change.

D. Bidding will commence on a designated day at 8:00 a.m. and run until 6:00 p.m. daily, in bidding intervals of twenty (20) minutes per Operator, i.e. the first Operator will on the first day of bidding, place his bid between 8:00 a.m. until 8:20 a.m.; the second man from 8:20 a.m. until 8:40 a.m.; the third man from 8:40 a.m. to 9:00 a.m. and continue in that manner.

E. No Operator will be allowed to bid on a run that he voluntarily vacated, unless displaced from present run.

F. Cushioning occasioned by the exercise of seniority rule shall not be paid for.

Section 4. NEW ASSIGNMENTS AND VACANCIES

All new runs and permanent vacancies in regular run assignments shall be advertised by the COMPANY by written notice on the bulletin boards, showing sign-on and sign-off points and time (furnishing a copy to the UNION); leaving and arriving time of schedules operated; hours and miles allowed for normal operation. New positions and vacancies shall be advertised within five (5) days after the vacancy or the new position is created and shall be advertised for five (5) days thereafter. New positions or vacant assignments (pending permanent assignments) shall be worked off the extra board of that division and shall be immediately offered to the senior extra board man of the extra board on that division in which the vacancy or new position occurs. Should the senior extra board Operator on the extra board of that division decline to take the assignment, it shall be offered to the next senior Operator and so down until the bottom of the board is reached at which time the assignment shall be given to the junior Operator on the extra board of that division.

Section 5. MATERIAL CHANGES IN ASSIGNMENTS

A. When a regular run is materially changed either as to time or working conditions from the current bid sheet, it shall be cancelled and re-advertised for seniority choice. The following will be considered as a material change: Change of terminals or assignments; change of over one (1) hour in signing on or off time of assignment; and change of days off or change of assignment resulting in a difference of ten dollars ($10.00) per month in earnings. It is understood that a change of assignment from terminal to garage or garage to terminal will not be considered a material change. It is understood that "current bid sheet" means the last general bid, and a bid assignment is any assignment on that bid sheet.

B. When an Operator on a Regular Bid assignment, which terminates in New York is instructed to take a bus to the Hoboken Garage, he will be paid six (6) miles for each round trip.

Section 6. REGULAR RUNS

A. On regular runs of less than one hundred sixty (160) miles, Operators shall be paid no less than a minimum day.

B. On regular runs of over one hundred sixty (160) miles, Operators shall be paid miles or hours whichever is greater. For all work over twelve (12) hours, Operators shall be paid an additional twenty (20) miles per hour until relieved from duty. For regular Operators on one (1) day turn-around service, time shall be computed as continuous from the time he is scheduled to report for duty until his scheduled time to be relieved from duty. A regular Operator on one (1) day turn-around service, instructed to perform additional duties during his layover time, shall be paid miles or hours whichever is greater for this additional time on duty in addition to his regular bid assignment. The COMPANY will furnish transportation to Operators on turn-around runs at away

from home terminals when they are required to drive a bus to, or get a bus from the garage.

C. Time begins at the time an Operator is required to report for duty, and ends when motor coach is delivered to designated place for tying up equipment, or when relieved from duty. If required to remain on duty after delivering motor coach at designated place for tying up equipment, actual minutes will be allowed for all time so held, as an additional allowance to all other earnings for the day's work.

Section 7. BUMPING

An Employee, deprived of his run through the fault of the COMPANY or no fault of his own, will be permitted to displace an Employee junior to him. Any Employee not wishing to exercise his seniority immediately will be placed on the extra board and must exercise seniority within five (5) days following displacement or remain on said board.

Section 8. BOOK-OFFS (REGULAR EMPLOYEES)

A. No regular Employee who has booked off will be permitted to pick up his run at any away-from-home terminal.

B. A regularly assigned Employee who has laid off for an indefinite period and who desires to report for his run will do so at least fifteen (15) hours prior to the scheduled departure time of his run. Failing to do so, he will be held from his run until its next departure time, unless there are no qualified extra Employees available.

Section 9. DISPLACEMENT NOTICE

Any Employee being displaced will be given twelve (12) hours notice or allowed to work his day's assignment.

Section 10. RETURNING FROM LEAVE

Employees returning from leave of absence may file applications for any assignment that his seniority will permit him to bid in the current bid book.

Section 11. ASSIGNMENT GUARANTEE AND FALL-BACK RULE

A. When a regular Operator is held from his run through the fault of the COMPANY, he shall be paid not less than he would have been paid had he not been so held from his run. Earnings shall be computed on a weekly basis. When service is suspended, any regular Operator who is due to report and has reported for work without being notiried by telephone one and one-half (1½) hours prior to scheduled departure time, shall be paid for his day's assignment. If cancelled enroute he shall be paid for the complete day's assignment.

B. Regular Operators shall be paid for all delays due to breakdowns, traffic conditions, storms, and all other conditions beyond the control of the Operator. Compensation shall be at the hourly rate after one (1) hour after sign-off time.

C. During adverse weather conditions or other acts of Providence which result in a slow down and/or delay of schedules affecting the majority of service in an area, regular Operators arriving too late at away-from-home terminals to pull their assigned scheduled return trips to their home terminals will be worked on a first-in first-out basis on regular schedules back to their home terminals only until the emergency is ended. Any regular assigned Operator so used will receive compensation at his applicable hourly rate for all time delayed in excess of one (1) hour of scheduled sign-off time of his regular assignment. The application of this rule. shall not be considered a violation of the extra board conditions during the emergency.

Section 12. REPORTING TIME

Operators of regular runs shall not be required to report for duty more than thirty (30) minutes prior to scheduled departing time of their runs. An Operator who is required to report more than thirty (30) minutes prior to his scheduled departure time shall be compensated for any such time in excess of thirty (30) minutes at his applicable rate.

Section 13. MOVING UP

Any regular Operator working a regular bid run who, in case of an emergency, is asked to pull another run to his home terminal prior to his regular departure time will be paid no less than his regular bid miles and will be paid at his hourly rate for any additional hours required to pull this assignment. It is understood that an Operator of a regular bid run will not be required to pull a longer run than his own, but may do this on a voluntary basis if requested.

Section 14. QUALIFYING ON ROUTES

All extra Operators will be expected to qualify on all runs during their first sixty (60) days of employment. When a new service is added, all Operators who are so instructed by the COMPANY will be expected to qualify and will receive a minimum day's pay for each day required to qualify.

Section 15. UNIFORMS

Operators shall wear a regulation uniform while on duty in public places or on COMPANY property. In the event the style or specifications of uniforms are changed at any time by the COMPANY, Operators will be permitted to wear uniforms of prior style or specifications as long as same are in a neat and serviceable condition.

All state chauffeur's license fees will be paid for by the Operator and all necessary public utilities or public service license fees will be paid for by the COMPANY.

Section 17. EQUIPMENT OF EMPLOYEES

Employees will not be required to bear the expense of badges, ornaments, service or other COMPANY insignia, name plates, rule books, or other equipment required by the COMPANY. However, should the Employee lose or damage such COMPANY equipment, he shall pay for the same at its cost to the COMPANY. The expense of any surety bonds required of the Employee will be borne by the COMPANY. No cash bond shall be required of any Employee.

Section 18. EXTRA WORK — OPERATORS

A. Extra work will be performed by extra Operators except that regularly assigned Operators may be used for extra work when qualified extra Operators are not available for service.

B. A rotating list will be maintained, in all dispatch offices, of all men who are willing to work assignments other than their regular bid assignments (subject to contract provisions). These men will be used before any outside men are called in. Operators on regular bid assignments desiring to work extra on their days off will place their names on the extra board and will be used first-in first-out after the extra board is exhausted. Operators desiring to step up at away-from-home terminals will advise the COMPANY that they will be available to step up in case it is necessary.

C. Regular Operators working extra will come under the rules and regulations governing the extra board until they return to their home terminal.

D. At terminals where the extra boards are maintained (a visual board in New York, Springfield, and Boston) extra Operators will be worked on a first-in first-out basis, except that an Operator away from his home terminal extra board shall be first out on all doubles and deadheads and one-way vacancies destined to his home terminal, provided he arrives thirty (30) minutes prior to scheduled departure time. Extra Operators available for work who are run around by other extra Operators (except by Operators away from their home terminals who are returning with doubles, deadheads, or vacancies above provided) shall receive a minimum day's pay at their applicable rate, and will remain first out on the extra board. It is further understood and agreed that only the first Operator on the board who is run around may claim time under this rule.

E. An extra Operator who has completed an assignment at a division point and goes on that extra board will be subject to be reassigned to another assignment when he becomes first out even though he has not had eight (8) hours off duty, provided he has

sufficient hours to complete the assignment. For example, if a Boston extra Operator drives an assignment to New York and goes on the extra board and six (6) hours later he becomes first out, he will be assigned to the next assignment to Boston, even though he has not had eight (8) hours off duty. If the first extra Operator does not have sufficient hours to complete the assignment and the second extra Operator is assigned, the first extra Operator will remain on top of the extra board and be assigned to the first assignment which can be completed in his available hours.

F. An extra Operator given an assignment at his home terminal and who returns to his home terminal within eight (8) hours will remain first up and shall be assigned to the next assignment provided he has sufficient hours to complete the additional assignment, and provided he arrives thirty (30) minutes prior to scheduled departure time.

G. All extra Operators will have one day a week off if they so desire not to exceed one Operator on Friday, Sunday and Holidays unless conditions permit more.

H. Order of assigning Operators to one-way trips, doubles or deadheads

From:

Gardner - Springfield - New Haven to New York

1. New York Operator
2. Springfield Operator
3. Boston Operator

New York - New Haven via Springfield - and beyond

1. Springfield Operator
2. New York Operator
3. Boston Operator

Haverhill - Manchester - Worcester - Boston to New York

1. New York Operator
2. Boston Operator
3. Springfield Operator

New York to Worcester - Haverhill

1. Boston Operator
2. New York Operator
3. Springfield Operator

New York to Boston and North

1. Boston Operator
2. New York Operator
3. Springfield Operator

North of Boston to Boston

1. Boston Operator
2. New York Operator
3. Springfield Operator

Hartford to Boston

1. Boston Operator
2. Springfield Operator
3. New York Operator

Boston to Hartford

1. Springfield Operator
2. New York Operator
3. Boston Operator

New York to Bridgeport

1. New York Operator
2. Springfield Operator
3. Boston Operator

Bridgeport to New York

1. New York Operator
2. Springfield Operator
3. Boston Operator

Extra Operators, working off their division, will be relieved at their home terminal or upon completion of the assignment. Exceptions will be:

1. New York and Springfield men will be relieved in Boston, if possible.
2. Boston and Springfield men will be relieved in New York, if possible.
3. Any Operator assigned to a schedule operating through Hartford will not be relieved in Hartford by another Operator.

I. In an emergency, when an extra man is used out of rotation to pull a run that goes to, or through, his extra board location, he will be relieved at that point by the first-up man, be paid not less than a minimum day, and retain his position on the extra board.

J. When two or more extra Operators return to their home terminal they will be reassigned according to their original positions on that board.

K. When an extra Operator is assigned at his home terminal to a regular bid assignment as outlined in the bid book, and completes the first portion, he will be eligible to operate the return portion, and will be paid for all actual work performed each day.

Example: When an extra Operator is called on duty at Boston at 12:01 p.m. and is assigned to cushion at 1:00 p.m. to Portland, arriving at 3:50 p.m., to cover the 6:00 p.m. to New York, he will be paid one (1) hour's protection from 12:01 p.m. to 1:00 p.m., cushion time from 1:00 p.m. to 3:50 p.m., protection from 3:50 p.m. to 5:30 p.m., and then for actual work performed driving and/or on duty for the remainder of that day. The same will apply in reverse on the return portion of the bid, actual driving miles from New York to Portland, plus hours on duty until a scheduled time to cushion to Boston, plus cushion time. However, this will not apply if the Operator is required to remain in Portland overnight in either direction, in which case the minimum day clause will apply.

In the case of a turnaround bid assignment between Springfield and New York, the Operator will be paid for actual protection time on duty or cushioning and the actual driving miles from Springfield to

New York, but not for lay-over time while in New York prior to the return portion of this assignment to Springfield.

L. Additional rules and regulations governing the extra board will be mutually agreed upon.

Section 19. EXTRA OPERATOR, ON-DUTY

A. MINIMUM DAY. When an extra Operator is called on duty, he will receive miles or hours, whichever is greater, at his applicable rate, for all work performed, including protection, cushion, driving, and charter work as set forth in Part III, Section 7, but in no case shall such Operator receive less than eight 8) hours pay at his hourly rate.

B. PROTECTION. An extra Operator performing protection under orders of an authorized COMPANY representative shall be paid at his hourly rate for each hour or portion thereof to the nearest quarter hour held in such service, until assigned, in addition to any other assignment, except when the combination of all assignments does not exceed a minimum day. It is understood that when an extra Operator is called on duty he shall remain on duty and be paid for all time on duty until relieved, except regular bid assignments.

C. CUSHION An extra Operator cushioning under orders of an authorized COMPANY representative shall be paid at his hourly rate for each hour or portion thereof to the nearest quarter hour held in such service, in addition to any other assignment, except when the combination of all assignments does not exceed a minimum day.

D. An extra Operator will be paid for all actual breakdown time in addition to all other work performed, except when the combination of all assignments does not exceed a minimum day.

E. AVAILABLE HOURS. Operators having been on duty for a period of six (6) hours will not be permitted to take an assignment where the hours of the assignment including prior on-duty time will be in excess of fifteen (15) hours from first sign-on time.

In emergencies when there are no other Operators available, Operators will be permitted to take an assignment after six (6) and up to eight (8) hours on duty where the total hours of on-duty time shall not exceed fifteen (15) hours, in no instance shall the driving hours exceed ten(10) hours except where permissible under Department of Transportation Hours of Service Regulations - Rules 395.10 - 395.11 - 395.12.

Section 20. PREFERENCE OF ASSIGNMENTS

Where there are two (2) or more assignments to be filled at the same time by Employees from the same extra board, the first available Employee will be given his choice, the second his choice, and so on.

Section 21. LAY-OVERS — OPERATORS

When an Operator is held away from his home terminal without work, he will receive lay-over pay as follows: First day's pay will begin after sixteen (16) hours from the time relieved from duty, not to exceed eight (8) hours; second day's pay will begin after fifteen (15) hours, not to exceed nine (9) hours; third day's pay will begin after fourteen (14) hours, not to exceed ten (10) hours and similarly thereafter for each twenty-four (24) hour period. For the purpose of applying this rule, the COMPANY will designate a home terminal for Operator.

Section 22. TELEPHONE NOTIFICATION

Extra Employees, in order to be considered as available must provide themselves with telephone service in order that they may be called in proper turn. An extra Employee not available for an assignment because he cannot be reached by telephone will not be considered as having been run around, providing proof is submitted that an attempt was made to reach him. The COMPANY will furnish all extra Employees, upon request, information as to their standing on extra board and the probable time that they may be called. Expense of telephone toll calls will be borne by Employees when in connection with the foregoing.

Section 23. HOLD-DOWNS

When it is known that a run is to be open for more than seven (7) days and not more than thirty (30) days, hold-downs will be bid and worked in the following manner:

A. Any bid assignment that is known to be open for more than seven (7) days will be posted in the following places: Portland, Boston, Worcester, Hartford and New York, for a period of five (5) days, and this bid will close twelve (12) hours before the assignment is due out. Senior extra Operator on the extra board in the division where the hold-down occurs and who is successful bidder will be assigned as soon as available and qualified, and will cover this hold-down for the duration unless bumped by a senior extra Operator while more than seven (7) days remain on the hold-down. All bids must be in the office of the Supervisor in that division in writing at the time of the closing of the bid.

B. Senior extra Operator exercising seniority privileges will come under the same terms of the contract as a regular Operator exercising his bumping privileges.

C. If an extra Operator has bid a hold-down, he will not be eligible to bid on any other hold-downs that are posted; however, he may exercise his seniority at the completion of the hold-down, provided there are more than seven (7) days left on any hold-down.

D. It is understood that when an extra Operator bids a hold-down, he takes the position and conditions of a regular Operator during the term of his hold-down.

E. If a new or regular run becomes open, it will be posted in the same manner. Regular runs becoming vacant between general bids will be advertised in the same manner as hold-downs, and the senior Operator bidding this vacancy will be awarded the run.

F. All time periods referred to in this section are intended to mean calendar days. If a hold-down is not bid, it will be assigned to the junior Operator on the extra board of that division. The COMPANY will furnish a room when the junior operator is assigned an assignment which requires an overnight stay away from his home terminal.

Section 24. SIGNING IN

Extra Operators shall be held responsible to sign in or to be signed in and to see that their names are properly placed on the extra board immediately upon arrival at a division point. They shall, also, be responsible for reporting their hours of service performed and time available for work under Department of Transportation regulations.

Section 25. REPORT TIME EXTRA MEN

A. Extra Operators at home terminal will be given a two (2) hour call.

B. Extra Operators at away-from-home terminal will be given no less than a one (1) hour call.

C. In an emergency when the first extra Operator cannot be available in less than the time specified in Paragraphs A and B of this Section the first available Operator may be used for this emergency and the extra Operator passed over will remain at the top of the extra board.

Section 26. ORDER OF ASSIGNMENT

When two (2) or more extra Operators are assigned as sections on the same run or assignment (either driving or cushioning), they shall be placed on the board at the destination point in the same order as they left the originating point provided they all arrive within fifteen (15) minutes. Operators arriving after this fifteen (15) minute period will be placed on the board in the order in which they arrive. The time will be determined by the first arrival of any of the extra Operators on this assignment, whether driving or cushioning. When one or more Operators arrive at an away-from-home dispatch point at the same time from different locations, first out will be determined by the time each Operator originally went on duty. The first man on duty will be first up at an away-from-home dispatch point.

Fueling a bus at the termination of a run or driving a bus to the garage shall not cause the Operator to lose his place on the board.

Section 27. BOOK-OFFS (EXTRA EMPLOYEES)

When extra Employees book-off, they must stay off the board for not less than twenty-hour (24) hours at their home terminal. An extra Employee may book-off at a point other than his home terminal for not less than twenty-four (24) hours when approved by his home division. He must book back on after twenty-four (24) hours or at the termination of his relieved period at the point at which he booked off.

Section 28. CHANGE OF TELEPHONE NUMBERS

When an Employee changes his telephone number to another number which is different from the one he has given the COMPANY as his regular number, only the Dispatcher advised and on duty at that time will be responsible for the temporary change of number.

Section 29. SLEEPING QUARTERS

Sleeping quarters, subject to UNION approval, shall be provided for Employees at away from home terminal.

Section 30. SAFETY COURT

When an Operator is involved in an accident, a COMPANY representative will make a determination as to the chargeability of this accident based on the information in the accident report and the COMPANY'S investigation. The Operator shall have the right to appeal this decision to a Safety Panel, by notifying the COMPANY in writing within ten (10) days of the day he is notified of the COMPANY'S determination, and it shall be heard within thirty (30) days after the COMPANY has been notified of his appeal. The Safety Panel, consisting of two (2) UNION representatives and two (2) COMPANY representatives, shall make their decision based on the written and/or oral information presented at the Safety Panel hearing. The COMPANY'S representative making the original determination shall not be eligible

to sit on the Safety Panel. In case of a tie vote, the UNION Business Agent and the COMPANY General Manager or his designee shall attempt, within ten (10) days after this decision to agree on a neutral safety representative in this area to make a determination of this decision based on the information presented to him in writing and/or orally. If the UNION Business Agent and the COMPANY General Manager or his designee cannot agree on a third party, then it shall be submitted to either the National Safety Council or the Safety Committee of National Trailways Bus System for its determination.

Section 31. INSPECTION OF EQUIPMENT

All Operators shall have the right and shall be expected to refuse any equipment which they feel is unsafe mechanically. After such equipment is determined to be mechanically safe by the shop foreman, an Operator shall fulfill his assignment unless there is reasonable justification for concluding that the foreman's determination is incorrect. If an Operator exaggerates or misrepresents any defect of equipment after the same has been checked by a qualified person for the COMPANY and it is found that he has misrepresented the case, he shall be subject to have disciplinary action taken against him.

APPENDIX H

REPRESENTATIVE PAGES FROM RECENT CTNE BID BOOK

TRAILWAYS OF NEW ENGLAND, INC.
OFFICIAL GENERAL BID
10/10/73

Original Bid M-1

1603	Lv. Manchester	12:25 pm	67+2
	Ar. Boston	1:50 pm	
1400	Lv. Boston	6:00 pm	149+1+2
	Ar. Plymouth	9:25 pm	
	Sign on Manchester Terminal	11:55 am	
	Sign off Plymouth Garage	9:40 pm	
	Pay Miles 221	On Duty 9 Hrs. 45 Mins.	
1401	Lv. Plymouth	8:10 am	149+1+2
	Ar. Boston	11:45 am	
	BUS TO BOSTON GARAGE		
1600	Lv. Boston	3:30 pm	55+2
	Ar. Manchester	4:45 pm	
	Sign on Plymouth Garage	7:40 am	
	Sign on Manchester Terminal	4:45 pm	
	Pay Miles 209	On Duty 9 Hrs. 20 Mins.	
	6 Days on	One Day Off	

No. 1 Eff: 9/10 Off: Sunday

No. 2 Eff: 9/11 Off: Saturday

TRAILWAYS OF NEW ENGLAND, INC.
OFFICIAL GENERAL BID
9/10/73

Original Bid Fitch-1

2301	Lv. Fitchburg	7:00 am	201+3+3
	Ar. New York	11:59 am	
	Sign on Fitchburg Garage	6:30 am	
	Sign on Hoboken Garage	12:15 pm	
2300	Lv. New York	4:00 pm	201+3+3+55
	Ar. Fitchburg connect with run 408 in Fitchburg	9:00 pm	2 3/4 Hrs. over 12
	Sign on Hoboken Garage	3:30 pm	
	Sign off Fitchburg Garage	9:15 pm	

Pay Miles 469 — On Duty 14 Hrs. 45 Mins.

1 Day On — 1 Day Off

No. 1 Eff: 9/10 — Off: 9/11

No. 2 Eff: 9/11 — Off: 9/10

TRAILWAYS OF NEW ENGLAND, INC.
OFFICIAL GENERAL BID
9/10/73

Original Bid B-9

1302	Lv. Boston	6:00 pm	183+2+2
	Ar. Berlin	10:30 pm	
	Report Boston Garage	5:30 pm	
	Sign off Berlin Garage	10:45 pm	
	Pay Miles 187	On Duty 5 Hrs. 15 Mins.	
1305	Lv. Berlin via Hampton Ctr.	8:00 am	185+2+2
	Ar. Boston	12:45 pm	
	Report Berlin Garage	7:30 am	
	Sign off Boston Garage	1:00 pm	
	Pay Miles 187	On Duty 5 Hrs. 30 Mins.	
	6 Days on	1 Day off	

No. 1 Eff: 9/10 Off: Wed.

No. 2 Eff: 9/12 Off: Tues.

TRAILWAYS OF NEW ENGLAND, INC.

OFFICIAL GENERAL BID

9/10/73

Original Bid B-8

1202	Lv. Boston	12:15 pm	120 + 2
	Ar. Laconia	3:03 pm	
1209	Lv. Laconia	3:30	120 + 2
	Ar. Boston	6:20	
	Report Boston Garage	11:45 am	
	Sign off Boston Garage	6:35 pm	
	Pay Miles 244	On Duty 6 Hrs. 50 Mins.	

Eff. 9/10 Off: Wed.& Thurs.

TRAILWAYS OF NEW ENGLAND, INC.
OFFICIAL GENERAL BID
9/10/73

Original Bid B-5

215	Lv. Boston	2:30 pm		232+2+3
	Ar. New York	8:36 pm		
	Report Boston Garage	2:00 pm		
	Sign off Hoboken Garage	8:51 pm		
	Pay Miles 237	On Duty 6 Hrs. 51 Mins.		
204	Lv. New York Via Ct.Pike	10:30 am		216+2+3
	Ar. Boston	2:55 pm		
	Report Hoboken Garage	10:00 am		
	Sign off Boston Garage	3:15 pm		
	Pay Miles 221	On Duty 5 Hrs. 10 mins.		
	6 Days on	1 Day off		

No. 1 Eff: 9/12 Off: Tues

No. 2 Eff: 9/10 Off: Wed.

TRAILWAYS OF NEW ENGLAND, INC.
OFFICIAL GENERAL BID
9/10/73

Original Bid B-2

207	Lv. Boston via Ct.Pike	9:00 am	216+2+3
	Ar. New York	1:25 pm	
	Report Boston Garage	8:30 am	
	Sign off Hoboker Garage	1:40 pm	
212	Lv. N.Y. Via Ct.Pike	3:30 pm	216+2+3
	Sign off Boston Garage	8:10 pm	
	Pay Miles 442	On Duty 11 Hrs. 40 Mins.	
	2 Days on	2 Days off	

No. 1 Eff: 9/10 Off: 9/11-12

No. 2 Eff: 9/11-12 Off: 9/10

APPENDIX I

CTNE SCHEDULE DURING NOVEMBER 1973

NEW YORK—NEW HAVEN—HARTFORD—WORCESTER—BOSTON

AM READ DOWN

Run Numbers (ET) 7880	400	114 PBN	116 PBN	302	104 PBN	402	250	202	412	204	106 PBN
Lv Washington, D.C. (7900)	7 30	9 30	10 30	1 30	1 30	1 30	3 30	5 00	3 30	3 30	6 30
Ar New York, N.Y. (PABT)	11 30	1 30	2 30	5 30	5 30	5 30	7 30	9 00	7 30	7 30	10 30
Lv Baltimore, Md. (7901)	8 00	8 00	12 30	1 25	1 25	1 25	1 25				7 00
Ar New York, N.Y. (PABT)	11 40	11 40	4 00	5 30	5 30	5 30	5 30				10 50
Lv Philadelphia, Pa. (7904)	8 30	11 00	12 01	3 35	3 35	3 35	5 30	7 00	7 30	8 00	8 00
Ar New York, N.Y. (PABT)	10 35	1 00	2 00	5 30	5 30	5 30	7 30	9 05	9 35	10 05	10 35
Lv New York, N.Y. (PABT)	12 01	2 00	5 00	6 45	7 00	7 00	s8 30	9 30	10 00	10 30	11 30
New York, N.Y. (GWBT)	12 25	2 25	5 25	7 15	7 30	7 30	s9 00	10 00	10 30	11 00	12 01
N.Y.-Conn. State Line Z			5 42	7 44	7 59	7 59					
Stamford, Conn. X						8 15					
Norwalk X						8 35					
Bridgeport X					8 35						
Ar New Haven, Conn. X		3 40	6 40	8 42	9 02		5-Star Extra Fare				
Lv New Haven, Conn. X		3 40	6 40	8 45	9 05						
Middletown X	2 00			9 26							
Ar Hartford, Conn. X		4 29	7 29	9 53	9 53	9 55					
Lv Hartford, Conn. X		4 35	7 35	10 00	10 00	10 00					
Conn.-Mass. St. Line Z		5 29	8 20	To	10 50	10 45					
Ar Worcester, Mass.	#3 30	5 50	8 45	Spring-		#11 10	s12 15		#1 40		
Lv Worcester, Mass.	3 45	5 50	8 50	field,		11 30	s12 15		2 10		
Framingham-Natick	To	6 25	9 25	Mass.	11 35	To	s12 50	1 30	To	2 30	3 30
Wellesley Hills	Hav-					Hav-			Hav-		
Ar Boston, Mass. (Pk. Sq.)	erhill	7 00	9 50		11 59	erhill	s1 15	1 55	erhill	2 55	3 55

PM READ DOWN

Run Numbers (ET) 7880	414	120 PWp	404	296 Note 2 FS	208	150 PBN	298 Note 2 FS	212	2300	252	602	222	216	220	328
Lv Washington, D.C. (7900)	7 30	7 30	8 30	8 30	9 30	9 30	10 30	10 30	11 30	12 30	12 30	1 30	3 30	6 30	6 30
Ar New York, N.Y. (PABT)	11 30	11 30	12 30	12 30	1 30	1 30	2 30	2 30	3 30	4 30	4 30	5 30	7 30	10 30	10 30
Lv Baltimore, Md. (7901)	7 00	7 00	9 00	9 00	9 00		11 00	11 00	12 01	12 01	12 01	2 00	3 00	6 15	6 15
Ar New York, N.Y. (PABT)	10 50	10 50	12 30	12 30	12 30		2 40	2 40	3 30	3 30	3 30	5 30	6 55	9 55	9 55
Lv Philadelphia, Pa. (7904)	9 30	9 30	9 30	11 00	11 00	12 01	12 01	1 00	2 00	2 30	2 30	2 30	6 00	8 30	8 30
Ar New York, N.Y. (PABT)	11 35	11 35	11 35	1 05	1 05	2 05	2 05	3 05	4 05	4 35	4 35	4 35	8 05	10 35	10 35
Lv New York, N.Y. (PABT)	12 01	12 30	1 00	•1 30	1 45	s2 30	•3 00	3 30	4 00	s5 00	5 30	6 00	8 30	11 00	11 00
New York, N.Y. (GWBT)	12 30	1 00	1 30	•2 00	2 15	s3 00	•3 30	4 00	4 30	s5 30	6 00	6 30	9 00	11 30	11 30
N.Y.-Conn. State Line Z	12 59				2 44		•3 59		4 59		6 29				
Stamford, Conn. X					3 00										
Norwalk X															
Bridgeport X															
Ar New Haven, Conn. X	1 57		2 57		3 47	5-Star Extra Fare	•4 57		5 57	5-Star Extra Fare			10 27		12 47
Lv New Haven, Conn. X	2 00		3 00		3 50		•5 00		6 00				10 30		12 50
Middletown X					4 31										
Ar Hartford, Conn. X					4 58		•5 48				8 05				1 38
Lv Hartford, Conn. X					5 00		•5 50				8 10				[illegible]
Conn.-Mass. St. Line Z	3 25				5 45		•6 40		7 30		8 55				To
Ar Worcester, Mass.	#3 50		4 40		6 10				7 35		9 20		12 10	2 20	Spring-
Lv Worcester, Mass.	4 20		5 00		6 10				8 45		9 40		12 10	2 25	field,
Framingham-Natick	To	4 30	To	•5 30	6 50	s6 30	•7 20	7 30		s9 00		10 00	D	D	Mass.
Wellesley Hills	Hav-		Hav-		7 00										
Ar Boston, Mass. (Pk. Sq.)	erhill	4 55	erhill	•5 55	7 25	s6 55	•7 45	7 55		s9 25		10 25	1 10	3 25	

BOSTON—WORCESTER—HARTFORD—NEW HAVEN—NEW YORK

AM READ DOWN

Run Numbers (ET) 7880	217	251	2301	601	205	207	101 PWP	601	151 PBN
Lv Boston, Mass. (Pk. Sq.)	12 01	s7 00			7 45	9 00	10 30	From	s11 30
Wellesley Hills								Manc-	
Framingham-Natick		s7 25			8 10	9 25	10 55	hester	s11 55
Ar Worcester, Mass.	1 00		7 55	9 30					
Lv Worcester, Mass.	1 30		8 25	9 45				11 35	
Conn.-Mass. State Line Z			8 40	10 11	8 55				5-Star Extra Fare
Ar Hartford, Conn. X				10 55	9 45				
Lv Hartford, Conn. X				11 00	9 45				
Middletown X									
Ar New Haven, Conn. X				11 48	10 33				
Lv New Haven, Conn. X				11 50	10 35				
Bridgeport, Conn. X									
Norwalk X									
Stamford, Conn. X					11 23				
N.Y.-Conn. State Line Z			10 34	12 48	11 32				
New York, N.Y. (GWBT)	4 05	s10 55	11 29	1 17	12 07	12 55	2 25	2 40	s3 25
Ar New York, N.Y. (PABT)	4 35	s11 25	11 59	1 47	12 37	1 25	2 55	3 10	s3 55
Lv New York, N.Y. (PABT)	x8 00	x12 01	x12 01	1 00	1 00	2 00	4 00	4 00	4 30
Ar Philadelphia, Pa. (7904)	x10 05	x2 00	x2 00	3 05	3 05	4 05	6 05	6 05	6 35
Lv New York, N.Y. (PABT)	x5 00	1 00	1 00	1 00	1 00	2 00	4 00	4 00	5 00
Ar Baltimore, Md. (7901)	x8 40	4 30	4 30	4 30	4 30	5 30	7 30	7 30	8 35
Lv New York, N.Y. (PABT)		x12 30	x12 30	1 30	1 30	2 30	3 30	3 30	4 30
Ar Washington, D.C. (7900)	x9 40	x4 30	x4 30	5 30	5 30	6 30	7 30	7 30	8 30

PM READ DOWN

Run Numbers (ET) 7880	299 Note 2 FS	411	211	417	213	117 PBN	215	107 PBN	253	413	121 PBN	415	219	119 PBN
Lv Boston, Mass. (Pk. Sq.)	•12 01	From	12 30		1 30	2 30	2 30	3 30	s4 30	From	6 00	From	8 15	9 15
Wellesley Hills		Hav-					2 55			Hav-		Hav-		
Framingham-Natick	•12 25	erhill	12 55		1 55	2 55	3 05	3 55	s4 55	erhill	6 25	erhill	8 40	9 40
Ar Worcester, Mass.				3 15			3 50							10 15
Lv Worcester, Mass.		1 55		3 30			3 50			5 30		8 00		10 15
Conn.-Mass. State Line Z	•1 10	2 20		3 55	2 45		4 15	4 45	5-Star Extra Fare				9 25	
Ar Hartford, Conn. X	•1 57						5 00					9 17	10 12	
Lv Hartford, Conn. X	•2 00						5 05					9 20	10 15	
Middletown X							5 32							
Ar New Haven, Conn. X	•2 48	3 43			4 05		6 13	6 05		7 18		10 08	11 03	
Lv New Haven, Conn. X	•2 50	3 45			4 10		6 15	6 10		7 20		10 10	11 05	
Bridgeport, Conn. X							6 42							
Norwalk X							7 07							
Stamford, Conn. X							7 22							
N.Y.-Conn. State Line Z	•3 48			5 50	5 08		7 37	7 08					12 03	
New York, N.Y. (GWBT)	•4 17	5 12	4 25	6 40	5 37	6 25	8 06	7 37	s8 25	8 47	9 55	11 37	12 32	1 25
Ar New York, N.Y. (PABT)	•4 47	5 42	4 55	7 10	6 07	6 55	8 36	8 07	s8 55	9 17	10 25	12 07	1 02	1 55
Lv New York, N.Y. (PABT)	5 30	6 00	5 30		6 30	8 00	9 00	9 00			12 15	2 30	2 30	2 30
Ar Philadelphia, Pa. (7904)	7 35	9 05	7 35		8 35	10 05	11 05	11 05			2 15	4 30	4 30	4 30
Lv New York, N.Y. (PABT)	7 00	7 00	7 00		7 00	9 00	9 00	9 00	10 30	10 30	12 15	5 00	5 00	5 00
Ar Baltimore, Md. (7901)	10 40	10 40	10 40		10 40	12 30	12 30	12 30	2 50	2 50	3 50	8 40	8 40	8 40
Lv New York, N.Y. (PABT)	5 30	6 30	5 30		6 30	7 30	9 30	8 30	9 30	10 30	11 30	2 30	2 30	2 30
Ar Washington, D.C. (7900)	9 30	10 30	9 30		10 30	11 30	1 30	12 30	1 30	2 30	3 30	6 30	6 30	6 30

PORTLAND—PORTSMOUTH—BOSTON—NEW YORK

READ DOWN

Run Numbers 7881 (ET) 10-28-73

Run Numbers			1701	101 PWp	151 PBN	1305	117 PBN	107 PBN	121 PBN	1903	119 PBN
			From Rochester, NH		5-Star via Maine Tpk. — Extra Fare	From Berlin, NH				From North Conway, NH	
*Portland, ME	YCTS	Lv		7 15	s 8 30		11 00	12 30	2 30		6 00
*Saco	Y			7 40			11 25	↓	2 55		6 25
*Biddeford	Y			7 43			11 28		2 58		6 28
*Kennebunk				7 57			11 42		3 15		6 42
*Wells Corner				8 06			11 51		3 27		6 51
Moody				8 10			11 55		3 33		6 55
*Ogunquit				8 14			11 59		3 38		6 59
Cape Neddick				8 21			12 06		3 45		7 06
York Corner, ME				8 25			12 10		3 50		7 10
*Portsmouth, NH			6 55	8 40	s 9 30	11 25	12 25	1 30	4 05	6 25	7 25
*Hampton			7 15	8 59		11 45				6 44	
Smithtown, NH			↓	↓	↓	↓	↓	↓	↓	↓	↓
Salisbury, MA	X										
*Amesbury	X						12 55				
*Newburyport	X										7 55
*Lynnfield	X		D	f		f	f	f	f	f	f
*Boston, MA	X	Ar	8 25	10 00	s10 45	12 45	1 50	2 45	5 20	7 45	8 50
Boston, MA (7880)		Lv	9 00	10 30	s11 30	*1 30*	2 30	3 30	6 00	*8 15*	9 15
Framingham Natick, MA		Ar	9 25	10 55	s11 55	*1 55*	2 55	3 55	6 25	*8 40*	9 40
Worcester, MA		Ar	↓	↓	↓	*x3 50*	↓	↓	↓	*x1015*	10 15
Hartford, CT		Ar				*x5 00*				*10 12*	↓
New Haven, CT		Ar				*4 05*		6 05		*11 03*	
New York, NY (GWBT) ▣		Ar	*12 55*	2 25	s 3 25	*5 37*	6 25	7 37	9 55	12 32	1 25
New York, NY (PABT)	CTS	Ar	*1 25*	2 55	s 3 55	*6 07*	6 55	8 07	10 25	1 02	1 55
Boston, MA	PPB	Lv	9 15	10 30	*12 01*	*1 15*	*2 15*	*3 15*	*6 30*	*8 30*	*9 30*
Springfield, MA	PPB	Ar	10 50	*1 15*	*2 00*	*2 50*	*4 25*	*5 00*	*8 15*	*11 00*	*11 05*

NEW YORK—BOSTON—PORTSMOUTH—PORTLAND

READ DOWN

Run Numbers 7881 (ET) 10-28-73

Run Numbers			114 PBN	1902	116 PBN	104 PBN	106 PBN	1700	1304	120 PWp	150 PBN
Springfield, MA	PPB	Lv	*3 15*	*7 15*	*8 15*	*10 15*	*1 15*	*2 15*	*3 15*	*3 15*	*5 15*
Boston, MA	PPB	Ar	*5 55*	*9 05*	*9 50*	*12 15*	*3 00*	*4 30*	*4 50*	*4 50*	*6 55*
New York, NY (PABT)	CTS	Lv	2 00	2 00	5 00	7 00	11 30	11 30	*12 30*	12 30	s 2 30
New York, NY (GWBT) ▣		Lv	2 25	2 25	5 25	7 30	12 01	*12 01*	*1 00*	1 00	s 3 00
New Haven, CT		Lv	3 40	3 40	6 40	9 05	↓	↓	↓	↓	↓
Hartford, CT		Lv	4 35	4 35	7 35	10 00					
Worcester, MA		Lv	5 50	5 50	8 50	↓					
Framingham Natick, MA		Lv	6 25	6 25	9 25	11 35	3 30	*3 30*	*4 30*	4 30	s 6 30
Boston, MA (7880)		Ar	7 00	7 00	9 50	11 59	3 55	*3 55*	*4 55*	4 55	s 6 55
*Boston, MA	X	Lv	7 45	8 45	10 30	1 00	4 15	5 00	6 00	6 00	s 7 30
*Lynnfield	X		8 05	9 05	10 50	1 20	↓	↓	6 20	6 20	
*Newburyport	X		8 35	↓	↓	↓			↓	↓	↓
*Amesbury	X		↓			1 55					
Salisbury, MA	X		f			↓					
Smithtown, NH			f								
*Hampton			8 49	9 45	11 30	↓	↓	6 11	↓	6 59	↓
*Portsmouth, NH			9 10	10 05	11 50	2 25	5 30	6 30	7 15	7 20	s 8 45
York Corner, ME			9 25	To North Conway, NH	12 06	2 40	↓	To Rochester, NH	To Berlin, NH	7 35	5-Star via Maine Tpk. — Extra Fare
Cape Neddick			9 29		12 10	2 44				7 39	
*Ogunquit			9 36		12 17	2 51				7 46	
Moody			9 40		12 21	2 55				7 50	
*Wells Corner			9 44		12 25	2 59				7 54	
*Kennebunk			9 53		12 34	3 08				8 03	
*Biddeford	Y		10 07		12 48	3 22				8 17	
*Saco	Y		10 10		12 51	3 25				8 20	
*Portland, ME	Y CTS	Ar	10 35		1 15	3 50	6 30			8 45	s 9 45

All trips operate daily unless otherwise noted.

Times shown in ITALICS indicate service via connecting trip or trips.

AM Light Face. **PM Bold Face.**

BOSTON - NASHUA - MANCHESTER - LITTLETON - COLEBROOK

10-28-73 READ DOWN

Run Numbers 7889 (ET)

Run Numbers			1404	1202	1204	1600	1802 Mon thru Fri	1400	602
New York, N.Y. (PABT)	CTS	Lv	5 00	7 00	9 30	10 30	*12 30*	*12 30*	5 30
New York, N.Y. (GWBT) ▣		Lv	5 25	7 30	10 00	11 00	*1 00*	*1 00*	6 00
New Haven, Conn.		Lv	6 40	9 05	↓	↓	↓	↓	↓
Hartford, Conn.		Lv	7 35	1000					8 10
Worcester, Mass.		Lv	8 50	↓					9 40
Framingham Natick, Mass.		Lv	9 25	1135	*1 30*	*2 30*	*4 30*	*4 30*	↓
Boston, Mass.		Ar	9 50	1159	*1 55*	*2 55*	*4 55*	*4 55*	
*Boston, Mass.	X	Lv	10 15	1215	2 15	3 30	5 15	6 00	
*Lowell, Mass.	X		11 00	↓	↓		↓	↓	10 50
*Nashua, N.H.			11 30	1 15	3 15		6 15	7 00	11 20
Thornton's Ferry			↓	f	↓	↓	↓	↓	↓
Merrimac				f					
Reeds Ferry				f					
*Manchester	Y	Ar	11 55	1 45	3 40	4 45	6 40	7 25	11 45
*Concord	Y	Ar	12 20	2 10	4 05	5 15	7 05	7 50	
*Franklin			12 52	2 42	4 37	5 47	Mon. thru Fri. Will not run Nov. 22, Dec. 25 and Jan. 1.	8 22	
*Tilton			12 58	2 48	4 43	5 53		8 28	
Winnisquam			1 06	2 56	4 51	↓		8 36	
*Laconia		Ar	1 13	3 03	4 58			8 43	
Lakeport			1 18					8 48	
Weirs (Stops on Rt. 3)			1 28					8 58	
*Meredith			1 37					9 07	
*Holderness			1 48					9 18	
*Ashland			1 53					9 23	
*Plymouth		Ar	2 05			6 23		9 35	
*Plymouth		Lv				6 43			
West Campton						6 53			
West Thornton						7 04			
Woodstock						7 10			
*North Woodstock						7 16			
The Flume						7 25			
Old Man of the Mtns.						7 30			
Aerial Tramway						7 35			
Franconia						7 43			
*Littleton		Ar				7 53			
*Whitefield						8 13			
*Lancaster						8 26			
*Groveton						8 41			
*No. Stratford						9 05			
*Colebrook, N.H.	CTS	Ar				9 23			

COLEBROOK - LITTLETON - MANCHESTER - NASHUA - BOSTON

10-28-73 READ DOWN

Run Numbers 7889 (ET)

Run Numbers			1803 Mon thru Fri	1201	601	1401	1603	1209	1403
*Colebrook, N.H.	CTS	Lv	Mon. thru Fri. Will not run Nov. 22, Dec. 25 and Jan. 1.				7 10		
*North Stratford							7 28		
*Groveton							7 52		
*Lancaster							8 05		
*Whitefield							8 20		
*Littleton		Lv					8 40		
Franconia							8 50		
Aerial Tramway							8 59		
Old Man of the Mtns.							9 03		
The Flume							9 13		
*North Woodstock							9 22		
Woodstock							9 28		
West Thornton							9 34		
West Campton							9 43		
*Plymouth		Ar					#9 53		
*Plymouth		Lv				8 10	10 08		4 20
*Ashland						8 20	↓		4 30
*Holderness						8 25			4 36
*Meredith						8 36			4 46
Weirs (Stops on Rt. 3)						8 45			4 55
Lakeport						8 55			5 05
*Laconia		Lv		6 40		9 00	10 53	3 30	5 10
Winnisquam				6 47		9 07	11 00	3 37	5 17
*Tilton				6 55		9 15	11 08	3 45	5 25
*Franklin				7 01		9 21	11 14	3 51	5 31
*Concord	Y	Lv	6 00	7 33		9 53	11 48	4 23	6 00
*Manchester	Y	Lv	6 20	8 00	9 30	10 20	12 25	4 50	6 25
Reeds Ferry			↓	↓	↓	↓	↓	f	↓
Merrimac								f	
Thornton's Ferry								f	
*Nashua, N.H.			6 50	8 25	9 55	10 45	12 50	5 20	6 50
*Lowell, Mass.	X		↓	↓	10 25	↓	↓	↓	7 15
*Boston, Mass.	X	Ar	8 00	9 25	↓	11 45	1 50	6 20	8 05
Boston, Mass. (7880)		Lv	9 00	10 30		*12 30*	*2 30*	*8 15*	*8 15*
Framingham Natick, Mass.		Ar	9 25	10 55		*12 55*	*2 55*	*8 40*	*8 40*
Worcester, Mass.		Ar	↓	↓	#1115	↓	*x3 50*	↓	*x1015*
Hartford, Conn.		Ar			↓		*x5 00*	*1012*	*10 12*
New Haven, Conn.		Ar					*6 13*	*1103*	*11 03*
New York, N.Y. (GWBT) ▣		Ar	*12 55*	*2 25*	2 40	*4 25*	*6 25*	1232	12 32
New York, N.Y. (PABT)	CTS	Ar	*1 25*	*2 55*	3 10	*4 55*	*6 55*	1 02	1 02

AMHERST—SPRINGFIELD—HARTFORD—NEW HAVEN—NEW YORK

READ DOWN

(ET) **7884** 10-28-73

Run Numbers →		301	303	331	205	307	323	401 ▼	309	311	313	299 Note 2 FS •	403	325	327	215	315	317	319	415	321	219	398 Note 1 Sun
So. Hadley, Mass. PPB	Lv		°6 20				°9 15				12 15			2 15			4 15				7 15		
Westover AFB PPB			°6 00				°9 35				12 30			2 35			4 35				7 35		
Springfield, Mass. PPB	Ar		°6 55				°10 00				1 00			3 00			5 00				8 00		
Boston, Mass. PPB	Lv				7 45				9 15		10 30	•12 01		1 15		2 30	3 15	4 15			6 30	8 15	
Springfield, Mass. PPB	Ar								10 50		1 15			2 50			5 00	5 50			8 20		
▲**Amherst, Mass.** PPB-CTS	Lv	①5 20		①7 05		①8 05	9 05	From Haverhill		①11 05	①12 05		1 00	2 05	3 05		①4 05	①5 05		From Haverhill	①7 50		§10 00
▲Northampton		①5 30		①7 20		①8 20	9 20			①11 20	①12 20		1 15	2 20	3 20		①4 20	①5 20			①8 05		§10 15
▲Holyoke		①5 45		①7 35		①8 35	9 35			①11 35	①12 35		1 30	2 35	3 35		①4 35	①5 35			①8 20		§10 30
▲**Springfield, Mass.** PPB-CTS	Ar	①6 00		①7 55		①8 55	9 55			①11 55	①12 55		#1 50	2 55	3 55		①4 55	①5 55			①8 40		§10 45
▲**Springfield, Mass.** CTS	Lv	6 15	7 15	8 15		9 15	10 15		11 15	12 15	1 15		2 15	3 15	4 15		5 15	6 15	7 15		9 15		§11 00
Conn.-Mass. State Line Z		6 22	7 22	8 22		9 22	10 22		11 22	12 22	1 22		2 22	3 22	4 22		5 22	6 22	7 22		9 22		§11 07
▲**Hartford, Conn.** X	Ar	6 47	7 47	8 47	9 42	9 47	10 47	10 55	11 47	12 47	1 47	•1 57	2 47	3 47	4 47	>5 00	5 47	6 47	7 47	9 17	9 47	10 12	§11 32
▲**Hartford, Conn.** X	Lv	6 50	7 50	8 50	9 45	9 50	10 50	11 00	11 50	12 50	1 51	•2 00	2 50	3 50	4 50	5 05	5 50	6 50	7 50	9 20	9 50	10 15	§11 35
▲Middletown X		7 17				10 17			12 17		2 17					5 32					10 17		
▲**New Haven, Conn.** X	Ar	7 58	8 38	9 38	10 33	10 58		11 48	12 58		2 58	•2 48	3 38	4 38		6 13	6 38	7 38	8 38	10 08	10 58	11 03	
▲**New Haven, Conn.** X	Lv	8 00	8 40	9 40	10 35	11 00		11 50	1 00		3 00	•2 50	3 40	4 40		6 15	6 40	7 40	8 40	10 10	11 00	11 05	
▲Bridgeport X																6 42							
▲Norwalk X																7 07							
▲Stamford, Conn. X					11 23											7 22							
N.Y.-Conn. State Line Z		8 58	9 38	10 38	11 38	11 58	12 02	12 48	1 58	2 02	3 58	•3 48	4 38	5 38	6 02	7 37	7 38	8 38	9 38	11 08	11 58	12 03	a1 11
▲**New York, N.Y.** (GWBT) ▣		9 27	10 07	11 07	12 07	12 27	12 55	1 17	2 27	2 55	4 27	•4 17	5 07	6 07	6 55	8 06	8 07	9 07	10 07	11 37	12 27	12 32	a1 40
▲**New York, N.Y.** (PABT) CTS	Ar	9 57	10 37	11 37	12 37	12 57	1 25	1 47	2 57	3 25	4 57	•4 47	5 37	6 37	7 25	8 36	8 37	9 37	10 37	12 07	12 57	1 02	a2 05

NEW YORK—NEW HAVEN—HARTFORD—SPRINGFIELD—AMHERST

READ DOWN

(ET) **7884** 10-28-73

Run Numbers →		400	114	102	302	104	324	326	304	306	308	208	310	408	298 Note 2 •FS	312	399 Note 1 Sun	314	316 ▼	318	320	322	328
▲**New York, N.Y.** (PABT) CTS	Lv	12 01	2 00	5 00	6 45	7 00	9 00	10 00	11 00	12 01	1 00	1 45	2 00	3 00	•3 00	4 00	§5 00	5 00	6 00	7 00	8 00	9 00	11 00
▲**New York, N.Y.** (GWBT) ▣		12 25	2 25	5 25	7 15	7 30	9 30	10 30	11 30	12 30	1 30	2 15	2 30	3 30	•3 30	4 30	§5 30	5 30	6 30	7 30	8 30	9 30	11 30
N.Y.-Conn. State Line Z			3 15	5 42	7 44	7 53	9 59	11 20	11 59	1 20	2 20	2 44	2 59	3 59	•3 59	5 20	§5 59	5 59	6 59	7 59	9 20	9 59	11 59
▲Stamford, Conn. X												3 00											
▲Norwalk X																							
▲Bridgeport X						8 35																	
▲**New Haven, Conn.** X	Ar		3 40	6 40	8 42	9 02	10 57		12 57			3 47	3 57	4 57	•4 57			6 57	7 57	8 57		10 57	12 47
▲**New Haven, Conn.** X	Lv		3 40	6 40	8 45	9 05	11 00		1 00			3 50	4 00	5 00	•5 00			7 00	8 00	9 00		11 00	12 50
▲Middletown X		2 00			9 21				1 41			4 31						7 36		9 36			
▲**Hartford, Conn.** X	Ar		4 29	7 29	9 48	9 53	11 48	12 35	2 10	2 35	3 35	4 58	4 40	5 48	•5 48	6 35		8 03	8 48	10 03	10 35	11 48	1 38
▲**Hartford, Conn.** X	Lv		4 35	7 35	9 55 ←→	10 00	11 50	12 40	2 15	2 40	3 40	5 00	4 50	5 50	•5 50	6 40		8 05	8 50	10 05	10 40	11 50	1 40
Conn.-Mass. State Line Z					10 20		12 15	1 05	2 40	3 05	4 05		5 15	6 15		7 05	§7 53	8 30	9 15	10 30	11 05	12 15	2 05
▲**Springfield, Mass.** CTS	Ar	To Haverhill		Via Worcester	10 27		12 22	1 12	2 47	3 12	4 12		5 22	*6 22		7 12	§8 00	8 37	9 22	10 37	11 12	12 22	2 12
▲**Springfield, Mass.** PPB-CTS	Lv				①10 35		12 30	1 30	①3 15	①4 35	①4 35		①6 10	6 45		①7 30	§8 05	①8 45	①9 45	①11 30	①11 30		
▲Holyoke					①10 50		12 45	1 45	①3 30	①4 50	①4 50		①6 25	7 05		①7 45	§8 20	①9 05	①10 00	①11 45	①11 45		
▲Northampton					①11 05		1 00	2 00	①3 45	①5 05	①5 05		①6 40	7 20		①8 00	§8 35	①9 20	①10 25	①11 59	①11 59		
▲**Amherst, Mass.** PPB-CTS	Ar				①11 25		1 20	2 20	①4 05	①5 25	①5 25		①7 00	7 35		①8 20	§8 55	①9 30	①10 35	①12 20	①12 20		
Springfield, Mass. PPB	Lv						1 15	2 15	3 15	5 15	5 15		6 15	•7 30		9 05		9 05					3 15
Boston, Mass. PPB	Ar		7 00	9 50		11 59	3 00	4 30	4 50	6 50	6 50	7 25	8 00	•9 45	•7 45	11 20		11 20					5 40
Springfield, Mass. PPB	Lv				11 15		1 15		3 15				6 30			‡8 30		8 50	‡10 00		11 30		
Westover AFB	Ar				11 40		1 40		3 40				6 55			‡8 55		10 15	‡10 25		11 55		
So. Hadley, Mass. PPB	Ar				11 59		2 00		4 00				7 15			‡9 15		10 00	‡10 45				

BOSTON—ROCHESTER—NORTH CONWAY—BERLIN

10-28-73 READ DOWN

(ET) **7887**

Run Numbers →			1902 ▼	1700	1304
New York, N.Y. (PABT) CTS		Lv	2 00	11 30	12 30
New York, N.Y. (GWBT) ▣		Lv	2 25	12 01	1 00
New Haven, Conn.		Lv	3 40		
Hartford, Conn.		Lv	4 35		
Worcester, Mass.		Lv	5 50		
Framingham-Natick, Mass.		Lv	6 25	3 30	4 30
Boston, Mass. (7880)		Ar	7 00	3 55	4 55
▲**Boston, Mass.**	X	Lv	8 45	5 00	6 00
▲Lynnfield, Mass.	X		9 05		6 20
▲**Hampton, N.H.**			9 45	6 11	
▲**Portsmouth, N.H.**			10 05	6 30	7 15
▲**Dover, N.H.**			10 30	6 52	7 37
▲**Rochester**			10 50	7 17	7 54
▲Farmington			11 02		8 06
▲New Durham			11 12		8 16
▲Alton			11 17		8 21
▲**Wolfeboro**			11 32		8 36
Allen A. (Resort)			11 37		8 40
Ossipee			11 45		8 49
▲**Center Ossipee**			11 55		8 59
W. Ossipee			12 05		9 09
▲Chocorua			12 11		9 15
▲Conway			12 25		9 29
▲**N. Conway**		Ar	12 35		9 39
Glen					9 48
▲Jackson (Rt. #16)					9 52
Dana Place					f
Wildcat Mtn.					f
Pinkham Notch (A.M.C.)					10 04
Glen House					10 09
▲Gorham					10 20
▲**Berlin, N.H.**		Ar			10 30

BERLIN—NORTH CONWAY—ROCHESTER—BOSTON

10-28-73 READ DOWN

(ET) **7887**

Run Numbers →			1701	1305	1903
▲**Berlin, N.H.** CTS		Lv		8 00	
▲Gorham				8 10	
Glen House				8 21	
Pinkham Notch (A.M.C.)				8 26	
Wildcat Mtn.				f	
Dana Place				f	
▲Jackson (Rt. #16)				8 38	
Glen				8 42	
▲**North Conway**		Ar		8 51	3 51
▲Conway				9 01	4 01
▲Chocorua				9 15	4 15
West Ossipee				9 21	4 21
▲**Center Ossipee**				9 31	4 31
Ossipee				9 41	4 41
Allen A. (Resort)				9 50	4 50
▲**Wolfeboro**				9 54	4 54
▲Alton				10 09	5 09
▲New Durham				10 14	5 14
▲Farmington				10 24	5 24
▲**Rochester**			6 10	10 36	5 36
▲**Dover**			6 30	10 58	5 58
▲**Portsmouth, N.H.**			6 55	11 25	6 25
▲**Hampton, N.H.**			7 15	11 45	6 44
▲Lynnfield, Mass.	X		D	f	f
▲**Boston, Mass.**	X	Ar	8 25	12 45	7 45
Boston, Mass. (7880)		Lv	9 00	1 30	8 15
Framingham-Natick, Mass.		Ar	9 25	1 55	8 40
Worcester, Mass.		Ar		x3 50	x10 15
Hartford, Conn.		Ar		x5 00	10 12
New Haven, Conn.		Ar		4 05	11 03
New York (GWBT), *N.Y.* ▣		Ar	12 55	5 37	12 32
New York (PABT), *N.Y.* CTS		Ar	1 25	6 07	1 02

NEW YORK—WORCESTER—LOWELL—MANCHESTER

READ DOWN

(ET) **7882** 10-28-73

Run Numbers →		400 ▼	114	116	1404	402	250 ♛	412	414	404	208	408	2300 ▼	602 ▼	216	220	328
			To Portland	To Portland	From Boston		Five Star Luxury Service Extra Fare; To Boston				To Boston				To Boston	To Boston	
▲**New York, N.Y.**(PABT)	**CTS** Lv	12 01	2 00	5 00		7 00	•8 30	10 00	12 01	1 00	1 45	3 00	4 00	5 30	8 30	11 00	11 00
▲**New York, N.Y.**(GWBT)	▣	12 25	2 25	5 25		7 30	•9 00	10 30	12 30	1 30	2 15	3 30	4 30	6 00	9 00	11 30	11 30
N.Y.-Conn. State Line	Z	12 54	2 54	5 42		7 59	•9 29	10 59	12 59	2 05	2 44	3 59	4 59	6 29	9 29	11 59	11 59
▲Stamford, Conn.	X					8 15											
▲Norwalk	X					8 30											
▲Bridgeport	X																
▲**New Haven, Conn.**	X Ar		3 40	6 40					1 57	2 57	3 42	4 57	5 57		10 27		12 47
▲**New Haven, Conn.**	X Lv		3 40	6 40					2 00	3 00	3 45	5 00	6 00		10 30		12 50
▲Middletown	X	2 00									4 26						
▲**Hartford, Conn.**	X Ar		4 29	7 29		9 55					4 53	5 48		8 05			1 38
▲**Hartford, Conn.**	X Lv		4 35	7 35		10 00					4 55	5 50		8 10			1 40
Conn.-Mass. State Line	Z											6 15					2 05
▲**Springfield, Mass.**	Ar											6*22					2 12
▲**Springfield, Mass.**	Lv											6 45					
▲Holyoke												7 05					
▲Northampton												7 20					
▲**Amherst**												7 35					
Pelham												7 48					
New Salem												8 00					
▲Orange												8 10					
Athol												8 20					
▲Gardner												8 43					
Conn.-Mass. State Line (UN)	Z	3 10	5 29	8 20		10 45	•11 50	1 15	3 25	4 15	5 40		7 30	8 55	11 45	1 55	
▲**Worcester, Mass.**	Ar	3 30	5 50	8 45		11*10	•12 15	1 40	3*50	4*40	6 05		7 55	9 20	12 10	2 20	
▲**Worcester, Mass.**	Lv	3 45	5 50	8 50		11 30	•12 15	2 10	4 20	5 00	6 05		8 15	9 40	12 10	2 20	
West Boylston		f				11 48		2 28		5 15			8 30				
Sterling		f				11 55		2 35		5 22			8 37				
Leominster		f				12 08		2 48		5 35			8 50				
▲**Fitchburg**		4 20				12 20		3 00		5 45		9 07	◄9 00				
Lunenburg		f				12 30		3 10		5 55		9 16					
Clinton																	
South Lancaster																	
Lancaster																	
Still River																	
Harvard																	
Fort Devens (Main P.X.)		f															
▲**Ayer** (Fort Devens)	Ar	4 45				12 45		3 25		6 10		9 30		10 25			
▲**Ayer** (Fort Devens)	Lv	4 45				12 45		3 25		6 10		9 30		10 25			
Littleton Common								3 35									
Chelmsford								3 45									
▲**Lowell**	Y	5 10			11 10	1 20		4 00	5 10	6 35		9 55		10 50			
▲**Lawrence**	Y	5 35				1 45		4 25	5 35	6 50		10 15					
▲**Haverhill**	Y Ar	5 55				2 05		4 45	5 55	7 10		10 35					
▲**Nashua, N.H.**					11 37									11 20			
▲**Manchester, N.H.**	Ar				11 55									11 45			

MANCHESTER—LOWELL—WORCESTER—NEW YORK

READ DOWN

(ET) **7882** 10-28-73

Run Numbers →		217	2301 ▼	401 ▼	601	403	411	417 ▼	215	413	415	1403	119
		From Boston							From Boston			To Boston	From Portland
▲**Manchester, N.H.**	**CTS** Lv				9 30							6 30	
▲**Nashua, N.H.**					9 55							6 55	
▲**Haverhill, Mass.**	Y Lv			7 00		9 45	11 00	1 45		2 45	5 20		
▲**Lawrence**	Y			7 15		10 00	11 15	2 00		3 00	5 35		
▲**Lowell**	Y			7 40	10 25	10 25	11 40	2 25		3 25	6 00	7 20	
Chelmsford										3 35			
Littleton Common										3 44			
▲**Ayer** (Fort Devens)	Ar			8 15		10 50	12 10			3 59	6 25		
▲**Ayer** (Fort Devens)	Lv			8 15		10 50	12 10			4 00	6 25		
Harvard													
Still River													
Lancaster													
Lunenburg				8 31		11 06	12 26			4 16	6 41		
▲**Fitchburg**			7 00	8 40		11 15	12 35			4 25	6 50		
Leominster			7 12	8 52			12 47			4 37	7 02		
Sterling			7 24	9 05			1 00			4 50	7 15		
West Boylston			7 37	9 12			1 07			4 57	7 22		
▲**Worcester, Mass.**	Ar	1 00	7*50	9*30	11*15		1 25	3 15	3 50	5 15	7*40		10 15
▲**Worcester, Mass.**	Lv	1 00	8 15	9 45	11 30		1 55	3 30	3 50	5 30	8 00		10 15
Conn.-Mass. State Line (UN)	Z	1 25	8 45	10 10	11 55		2 20	3 55	4 15	5 55	8 25		10 40
▲Gardner						11 45							
Athol						12 15							
▲Orange						12 25							
New Salem						12 35							
Pelham						12 47							
▲**Amherst**						1 00							
▲Northampton						1 15							
▲Holyoke						1 30							
▲**Springfield, Mass.**	Ar					1*50							
▲**Springfield, Mass.**	Lv					2 15							
Conn.-Mass. State Line	Z					2 22							
▲**Hartford, Conn.**	X Ar			10 55		2 47			5 00		9 17		
▲**Hartford, Conn.**	X Lv			11 00		2 50			5 05		9 20		
Middletown	X								5 32				
▲**New Haven, Conn.**	X Ar			11 49		3 38	3 43		6 13	7 18	10 08		
▲**New Haven, Conn.**	X Lv			11 50		3 40	3 45		6 15	7 20	10 10		
▲Bridgeport, Conn.	X								6 42				
▲Norwalk, Conn.	X								7 07				
▲Stamford, Conn.	X								7 22				
N.Y.-Conn. State Line	Z	3 20	10 34	12 48	1 50	4 38	4 43	5 50	7 37	8 18	11 08		12 35
▲**New York, N.Y.**(GWBT)	▣	4 05	11 29	1 17	2 40	5 07	5 12	6 40	8 06	8 47	11 37		1 25
▲**New York, N.Y.**(PABT)	Ar	4 35	11 59	1 47	3 10	5 37	5 42	7 10	8 36	9 17	12 07		1 55

REFERENCE MARKS

(ET)—Eastern Time.
ExS or †—Daily except Sunday.
Sun or §—Sunday only.
Mon or a—Monday only.
Fri or e—Friday only.
Sat or k—Saturday only.
FS or •—Friday and Sunday only.
FSS or ÷—Friday, Saturday and Sunday.
DS or ;—Daily except Saturday.
SH or ‡—Sundays and Holidays.
Sa-Mo or 5—Saturday and Monday only.
ESH or —Daily except Sundays and Holidays.
FSSM—Friday, Saturday, Sunday and Monday only.
x—Via Connection.
*—Rest stop.
•—Change bus.
f—Flag stop.
Ar—Arrive.
Lv—Leave.

• or ♛ **5-Star Limited Service, Extra Fare, Reservations.**
s—Complimentary food service.
▲—Agency station to which baggage may be checked and to which prepaid, collect and C.O.D. express may be shipped.
D—Will stop to discharge passengers.
X, Y—No local passengers between points marked with same letters.
Z—Passengers cannot be picked up or discharged at Conn. State Line.
ALL—Acadian Lines.
CTS—Continental Trailways.
MKB—MacKenzie Bus Line Ltd.
PPB or ⊤—Peter Pan Bus Lines.
VT—Vermont Transit.
(GWBT)—George Washington Bridge Terminal.
(PABT)—Port Authority Bus Terminal.
▼—Indicates change since last issue.
▣—This terminal also serves Bronx, N.Y., Fort Lee, N.J., and Englewood, N.J.
+—Fridays, Sundays and Holidays.
●—Prince of Fundy Line.
Note 1—**Will also** operate Dec. [illegible] and Jan. 1.
Note 2—**Will also** operate Nov. [illegible], Dec. [illegible] and Jan. 1.

THRU SERVICE

PBN—**ThruLiner** between Portland, Boston and New York.
PWp—**ThruLiner** between Portland, Maine and Williamsport, Pa.

All trips operate daily unless otherwise noted.

Times shown in ITALICS indicate service via connecting trip or trips.

AM—Light Face. **PM—Bold Face.**