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Proving Ground Comparison of M.A.N. Methanol and Diesel Transit Buses

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EXECUTIVE SUMMARY

This is the first of a series of proving ground comparisons of methanol demonstration and diesel control transit buses. These were cold and warm weather tests of three methanol-fueled and three diesel-fueled M.A.N. transit buses taken from revenue service at Seattle Metro.

The first test was a new driveability test structured to evaluate abnormal responses of the bus propulsion systems in a carefully controlled environment. The second test was an acceleration and gradeability test to compare the performance of the demonstration and control buses. The third test was to compare the interior and exterior noise of the six buses under several different operating conditions.

The tests compared mature diesel engine technology with recently developed methanol engine technology and reflect the current state of development of one manufacturer's methanol-fueled bus. In the driveability test, the cold starting characteristics of the methanol engine were very poor during the January tests and better but not completely satisfactory in August when the temperature was 24°F higher. There was some hesitation and stumble during acceleration of the methanol buses while the driveability of the diesel buses was almost flawless. It should be noted that the buses were tested as equipped for revenue service. The diesel buses were equipped with air starters and fluid starting aids. The methanol buses were equipped with electric starters and during the January tests ether was sprayed into the engine air intakes before the buses started.

In the acceleration and gradeability tests, the average times required for the methanol and diesel buses to reach a speed of 50 mph were almost equal and the gradeabilities of the demonstration and control buses were virtually equal.

In the noise tests, the methanol buses had higher average noise levels than the diesel buses in all three interior noise tests and in the exterior idle and pull-away tests. However, the differences were so small that they should not be important to anyone purchasing transit buses.

PROVING GROUND COMPARISONS
OF M.A.N. METHANOL AND DIESEL TRANSIT BUSES

1.0 BACKGROUND

The Urban Mass Transportation Administration (UMTA) Methanol Bus Demonstration Program was established to develop information concerning safety, cost of ownership, maintainability, public health, and reliability issues arising from the operation of methanol fueled transit buses. It is anticipated that seven transit agencies will participate in the demonstration program with a total of 59 methanol buses. The first U.S. transit agency with methanol buses completely integrated into their diesel fleet and operating daily on regular scheduled routes is Seattle Metro with ten 40-foot M.A.N. methanol buses operating out of Ryerson Base. Seattle Metro also has M.A.N. diesel buses operating out of the same base and data on revenue operations are being collected to compare the 10 methanol buses with 10 diesel control buses.

UMTA recognized that some of the information needed to complete the comparison of the methanol and diesel buses could best be obtained under carefully controlled test conditions at a proving ground. Even though passenger and driver surveys document feelings and opinions on subjects like noise, performance or acceleration, and driveability, a need for test data in these areas was recognized.

2.0 INTRODUCTION

The purpose of these tests was to compare three methanol test buses from the demonstration fleet and three diesel control buses under carefully controlled proving ground conditions. It is important to recognize that these test results are not conclusive on the general acceptability of methanol buses for transit service. The tests compare mature diesel engine technology with more recently developed methanol engine technology and are limited to buses and propulsion systems produced by one manufacturer.

The buses were tested for interior and exterior noise, acceleration and gradeability, and driveability. The acceleration and gradeability tests are measures of performance which are sometimes confused with driveability. Performance measures are acceleration, gradeability, and top speed. Driveability measures are startability, quality of idle, frequency of stalls, and the severity and frequency of hesitation, stumble, surge and backfire.

Two series' of tests were performed. The first was January 30 and 31, 1988, to obtain data during typically cool ambient temperatures at the demonstration site. The second was August 13 and 14, 1988, to obtain data during warm weather.

Future tests will be performed at other demonstration sites such as Southern California Rapid Transit District and the Denver Regional Transit District. These future tests will be of buses and engines produced by a different manufacturer and will be performed during seasons of extremely hot and cold temperature at the demonstration sites.

3.0 PROGRAM PARTICIPANTS AND SUPPORTERS

UMTA, through the Office of Technical Assistance and Safety, was responsible for the technical direction of the program. Battelle Columbus Division (BCD) was responsible for developing the test procedures, and planning, coordinating and conducting the tests. The test staff included personnel from BCD, Transportation Research Center of Ohio, the PACCAR Technical Center, and Seattle Metro.

The important support of Seattle Metro included providing buses and drivers for the tests as well as the maintenance and support staff needed to prepare for the tests and to complete the tests according to very ambitious time schedules.

4.0 OVERVIEW OF THE TESTS

The nonrevenue tests were developed for the following three comparisons of the test methanol-fueled transit buses and the control diesel-fueled transit buses.

- Driveability
- Acceleration and Gradeability
- Interior and Exterior Noise

By conducting the cold weather and warm weather comparisons with six intervening months it was also possible to compare the effects of continuing use, time, and temperature on both the methanol and diesel buses. All of the tests are based on tests that have been performed on highway vehicles. The test plans and procedures were developed with a number of objectives in mind.

The first objective was to accurately compare the methanol and diesel buses under carefully controlled test conditions. This would require that the primary and possibly only significant variable in the tests be related to the engine, its auxiliaries, and the fuel system.

The second objective was to test the buses with the same level of servicing and preparation for operation that they receive before use in revenue service. This objective was achieved.

The third objective was to make the tests simple, requiring a minimum of instrumentation and no modifications to the bus. This was important to Seattle Metro and will be important to other transit operators in the future, since removing 6 buses from revenue service for extended periods could be difficult. Seattle Metro provided all staff for loading, maintaining, and operating the buses during the tests as will the transit operators at other methanol bus demonstration sites.

The fourth objective was to have test procedures that can be used at all methanol bus demonstration locations. The PACCAR Technical Center proving ground facilities were excellent and permitted running all tests according to the procedures as written. It is anticipated that tests at other methanol bus program demonstration sites will be performed at less appropriate facilities and that changes in procedural detail will be required. The procedures were prepared with this in mind so they can be adapted to different test locations without compromising the quality of the bus comparisons at those sites. The change in procedures between demonstration sites is acceptable because there should be no comparison between buses at different locations operating in different environments.

4.1 Test and Control Bus Selection

The three methanol test buses and three diesel control buses were selected from among very similar M.A.N. methanol and diesel buses. The six buses were selected after reviewing revenue service data on maintenance, accidents, and oil consumption. None of the buses selected had been in an accident, had an engine changed out, or had excessive oil consumption. The buses were selected from among the ten methanol buses and the ten control buses that are the subject of revenue service data analysis in the Methanol Bus Demonstration Program. There were no accidents or major maintenance actions during the six months between the cool-weather and warm-weather comparisons that precluded use of the same six buses for both comparisons.

The specifications of the methanol and diesel buses are shown in Appendix A. The differences between the methanol and diesel buses are shown in Table 4.1.

An important difference between the two buses is that the diesel buses have air starters and fluid starting aid systems while the methanol buses have electric starters with no fluid starting aids. Ether was sprayed into the engine air intake for cold starting of the methanol buses during the January tests but was not used during August.

The buses selected for use in these comparative tests are identified in Table 4.2. The differences in accumulated mileage in January reflect the differences in dates of delivery of the methanol and diesel buses to Seattle Metro.

The accumulated mileage in August shows that all six buses had similar amounts of use during the six months.

4.2 Test Site

All nonrevenue comparisons of the methanol and diesel buses were performed at the PACCAR Technical Center located near Mount Vernon, WA, about 70 miles north of Seattle. The high-speed test track and the skid test pad were used.

The high-speed test track has two 15-foot wide lanes and is 1.6 miles long. The inner lane is superelevated 12 percent and the outer lane is superelevated 29 percent at the turns for heavy vehicle operation at speeds up to more than 70 mph. The skid test pad adjacent to the high-speed track was used for noise testing. These facilities were excellent and PACCAR provided outstanding support during the tests.

TABLE 4.2 SEATTLE METRO BUSES USED IN COMPARISON OF METHANOL AND DIESEL BUSES

Bus Number	Schedule Identification	Mileage, January	Mileage, August
3151	T_1 (Methanol Test Bus)	23,280	50,470
3155	T_2	24,770	50,690
3157	T_3	24,340	49,320
3137	C_1 (Diesel Control Bus)	62,450	89,060
3142	C_2	47,020	70,680
3144	C_3	63,790	87,140

TABLE 4.1 DIFFERENCES BETWEEN METHANOL AND DIESEL BUS SPECIFICATIONS

	Methanol Bus	Diesel Bus
Engine Type	4 Stroke Spark Ignition	4 Stroke Diesel
Fuel Injector	2683 - 2799 psi, 0.036 Spray Hole Diameter	3480 - 3596 psi, 0.029 Spray Hole Diameter
Fuel Pumps	One Electrical One Mechanical	One Mechanical
Fuel Type	Neat Methanol	#2 Diesel
Fuel Capacity	250 Gallons	125 Gallons
Fuel Vent Flame Arrestor	Yes	No
Starter	Electrical	Air
Curb Weight	28,740 lb.	27,800 lb.
Seated Load Weight	35,340 lb.	34,400 lb.
Ether Starting System	No	Yes

4.3 Test Schedules

The detailed test schedules for January and August are shown in Appendix B. The schedules were structured to complete testing in two days (weekends) when Seattle Metro had less need for the buses and when PACCAR had the test facility available for use. During January when noise comparisons were made, the schedule was very difficult to maintain. The August comparison when no noise tests were performed and when all tests were performed at seated load weight was less demanding from a time standpoint.

In the test schedules and throughout the remainder of this report, the test buses are the methanol buses and the control buses are the diesel buses. The bus numbers and their schedule identifications are shown in Table 4.2.

5.0 DRIVEABILITY

The driveability test was structured to identify and evaluate abnormal responses of the bus propulsion systems in a carefully controlled environment. The driveability test did not include measurement of performance characteristics such as acceleration and gradeability.

5.1 Driveability Test Plan and Procedure

The driveability test is a new test for buses and was developed expressly for comparing methanol and diesel transit buses. The test is based on procedures developed by the Coordinating Research Council (CRC) to investigate the effect of alcohol fuel on the driveability of twenty-eight 1986 model-year cars and light trucks. Tests similar to these using the CRC procedures have been used for years by passengers car vehicle and engine manufacturers. However, this type of test has not been performed on heavy-duty diesel vehicles according to responsible engineers and managers at CRC.

The "Transit Bus Driveability" test procedure and "Bus Driveability Data Sheets" are in Appendix C. The procedure rates vehicles by assigning demerits based on a grading system described under the next heading.

All driveability tests in this series were performed by the same driver and same observer. This is important because some of the scoring of the driveability tests are subjective. Malfunctions discerned only by the driver were recorded as a trace (T) and malfunctions also noticeable to the observer were recorded as moderate (M). There were no heavy (H) severity malfunctions.

5.2 Driveability Test Results

The driveability test results are separated into 2 groups; those that were not used to calculate the weighted demerits of the test and control buses and those that were used in calculating the demerits. In both cases, the data is related to the steps listed in Appendix C.

The driver in all tests was Ron Dunn who has been driving transit buses at Seattle Metro for 11 years, two of the years including duty as a driving instructor. The observer was Gerald A. Francis who has 37 years of engineering experience with the most recent 10 years in bus and heavy truck research and engineering.

Important information from the data sheets that is not included in the calculation of demerits is shown in Tables 5.1 and 5.2. The tables show that the weather for all tests was excellent. The differences in ambient temperature for tests between the two seasons ranged from 16° to 30°F. The tables also show the considerable cranking time required for cold starting the methanol buses, especially at the lower temperatures. All methanol bus cold starts in January required spraying ether into the engine air intake during at least one cranking period. All six methanol buses started satisfactorily after sustained operation. The data from Steps 5, 6, and 7 on idle roughness after a cold start are not included in the weighted demerits because this roughness does not effect the quality of transit service or bus reliability.

A numerical value for driveability during the test was obtained by assigning demerits to operating malfunctions as shown in Table 5.3. Depending upon the type of malfunction, demerits were assigned in various ways. Demerits for poor starting were obtained by subtracting 3 seconds from the measured starting (cranking) time. There were no stalls during the tests.

TABLE 5.1 SUMMARY OF DRIVEABILITY TEST DATA ON METHANOL TEST BUSES

BUS NO. 3151 (T_1)

Date: January 30, 1988 Time: 8:45 a.m.

Temperature: 41°F Relative Humidity: 72 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time,	sec.:	7.29
Second Cranking Time,	sec.:	13.39
Third Cranking Time,	sec.:	21.56 (E)*
Total		42.24

Steps 5, 6, and 7

Trace of Idle Roughness in Both "Neutral" and "Drive"

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 2.00

BUS NO. 3151 (T_1)

Date: August 13, 1988 Time: 8:17 a.m.

Temperature: 57°F Relative Humidity: 61 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time, sec.: 7.08

Steps 5 and 6

Trace of Idle Roughness in "Neutral"

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 2.00

*Ether was sprayed into engine air intake

TABLE 5.1 SUMMARY OF DRIVEABILITY TEST DATA ON METHANOL TEST BUSES (CONTINUED)

BUS NO. 3155 (T_2)

Date: January 30, 1988 — Time: 11:30 a.m.

Temperature: 40°F — Relative Humidity: 72 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time,	sec.:	7.56
Second Cranking Time,	sec.:	3.07
Third Cranking Time,	sec.:	5.00 (E)
Fourth Cranking Time,	sec.:	2.53 (E)
Total		18.16

Steps 5, 6, and 7

Trace of Idle Roughness in Both "Neutral" and "Drive"

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 0.80

Bus No. 3155 (T_3)

Date: August 13, 1988 — Time: 11:50 a.m.

Temperature: 63°F — Relative Humidity: 35 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time, sec.: 5.01

Step 7.

Trace of Idle Roughness in "Drive"

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 1.03

TABLE 5.1 SUMMARY OF DRIVEABILITY TEST DATA ON METHANOL TEST BUSES (CONTINUED)

BUS NO. 3157 (T3)

Date: January 31, 1988 Time: 9:53 a.m.

Temperature: 30°F Relative Humidity: 28 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time,	sec.:	14.26
Second Cranking Time,	sec.:	16.61
Third Cranking Time,	sec.:	2.34 (E)
Total		33.21

Steps 5, 6, and 7

Trace of Idle Roughness in Both "Neutral" and "Drive"

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 0.54

BUS NO. 3157 (T3)

Date: August 14, 1988 Time: 9:54 a.m.

Temperature: 60°F Relative Humidity: 46 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time, sec.: 7.62

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 1.14

TABLE 5.2 SUMMARY OF DRIVEABILITY TEST DATA ON DIESEL CONTROL BUSES

BUS NO. 3137 (C_1)

Date: January 30, 1988 | Time: 9:50 a.m.

Temperature: 41°F | Relative Humidity: 72 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time, sec.: 0.78

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 0.15

BUS NO. 3137 (C_1)

Date: August 13, 1988 | Time: 9:37 a.m.

Temperature: 59°F | Relative Humidity: 47 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time, sec.: 1.21

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 1.57

BUS NO. 3142 (C_2)

Date: January 31, 1988 | Time: 11:47 a.m.

Temperature: 32°F | Relative Humidity: 29 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time, sec.: 1.29

TABLE 5.2 SUMMARY OF DRIVEABILITY TEST DATA ON DIESEL CONTROL BUSES (CONTINUE)

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 0.94

BUS NO. 3142 (C_2)

Date: August 14, 1988 Time: 11:10 a.m.

Temperature: 59°F Relative Humidity: 51 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time, sec.: 0.01

Step 8. Maneuver

Trace of Hesitation During Acceleration

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 0.01

BUS NO. 3144 (C_3)

Date: January 31, 1988 Time: 9:05 a.m.

Temperature: 29°F Relative Humidity: 31 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time, sec.: 1.48

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 0.01

TABLE 5.2 SUMMARY OF DRIVEABILITY TEST DATA ON DIESEL CONTROL BUSES (CONTINUE)

BUS NO. 3144 (C_3)

Date: August 14, 1988 — Time: 9:05 a.m.

Temperature: 58°F — Relative Humidity: 50 percent

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time, sec.: 0.71

Steps 17 and 18. Hot Start-up Data

Initial Start Cranking Time, sec.: 0.37

TABLE 5.3 METHOD FOR CALCULATING TOTAL WEIGHTED DEMERITS (TWD)

Demerits for Poor Starting:

Demerits = Starting Time(s) - 3

Demerits for Stalls:

Demerits = (No. of Idle Stalls) x 8 + (No. of Maneuvering Stalls) x 32

Demerits for Malfunctions Rated Subjectively:

Demerits for Subjective Ratings

Trace	= 1
Moderate	= 2
Heavy	= 4

Weighting Factors for Each Malfunction

Idle Roughness	= 3
Surge	= 4
Backfire, Stumble, Hesitation	= 6

Calculation:

Total Weighted Demerits (TWD) = Weighted Demerits + Demerits for Stalls + Demerits for Poor Starting

Note: When more than one malfunction occurs in a driving maneuver, only the malfunction giving the highest weighted demerits is counted.

Other malfunctions, such as hesitation, stumble, surge, idle roughness, and backfire, were rated subjectively by the driver and observer on a scale of trace, moderate, or heavy. For these malfunctions, a certain number of demerits were assigned to each of the subjective ratings. However, since all malfunctions are not of equal importance, the demerits were multiplied by the weighting factors shown in Table 5.3 to yield weighted demerits. The only operating characteristics that resulted in demerits during these tests were starting time, rough idle, stumble during acceleration, and hesitation during acceleration.

Weighted demerits and demerits for poor starting were summed to obtain total weighted demerits (TWD), which are used as an indication of driveability during the test. As driveability deteriorates, TWD increases. The weighted demerits for the three methanol test buses are described in Table 5.4 and for the diesel test buses are described in Table 5.5. The results are summarized in Table 5.6 which shows a very large difference in driveability between the test and control buses.

5.3 Driveability Test Conclusions

In reaching conclusion on all of the bus comparisons, it is important to recognize that the tests were of one bus model with one diesel engine and one methanol engine produced by one bus manufacturer. It is also important that the six buses had no special preparation for the test so the results are what should be expected in revenue service.

The driveability test results show that:

1. The new driveability test developed for this comparison identifies significant differences between the methanol and diesel buses.

2. The cold starting characteristics of the methanol buses was inferior to that of the diesel buses under all temperature conditions.

3. A professional driver can frequently detect idle roughness in the methanol engines, but seldom detects it in the diesel engines.

4. More discrimination among the levels of malfunction might reduce the magnitude of the differences in total weighted demerits for the methanol and diesel engines but would not change the conclusion on relative driveability.

5. The warm weather or some other factor made a very significant improvement in the cold starting of the methanol buses between January and August.

6. The driveability of one methanol bus deteriorated and one improved between January and August.

7. The driveability of the three diesel control buses remained uniformly superior during both series of tests.

TABLE 5.4 WEIGHTED DEMERITS OF METHANOL TEST BUSES

Bus No. 3151 (T_1) - January		
Steps 2 and 3.	Poor Cold Starting: 42 sec. - 3	= 39
Step 24.	Idle Roughness in "Neutral" 1 x 3	= 3
Total Weighted Demerits		42
Bus No. 3151 (T_1) - August		
Steps 2 and 3.	Poor Cold Starting: 7 sec. - 3	= 4
Step 8.	Hesitation During Acceleration 2 (Moderate) x 6 (Weighing Factor)	= 12
	Stumble During Acceleration 2 x 6	= 12
Step 9.	Stumble During Acceleration 2 x 6	= 12
Step 10.	Hesitation During Acceleration 2 (Moderate) x 6 (Weighing Factor)	= 12
	Stumble During Acceleration 1 (Trace) x 6 (Weighing Factor)	= 6
	Idle Roughness 1 x 3 (Weighing Factor)	= 3
Steps 20 and 21.	Idle Roughness 2 x 3	= 6
Step 23.	Hesitation During Acceleration 1 x 6	= 6

TABLE 5.4 WEIGHTED DEMERITS OF METHANOL TEST BUSES (CONTINUED)

Step 24.	Hesitation During Acceleration 1 x 6	= 6
	Idle Roughness 1 x 3	= 3
Total Weighted Demerits		82

Bus No. 3155 (T_2) - January

Steps 2 and 3.	Poor Cold Starting: 18 sec. - 3	= 15
Step 8.	Stumble During Acceleration 2 (Moderate) x 6 (Weighing Factor)	= 12
Step 11.	Hesitation During Acceleration 1 x 6 (Weighing Factor)	= 6
Step 23.	Hesitation During Acceleration 2 x 6	= 12
	Total Weighted Demerits	45

Bus No. 3155 (T_2) - August

Steps 2 and 3.	Poor Cold Starting: 5 sec. - 3	= 2
Step 11.	Idle Roughness 1 (Trace) x 3 (Weighing Factor)	= 3
Step 20 and 21.	Idle Roughness 1 x 3	= 3

TABLE 5.4 WEIGHTED DEMERITS OF METHANOL TEST BUSES (CONTINUED)

Step 24.	Idle Roughness 1 x 3	= 3
	Total Weighted Demerits	11
Bus No. 3157 (T_3) - January		
Steps 2 and 3.	Poor Cold Starting: 33 sec. - 3	= 30
Step 8.	Hesitation in Acceleration 1 x 6	= 6
	Stumble During Acceleration 1 x 6	= 6
Step 9.	Stumble During Acceleration 1 x 6	= 6
Step 10.	Stumble During Acceleration 2 (Moderate) x 6	= 12
Step 11.	Idle Roughness in "Neutral" 1 x 3	= 3
Steps 20 and 21.	Idle Roughness in "Neutral" 2 x 3	= 6
Step 22.	Idle Roughness in "Drive" 2 x 3	= 6
Step 23.	Idle Roughness in "Drive" 1 x 3	= 3

TABLE 5.4 WEIGHTED DEMERITS OF METHANOL TEST BUSES (CONTINUED)

Step 24.	Stumble During Acceleration 2 x 6	= 12
	Idle Roughness in "Neutral" 1 x 3	= 3
	Total Weighted Demerits	93

Bus No. 3157 (T_3) - August

Steps 2 and 3.	Poor Cold Starting: 8 sec. - 3	= 5
Step 8.	Hesitation During Acceleration 2 (Moderate) x 6 (Weighing Factor)	= 12
	Stumble During Acceleration 2 x 6	= 12
	Idle Roughness 1 (Trace) x 3 (Weighing Factor)	= 3
Step 9.	Hesitation During Acceleration 1 x 6	= 6
	Stumble During Acceleration 1 x 6	= 6
	Idle Roughness 1 x 3	= 3
Step 10.	Stumble During Acceleration 1 x 6	= 6
	Idle Roughness 2 x 3	= 6
Step 11.	Idle Roughness 1 x 3	= 3

TABLE 5.4 WEIGHTED DEMERITS OF METHANOL TEST BUSES (CONTINUED)

Steps 20 and 21.	Idle Roughness 2 x 3	= 6
Step 23.	Idle Roughness 1 x 3	= 3
Step 24.	Idle Roughness 2 x 3	= 6
Total Weighted Demerits		77

TABLE 5.5 WEIGHTED DEMERITS OF DIESEL CONTROL BUSES

Bus No. 3137 (C_1) - January	
Total Weighted Demerits	= 0
Bus No. 3137 (C_1) - August	
Total Weighted Demerits	= 0
Bus No. 3142 (C_2) - January	
Step 24. Idle Roughness in Neutral 1 (Trace) x 3 (Weighing Factor)	= 3
Total Weighted Demerits	3
Bus No. 3142 (C_2) - August	
Step 8. Hesitation During Acceleration 1 (Trace) x 6 (Weighing Factor)	= 6
Total Weighted Demerits	6
Bus No. 3144 (C_3) - January	
Total Weighted Demerits	= 0
Bus No. 3144 (C_3) - August	
Step 10. Hesitation During Acceleration 1 (Trace) x 6 (Weighing Factor)	= 6
Total Weighted Demerits	6

TABLE 5.6 SUMMARY OF WEIGHTED DEMERITS OF METHANOL TEST BUSES (T) AND DIESEL CONTROL BUSES (C)

Identification	Total Weighted Demerits	
	January	August
T_1	42	82
T_2	45	11
T_3	93	77
C_1	0	0
C_2	3	6
C_3	0	6

6.0 ACCELERATION AND GRADEABILITY TEST

The general objectives of the nonrevenue tests are discussed in Section 4.0. The specific objectives of this test are to compare the acceleration and gradeability of the diesel and methanol buses and to determine the change in performance of each bus after six months of revenue service and at a higher ambient temperature. The detailed test procedure and data sheets are shown in Appendix D.

6.1 Acceleration Test

Acceleration times were measured by generating velocity versus time strip chart recordings using a Labeco fifth wheel system and a Honeywell 1958 oscillographic recorder. An event marker switch was installed on the bus accelerator pedal so elapsed time to any required speed could be determined from the time the pedal was first depressed.

All tests were performed on the straight sections of the PACCAR Technical Center High Speed Test Track. Each vehicle reached maximum speed (approx. 55 mph) after entering the first turn on the track. Two test runs were made on each straight section of track while driving in the clockwise direction.

6.2 Gradeability Test

Gradeability performance at 44 mph was calculated from instantaneous acceleration data obtained from the slope of the tangent line (at 44 mph) drawn on the velocity versus time recordings obtained during the previous acceleration tests. With the instantaneous acceleration known, the maximum slope the vehicle can maintain at the given speed was determined as follows:

$$\text{Degree Slope} = \text{Arc Sin} \left[\frac{\text{Acceleration (ft/sec}^2)}{32.2 \text{ (ft/sec}^2)} \right]$$

$$\% \text{ Slope} = \text{Tan (Degree Slope)}$$

Gradeability performance at 7 mph was calculated from velocity versus time recordings obtained while first bringing the engine to full stall rpm by simultaneously applying full throttle and service brake and then releasing the service brake, permitting the vehicle to accelerate through 10 mph. This method is used for gradeability calculations at lower speeds (less than 10 mph).

6.3 Acceleration and Gradeability Test Results

The same three methanol-fueled test buses (T) and three diesel-fueled control (C) buses were tested for acceleration and gradeability in January and August of 1988.

The average time to attain speeds are shown in Table 6.1. The table shows that the average performance of the methanol and diesel buses were very similar in both January and August and that there was no significant degradation in performance of the buses during the period. Figure 6.1 is a plot of the overall average time for the buses to reach different speeds and the average times for both groups of methanol and diesel buses in January and August.

Table 6.2 is a more detailed summary of acceleration test data. It shows that in general there were only minor changes in performance of individual buses between January and August. The most significant change in performance was the decrease in acceleration of bus T_3 during August testing. The decrease was noticed by the technician during the test.

The gradeability test results are shown in Table 6.3. This table is structured similar to Table 6.2 to show the measured changes in gradeability between January and August. The results are in general agreement with the acceleration data reflecting the decreased performance of bus T_3. The only anomalies in the data are the decreases in percent slope at 7 mph for buses T_3 and C_1. Driving for the gradeability test is more difficult than for the acceleration test, so complete engine torque may not have been achieved during the August tests.

6.4 Acceleration and Gradeability Test Conclusions

The acceleration and gradeability test results show that:

1. The average acceleration of methanol and diesel buses are virtually equal with practically no change between January and August.

2. There was a larger variation in acceleration rates among the methanol buses. The methanol bus that had the highest rate of acceleration in January had the lowest rate in August.

3. The gradeability of the methanol and diesel buses should be considered equal.

TABLE 6.1 COMPARISON OF BUS ACCELERATION DATA

Buses	Average Time, Seconds									
	0-10 MPH		0-20 MPH		0-30 MPH		0-40 MPH		0-50 MPH	
	Jan	Aug	Jan	Aug	Jan	Aug	Jan	Aug	Jan	Aug
3 Methanol Buses	4.1	4.2	9.1	9.7	16.2	17.2	25.9	27.5	43.4	43.4
3 Diesel Buses	4.2	4.3	9.3	9.6	16.2	16.9	26.3	27.0	44.1	41.9

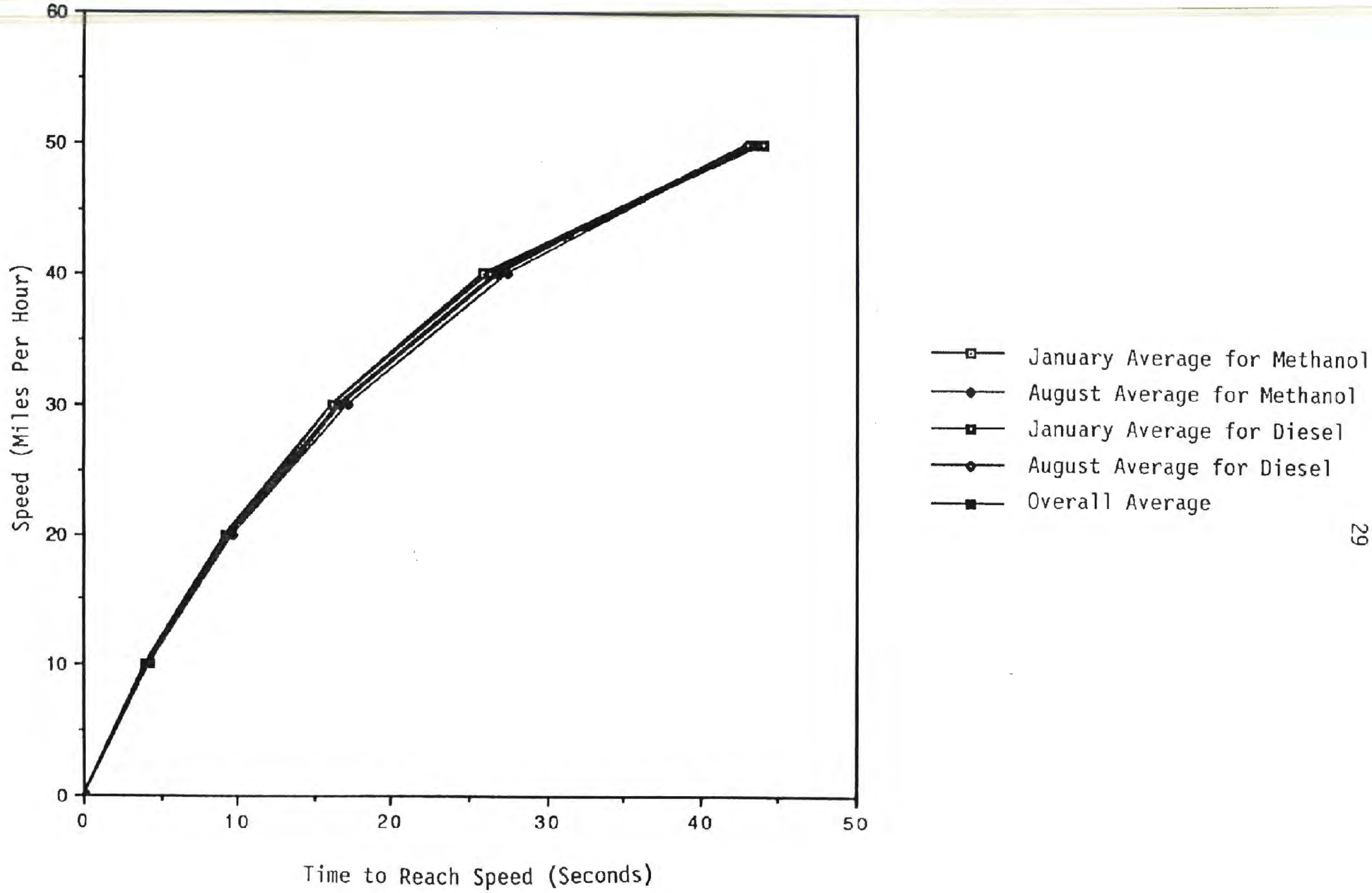

FIGURE 6.1 AVERAGE ACCELERATION OF METHANOL AND DIESEL BUSES

TABLE 6.2 SUMMARY OF ACCELERATION TEST RESULTS

Bus Identification		Time (Seconds)					Air Temperature °F
January	August	0-10 MPH	0-20 MPH	0-30 MPH	0-40 MPH	0-50 MPH	
T_1-3151		4.2	9.4	17.0	27.4	46.6	41
	T_1-3151	4.3	9.6	16.8	26.7	40.9	59
T_2-3155		4.2	9.2	16.2	25.8	43.2	41
	T_2-3155	4.0	9.4	16.8	26.8	41.9	65
T_3-3157		3.8	8.8	15.4	24.6	40.4	34
	T_3-3157	4.4	10.1	17.9	29.0	47.5	58
C_1-3137		4.3	9.4	16.3	26.6	43.2	41
	C_1-3137	4.3	9.6	17.0	27.2	43.1	63
C_2-3142		4.2	9.4	16.4	26.5	44.6	34
	C_2-3142	4.4	9.9	17.4	28.0	46.0	62
C_3-3144		4.2	9.2	16.0	25.8	44.4	34
	C_3-3144	4.2	9.4	16.3	25.8	40.0	60

TABLE 6.3 SUMMARY OF GRADEABILITY TEST RESULTS

Bus Identification		Percent Slope	
January	August	7 MPH	44 MPH
T_1-3151		16.5	2.7
	T_1-3151	13.0	3.1
T_2-3155		16.2	3.1
	T_2-3155	15.1	3.1
T_3-3157		17.2	3.0
	T_3-3157	12.9	2.8
C_1-3137		16.0	3.1
	C_1-3137	13.5	3.0
C_2-3142		16.0	3.0
	C_2-3142	14.0	2.8
C_3-3144		15.6	2.7
	C_3-3144	16.5	3.1

7.0 INTERIOR AND EXTERIOR NOISE

The noise tests were performed in January. They were not repeated in August because no changes in noise levels were expected and the results of the January tests revealed no need for further testing. This subject is discussed further in the conclusions (Section 7.3).

7.1 Interior and Exterior Noise Test Plans and Procedures

Prior to the noise tests, the vehicles were driven approximately 15 miles at 40 mph to assure adequate warm-up of engine and fluids. Each vehicle was at curb weight (plus operator and test personnel) during the tests.

A Bruel & Kjaer Type 2230 sound level meter was used for all noise testing. The meter was calibrated prior to each procedure using a Bruel & Kjaer type 4220 pistonphone.

The detailed interior and exterior noise test procedures and data sheets are shown in Appendix E.

Interior Noise Test. With the bus at idle and in neutral, the dB(A) noise level was measured in the center aisle, four feet above the floor, at the front of the bus (adjacent to the operator), at the center of the bus (adjacent to the front edge of the door) and at the rear of the bus. The meter was set on A-weighting, rms*, slow response and random incidence.

Noise tests were performed with all accessories (heaters and lights) on maximum and then again with all accessories off. Each noise test was repeated while cruising at 35 mph and 55 mph.

Exterior Idle Noise Test. With the vehicle idling in neutral, all lights on and all other accessories off, the left and right side dB(A) noise levels were recorded at points 15 feet from and perpendicular to the vehicle centerline at the rear bumper. The meter was set on A-weighting, rms, slow response and frontal incidence with the microphone at a height of four feet above the ground. The microphone windscreen was used during the tests.

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* Sound pressure reference for measurement of sound in air.

Pull-Away Noise Test. With the microphone located 15 feet from and perpendicular to the vehicle centerline at the front bumper, and at a height of four feet above the ground, the peak dB(A) noise level was recorded as the bus was accelerated at wide open throttle. All vehicle accessories (heaters and lights) were turned on maximum. The meter was set on A-weighting, rms, fast response and frontal incident with the microphone windscreen installed. Three replications were made on both sides of the vehicle.

Constant Speed Pass-By Noise Test. With the microphone located 50 feet from the vehicle centerline and at a height of four feet above the ground, the peak dB(A) noise level was recorded as the vehicle passed by the microphone at constant speeds of 20 and 30 mph. All accessories were turned on maximum. The meter was set on A-weighting, rms, fast response and frontal incidence with the microphone windscreen installed. Three replications were made on both sides of the vehicle.

7.2 Interior and Exterior Noise Test Results

The results of the interior noise tests are summarized in Table 7.1. The results of the exterior noise tests are summarized in Table 7.2.

7.3 Interior and Exterior Noise Test Conclusions

The noise tests have more variability than the other tests. This is especially true of the exterior constant speed pass-by tests where even very small changes in throttle setting entering or in the measurement zone produced large differences in measured noise levels. The most comparable tests were assumed to be the acceleration tests where all measurements were made with wide open throttle setting. It is also quite possible that the measured differences in noise level in all of the tests could have been related to small differences in the construction of the buses as much as the differences in the engines. The noise test results show that:

1. In all 3 interior noise tests, the methanol buses had higher average noise levels than the diesel buses; 2.2 db(A) at idle, 3.1 dB(A) at 35 mph cruise, and 1.6 dB(A) at 55 mph cruise.

2. The average exterior idle noise of the methanol buses was one (1) dB(A) higher than that of the diesel buses.

3. The average pull-away noise of the methanol buses was 1.8 dB(A) higher than that of the diesel buses.

4. The average pass-by noise of the methanol buses and diesel buses was equal.

TABLE 7.1 SUMMARY OF INTERIOR NOISE TEST RESULTS

Idle

Bus No.	Noise Level dB(A)					
	Accessories On			Accessories Off		
	Front	Center	Rear	Front	Center	Rear
T_1-3151	*	*	*	*	*	*
C_1-3137	74.4	73.2	71.6	61.6	59.5	60.1
T_2-3155	74.8	71.8	70.8	57.6	61.9	65.5
C_3-3144	74.9	72.6	71.1	52.9	57.4	61.3
T_3-3157	75.9	74.0	73.1	59.8	65.0	67.3
C_2-3142	**	**	**	**	**	**

35 mph Cruise

Bus No.	Noise Level dB(A)					
	Accessories On			Accessories Off		
	Front	Center	Rear	Front	Center	Rear
T_1-3151	*	*	*	*	*	*
C_1-3137	77.0	77.4	77.0	74.2	75.2	76.2
T_2-3155	80.0	81.5	79.0	78.0	81.8	80.5
C_3-3144	77.2	77.5	77.0	73.2	76.5	76.0
T_3-3157	77.0	79.0	78.0	75.4	79.5	80.0
C_2-3142	74.9	76.9	76.5	74.4	75.8	74.8

TABLE 7.1 SUMMARY OF INTERIOR NOISE TEST RESULTS (CONTINUED)

55 mph Cruise

Bus No.	Noise Level dB(A)					
	Accessories On			Accessories Off		
	Front	Center	Rear	Front	Center	Rear
T_1-3151	*	*	*	*	*	*
C_1-3137	82.4	81.2	80.4	81.2	80.1	79.6
T_2-3155	82.8	82.2	83.2	82.2	83.5	83.8
C_3-3144	82.4	81.0	80.9	80.5	81.0	81.9
T_3-3157	82.2	82.8	83.8	81.8	83.8	84.5
C_2-3142	81.3	81.7	80.4	82.1	82.8	84.2

* Bus No. 3151 was not tested due to starting difficulties.

** No data obtained.

TABLE 7.2 SUMMARY OF EXTERIOR NOISE TEST RESULTS

Idle

Bus No.	Noise Level dB(A)	
	Left	Right
T_1-3151	*	*
C_1-3137	69.4	71.3
T_2-3155	72.1	72.5
C_3-3144	72.8	72.0
T_3-3157	73.2	72.0
C_2-3142	72.2	70.7

Pull-Away

Bus No.	Noise Level dB(A)	
	Left	Right
T_1-3151	*	*
C_1-3137	88.2	90.4
T_2-3155	89.7	89.6
C_3-3144	86.4	87.7
T_3-3157	89.3	88.4
C_2-3142	86.7	85.2

TABLE 7.2 SUMMARY OF EXTERIOR NOISE TEST RESULTS (CONTINUED)

Constant Speed Pass-By

Bus No.	Noise Level dB(A)			
	20 mph		30 mph	
	Left	Right	Left	Right
T_1-3151	*	*	*	*
C_1-3137	70.8	73.0	73.7	74.6
T_2-3155	72.9	73.8	73.3	75.0
C_3-3144	71.7	72.7	74.8	74.9
T_3-3157	72.1	71.4	75.9	75.6
C_2-3142	73.3	73.4	78.3	78.4

* Bus No. 3151 was not tested due to starting difficulties.

8.0 OVERALL CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The overall conclusions of the January and August nonrevenue comparison of the methanol and diesel transit buses are that:

1. There should be no conclusions on the general acceptability of methanol buses based on this series of tests because the tests compare mature diesel engine technology with recently developed methanol engine technology. The other methanol engines being used elsewhere in this demonstration program are significantly different from M.A.N.'s in design and operation.

2. The driveability rating of the M.A.N. diesel buses in operation at Seattle Metro is superior to that of the M.A.N. methanol buses.

3. The average 24°F difference in ambient temperature between January and August testing had significant impact on methanol engine startability.

4. The acceleration and gradeability of the test and control buses were so similar that the differences are believed to be of no practical consequence.

5. The difference in ambient temperature between January and August had no significant impact on either methanol or diesel bus performance.

6. The methanol buses generated more noise than the diesel buses, but the differences were so small that they should not be important to anyone purchasing transit buses.

8.2 Recommendations

It is recommended that the methanol demonstration proving ground comparisons of methanol and diesel transit buses be continued as originally planned. It is important to perform tests with buses and engines by other manufacturers. Some testing should be at extreme high and low ambient temperatures.

It is recommended that future comparative testing be limited to buses and methanol engines that are available to bus purchasers on a current basis. The testing of developmental engines would not add to the industry's useful knowledge. It is important that production methanol engines produced by other manufacturers be tested. The buses at Southern California Rapid Transit District and at Denver Regional Transportation District will feature engines by the other manufacturer now producing methanol engines for the transit industry.

APPENDIX A

METHANOL AND DIESEL BUS SPECIFICATIONS

METHANOL TEST BUS SPECIFICATIONS

Transit Agency Seattle Metro Bus Numbers 3151, 3155, & 3157

Bus Manufacturer M.A.N. Model Number SL40102LM

Vehicle Identification Number (VIN) ____________

Date of Delivery to Transit Agency January, 1987

Length, ft.	40'1"	
Width, in.	102"	
Height, in.	120"	
Passenger seats, no.	44	
Engine Type:	4 Stroke Spark Ignition	*
Manufacturer	M.A.N.	
Model Number	M2566LUH	*
Fuel Injector Type:	BOSCH #PES6 P130 A720LV16379	*
Size	2683-2799 psi, 0.036 inch spray hole diameter	*
Fuel Type	Neat Methanol	*
Fuel Pump(s): Type	Electrical Y580700151 43.5 psi Mechanical BOSCH Double Acting 14.5 psi	*
Fuel System:	M.A.N.	
Tank Capacity, gallons	266 Volume & 250 Usable	*
Fillpipe Flame Arrestor	Yes ____ No √	*
Vent Flame Arrestor	Yes √ No ____	
Generator:	Delco Remy	
Output at Normal Idle	Amps ____ Volts ____	
Maximum Rating	Amps 270 Volts 28	

NOTE: * Indicates a spec difference between the methanol and diesel buses

METHANOL TEST BUS SPECIFICATIONS (CONTINUED)

Bus Numbers 3151, 3155, & 3157

Starter Type:	Electrical √ Air ____	*
Manufacturer	BOSCH	*
Model	KB	*
Heating System Type:	Forced Air Hot Water	
Capacity, btu/hr		
Air Conditioning:	None	
System Capacity, btu/hr	N/A	
Compressor Manufacturer	N/A	
Compressor Model Number	N/A	
Air Compressor:		
Manufacturer	WABCO 35.67 cu. in.	
Model Number	4110338062	
Capacity, cubic ft/min	20.5 CFM @ 145 psi	
Transmission Type:	Automatic - Hydraulic	
Manufacturer	Renk	
Model Number	Doromat 874B	
Converter Torque Multiplication	811.2 ft. lbs. @ 1600 rpm (2200 rpm max)	
Retarder Type:	Integral - Hydraulic	
Manufacturer	Renk	
Model Number		
Brakes, Type:	Drum "S" CAM	
Manufacturer	M.A.N.	

NOTE: * Indicates a spec difference between the methanol and diesel buses

METHANOL TEST BUS SPECIFICATIONS (CONTINUED)

Bus Numbers 3151, 3155, & 3157

Drive Axle:	
Manufacturer	M.A.N.
Model Number	
Axle Ratio	5.22
Tires:	
Manufacturer	Firestone
Type	Bias Ply - Tubeless
Size	12.5 x 22.5
Curb Weight:	
Front Axle	10,700 lbs.
Rear Axle	18,040 lbs.
Total	28,740 lbs. *
Seated Load Weight:	
Front Axle	
Rear Axle	
Total	35,340 lbs. *
Other attributes or features: (wheelchair lifts, wheelchair position, bicycle racks, any items that make this bus different from the other test or control buses)	1. Wheelchair lift - front door

NOTE: *Indicates a spec difference between the methanol and diesel buses

DIESEL CONTROL BUS SPECIFICATIONS

Transit Agency: Seattle Metro   Bus Numbers: 3137, 3142, & 3144

Bus Manufacturer: M.A.N.   Model Number: SL40102L

Vehicle Identification Number (VIN): ____________

Date of Delivery to Transit Agency: July, 1986

Length, ft.	40'1"	
Width, in.	102"	
Height, in.	120"	
Passenger seats, no.	44	
Engine Type:	4 Stroke #2566 MLUH/US/240	*
Manufacturer	M.A.N.	
Model Number	D2566MLUH	*
Fuel Injector Type:	BOSCH #PES6 P120 A720LS388	*
Size	3480-3596 psi, 0.029 inch spray hole diameter	*
Fuel Type	#2 Diesel	*
Fuel Pump(s): Type	Electrical ____ Mechanical BOSCH	*
Fuel System:	M.A.N.	
Tank Capacity, gallons	133 Volume & 125 Usable	*
Generator:	Delco Remy	
Output at Normal Idle	Amps ____ Volts ____	
Maximum Rating	Amps 270 Volts 28	
Starter Type:	Electrical ____ Air √	*
Manufacturer	Ingersoll Rand	*
Model	SS350GB03R85-1537	*

NOTE: * Indicates a spec difference between methanol and diesel buses

DIESEL CONTROL BUS SPECIFICATIONS (CONTINUED)

Bus Numbers 3137, 3142, & 3144

Heating System Type:	Forced Air Hot Water
Capacity, btu/hr	
Air Conditioning:	None
System Capacity, btu/hr	N/A
Compressor Manufacturer	N/A
Compressor Model Number	N/A
Air Compressor:	
Manufacturer	WABCO 35.67 cu. in.
Model Number	4110338062
Capacity, cubic ft/min	20.5 CFM @ 145 psi
Transmission Type:	Automatic - Hydraulic
Manufacturer	Renk
Model Number	Doromat 874B
Converter Torque Multiplication	811.2 ft. lbs. @ 1600 rpm (2200 rpm max)
Retarder Type:	Integral - Hydraulic
Manufacturer	Renk
Model Number	
Brakes, Type:	Drum "S" CAM
Manufacturer	M.A.N.

NOTE: * Indicates a spec difference between methanol and diesel buses

DIESEL CONTROL BUS SPECIFICATIONS (CONTINUED)

Bus Numbers 3137, 3142, & 3144

Drive Axle:		
Manufacturer	M.A.N.	
Model Number		
Axle Ratio	5.22	
Tires:		
Manufacturer	Firestone	
Type	Bias Ply - Tubeless	
Size	12.5 x 22.5	
Curb Weight:		
Front Axle	10,100 lbs.	
Rear Axle	17,700 lbs.	*
Total	27,800 lbs.	
Seated Load Weight:		
Front Axle		
Rear Axle		*
Total	34,400 lbs.	
Other attributes or features: (wheelchair lifts, wheelchair position, bicycle racks, any items that make this bus different from the other test or control buses)	1. Wheelchair lift - front door 2. Diesel engine starting aid - Kold Ban International, Ltd. (KBI) Fluid Starting System	*

NOTE: *Indicates spec difference between the methanol and diesel buses

APPENDIX B

SCHEDULE OF TESTS

SCHEDULE OF TESTS
at
PACCAR Technical Center

January 29-31, 1988

Friday, January 29

Three buses ballasted to seated load weight (SLW) arrived at the proving ground for overnight cool down for driveability tests. The three buses will be:

T_1 = Bus No. 3151
C_1 = Bus No. 3137
T_2 = Bus No. 3155

Saturday, January 30

Three empty buses arrived at the proving ground by 7:00 a.m. These three buses will be:

C_3 = Bus No. 3144
T_3 = Bus No. 3157
C_2 = Bus No. 3142

(All six of these buses were selected because there have been no engine changes, no accidents, and their oil consumptions are normal. If any of these buses are not available, the following alternates should be used:

T_x = Bus No. 3152 or 3158
T_x = Bus No. 3145 or 3146

Saturday Tests

Started SLW buses on driveability tests and tested in the following order: T_1, C_1, and T_2.

Started empty buses on noise tests and test in the following order: C_3, T_3, and C_2.

Perform acceleration tests on the SLW buses in the same order that the driveability tests were performed. Stay with this same order of tests within the groups of buses on Sunday.

After completion of tests on Saturday, move ballast to the three empty buses.

Sunday Tests

Start SLW buses on driveability tests and test in the following order: C_3, T_3, and C_2.

Start empty buses on noise tests and test in the following order: T_1, C_1 and T_2.

Perform acceleration tests on SLW buses in the same order that the driveability tests were performed.

Table of Tests

	Saturday	Sunday
Driveability	T_1, C_1, T_2	C_3, T_3, C_2
Acceleration	T_1, C_1, T_2	C_3, T_3, C_2
Noise	C_3, T_3, C_2	T_1, C_1, T_2

This test schedule will permit completion of the tests in two days. We will run rain, snow, wind,or shine. Ice or compacted snow on the track will be the only acceptable reason for not running.

This schedule requires that drivers become familiar with the tests to be run before arrival on site. It also requires that instrumentation of buses be very well planned before Saturday. Jim Stricklin and Jerry Francis will be at Seattle Metro Thursday afternoon and Friday morning and at the PACCAR Technical Center late Friday afternoon.

SCHEDULE OF TESTS
at
PACCAR Technical Center

August 12 - 14, 1988

Friday, August 12

Three buses ballasted to seated load weight (SLW) arrive at the proving ground for overnight cool down for driveability tests. The three buses will be:

T_1 = Bus No. 3151
C_1 = Bus No. 3137
T_2 = Bus No. 3155

Buses 3151 and 3137 will have brackets for mounting fifth wheel installed by Metro at Ryerson.

Saturday, August 13

Three empty buses arrive at the proving ground by 7:00 a.m. These three buses will be:

C_3 = Bus No. 3144
T_3 = Bus No. 3157
C_2 = Bus No. 3142

All six of these buses were selected because they were used for the cold weather tests and there have been no engine changes, no accidents, and their oil consumptions are normal. If any of these buses are not available, the following alternates should be used:

T_x = Bus No. 3158 or 3159
C_x = Bus No. 3145 or 3146

Saturday Tests

Start SLW buses on driveability tests and test in the following order: T_1, C_1, and T_2.

Perform acceleration and gradeability tests on the SLW buses in the same order that the driveability tests were performed.

After completion of tests on Saturday, move ballast to the three empty buses and move the brackets for the fifth wheel to bus Nos. 3144 and 3157.

Sunday Tests

Start SLW buses on driveability tests and test in the following order: C_3, T_3, and C_2.

Perform acceleration and gradeability tests on SLW buses in the same order that the driveability tests were performed.

Table of Tests

	Saturday	Sunday
Driveability	T_1, C_1, T_2	C_3, T_3, C_2
Acceleration and Gradeability	T_1, C_1, T_2	C_3, T_3, C_2

This test schedule will permit completion of the tests in two days. We will run rain, snow, wind, or shine. Ice or compacted snow on the track will be the only acceptable reason for not running.

This schedule requires that drivers become familiar with the tests to be run before arrival on site. It also requires that the brackets made in January be on the buses. PACCAR will supply all other instrumentation and equipment for the acceleration and gradeability tests. Jerry Francis will be at Seattle Metro Friday morning and at the PACCAR Technical Center Friday afternoon.

APPENDIX C

DRIVEABILITY TEST PROCEDURE AND DATA SHEETS

TRANSIT BUS DRIVEABILITY TEST

Introduction

The cold start, hot start, and driveability tests are structured to relate as closely as possible to conditions encountered in transit operations, to require a minimum of instrumentation, and to give accurate comparison of the demonstration and control bus driveabilities.

The driving cycle is based on transit authority environment simulating start and warm-up in the morning and hot starts. The wide open throttle accelerations, dwell times, and idle times are based on the "White Book" or Transit Coach Operating Duty Cycle.

The test results are weighed summations of the driver's opinions. Therefore, the drivers must be experienced and objective in evaluation of the buses. The same driver that drives one, two, or three of the methanol demonstration buses must drive an equal number of diesel control buses. The order of test will be one diesel, one methanol, one diesel, one methanol, one diesel, one methanol. The same drivers should participate in all driveability testing at a demonstration site.

The driveability test procedures are based on much more detailed Coordinating Research Council (CRC) tests that have been used for comparing the driveability of passenger automobiles. The tests by CRC are based on many years of experience and the close cooperation and support of the American Petroleum Institute and the Society of Automotive Engineers.

Test Temperatures

The target air temperatures for the tests are the maximum and minimum local air temperatures at the demonstration site. Therefore, one series of tests will be performed in July or August and another in January or February.

Test Fuels

The diesel control buses will use the same fuel as that used by other buses in revenue service. The methanol demonstration buses will use the same fuel as the methanol buses use in revenue service.

TRANSIT BUS DRIVEABILITY TEST (CONTINUED)

Test Vehicles

Both the three methanol test and three diesel control buses will be selected from the operating demonstration and control fleets. The same buses will then be used for both the hot weather and cold weather tests. All test vehicles will have thorough mechanical inspections before the tests, but shall not have any engine or drive train maintenance beyond that typical for the other buses at the demonstration site.

The buses to be tested will be loaded to 150 pounds per seating position. All cold start tests will be initiated after the bus has been out of operation at least 12 hours.

Test Location and Timing

The tests will be performed at a site selected by the transit agency. The most important site characteristics are that it be level, smoothly paved, free of interference from other traffic, and permit wide open throttle acceleration to governed speed with three miles of cruise and a safe stopping distance.

Test Personnel

The test personnel will include an experienced driver who will rate the bus driveability and an observer who will ride with the driver to assist in maintaining the test procedure and to record test data.

Test Instrumentation

The instrumentation required is a stop watch, a thermometer, and the bus speedometer and odometer.

Definitions and Explanations

The following definitions and explanations are important to understanding the test procedures and data recording.

TRANSIT BUS DRIVEABILITY TEST (CONTINUED)

Test Run

Operation of a vehicle throughout the complete 25 steps of the test procedure.

Starting Time

The cumulative total seconds of cranking necessary to start the engine.

Maneuver

A specified single vehicle operation or change of operating conditions (such as idle, acceleration, deceleration, or cruise) that constitutes one segment of the driveability driving schedule.

Cruise

Operation at a prescribed constant vehicle speed with a fixed throttle position on a level road.

Wide Open Throttle (WOT) Acceleration

"Floorboard" acceleration through the gears from stop to cruising speed. Rate at which throttle is depressed is to be as fast as possible without producing tire squeal or appreciable slippage.

Malfunctions

A malfunction is any abnormal response of the bus propulsion system during a test. An abnormal response is performance that is not equal to that which is expected from a typical transit bus in revenue service. The following malfunctions will be evaluated in these tests.

TRANSIT BUS DRIVEABILITY TEST (CONTINUED)

1. Stall

   Any occasion during a test when the engine stops involuntarily during a test. Two types of stall, indicated by location on the data sheet, are:

   a. Stall; idle - Any stall experience when the vehicle is not in motion, or when another maneuver is not being attempted.

   b. Stall; maneuvering - Any stall which occurs during another prescribed maneuver or attempt to maneuver.

2. Idle Roughness

   An evaluation of the idle quality or degree of smoothness while the engine is idling.

3. Backfire

   An explosion in the induction or exhaust system.

4. Hesitation

   An excessive delay in vehicle response to opening of the throttle.

5. Stumble

   A short, sharp reduction in acceleration after the vehicle is in motion.

6. Surge

   A continued condition of short fluctuations in power occurring during acceleration or cruise.

TRANSIT BUS DRIVEABILITY TEST (CONTINUED)

Malfunction Severity Ratings

The number of stalls encountered during any maneuver are to be listed in the appropriate test steps. Each of the other malfunctions must be rated by severity and the letter designation entered on the data sheet. The following definitions of severity are to be applied in making such ratings.

1. Trace (T) - A level of malfunction severity that is just discernible to a test driver but not to most layman.

2. Moderate (M) - A level of malfunction severity that is probably noticeable to the average layman.

3. Heavy (H) - A level of malfunction severity that is pronounced and obvious to both test driver and layman.

Enter a T, M, or H on the data sheet to indicate both the occurrence of the malfunction and its severity. If no malfunctions occur, enter a dash (-) to indicate that the maneuver was performed and operation was satisfactory during that maneuver.

Test Procedure and Data Recordings

Cold Start and Operation

The following steps correspond to the steps listed on the attached Bus Driveability Data Sheet.

Step 1. Complete recording of all information requested.

Step 2. Start engine according to procedure used at the transit agency. Record cranking time to start.

Step 3. If engine fails to start after initial cranking, repeat cranking and record total cranking time until engine starts.

TRANSIT BUS DRIVEABILITY TEST (CONTINUED)

Step 4. All lights will be ON. A/C and heater will be OFF. Idle engine for 3 minutes.

Step 5. Record idle quality in "Neutral". Foot should be removed from accelerator pedal.

Step 6. If engine stalls, repeat Steps 2 and 3. Record number of stalls and total cranking time required for restarts.

Step 7. Idle engine for 3 minutes. Apply brakes, shift to drive gear normally used, and record idle quality. (If engine stalls, restart immediately. Record number of stalls and total cranking time required for restart.) Idle for 5 seconds in drive gear normally used.

This completes the start-up portion of the cold start procedure.

Step 8. After the 5 seconds of idle specified in Step 7, accelerate to 20 miles per hour at wide open throttle (WOT). After 30 seconds at cruise, decelerate from 20 mph to stop in approximately 5 seconds and idle for 10 seconds. During this series of maneuvers, observe and record the severity of the following malfunctions as described in the Definitions and Explanations.

a. Hesitation

b. Stumble

c. Surge

d. Backfire

e. Idle Roughness

f. Number of Stalls

Record maneuvers on data sheet.

Step 9. Repeat Step 8.

TRANSIT BUS DRIVEABILITY TEST (CONTINUED)

Step 10. Accelerate at WOT to maximum speed (it will require about 1 mile or 90 seconds), cruise for 3 minutes at maximum speed, decelerate to a stop in 12 to 15 seconds and idle in "neutral" for 20 seconds. Record maneuvers on data sheet.

Step 11. Repeat Step 10.

Step 12. Record time and temperature.

This completes the cold start and operation test. The following steps are required to evaluate hot start and operation of the buses. Ideally this test would be performed immediately after the completion of Step 12.

Hot Start and Operation

Step 13. Start the bus engine according to the bus manufacturer's recommended procedure. Air conditioner and heater will be OFF. All lights will be ON throughout all bus tests except for starting.

Step 14. Allow engine to idle in neutral for 3 minutes.

Step 15. Accelerate at WOT to 40 mph and cruise for 15 miles.

Step 16. Bring bus to a stop, idle for 3 minutes in neutral, and stop engine for 3 minutes.

Step 17. With accessories OFF, start bus by following procedure used at the transit agency. Record cranking time to start engine.

Step 18. If engine fails to start after initial cranking, repeat cranking and record total cranking time until engine starts.

Step 19. Turn on all lights. Idle for 3 minutes.

TRANSIT BUS DRIVEABILITY TEST (CONTINUED)

Step 20. Record idle quality in "Neutral". Foot should be removed from the accelerator.

Step 21. If engine stalls, repeat Step 18 and record number of stalls and total cranking time to restart.

Step 22. Apply brake, shift to drive gear normally used, and record idle quality. (If engine stalls, record number of stalls and total cranking time to restart.) Idle for 5 seconds in drive gear normally used.

This completes the start-up portion of the hot start procedure.

Step 23. After the 5 seconds of idle specified in Step 22, accelerate to 20 miles per hour at WOT. After 30 seconds of cruise, decelerate from 20 mph to stop in approximately 5 seconds and idle for 10 seconds in drive. During this series of maneuvers, observe and record the severity of the following malfunctions.

a. Hesitation

b. Stumble

c. Surge

d. Stall

e. Backfire

f. Idle Roughness

g. Number of Stalls

Step 24. Acceleration at WOT to maximum speed (it will require about 1 mile or 90 seconds), cruise for 3 minutes at maximum speed, decelerate to a stop in 12 to 15 seconds and idle in "neutral" for 5 minutes. Record maneuvers on data sheet.

Step 25. Record time and temperature.

This completes the driveability test.

BUS DRIVEABILITY DATA SHEET

BUS NO. ________ DATE ________ TEST RUN NO. ________

MILEAGE AT START OF TEST ________

Step 1.

Transit Agency: ________

Time of Day: ________ Temperature, deg F: ________

Relative Humidity: ________

Driver (Rater): ________ Observer: ________

Track Description:

Type of Surface: ________

Slope %: ________

Elevation Ft.: ________

Steps 2 and 3. Cold Start-up Data

Initial Start Cranking Time, sec.: ________

Second Cranking, sec.: ________

Third Cranking, sec.: ________

Fourth Cranking, sec.: ________

Step 4. Lights **ON**, A/C and Heater **OFF**, check box ☐

Steps 5 and 6. Idle in "Neutral"

Idle Roughness in "Neutral" ________ Number of Stalls: ________

Total Cranking Time, sec: ________

Step 7. Idle in "Drive"

Idle Roughness in "Drive" ________ Number of Stalls: ________

Total Cranking Time, sec: ________

BUS DRIVEABILITY DATA SHEET (CONTINUED)

BUS NO. ____________ DATE ____________ TEST RUN NO. ____________

MILEAGE AT START OF TEST ____________

Step 8. Maneuvers

	0-20 mph WOT Acceleration	Cruise for 30 Sec.	Deceleration to Stop in 5 Sec.	Idle in Drive for 10 Sec.
Hesitation				
Stumble				
Surge				
Backfire				
Idle Roughness				
Number of Stalls				

Step 9. Maneuvers

	0-20 mph WOT Acceleration	Cruise for 30 Sec.	Deceleration to Stop in 5 Sec.	Idle in Drive for 10 Sec.
Hesitation				
Stumble				
Surge				
Backfire				
Idle Roughness				
Number of Stalls				

BUS DRIVEABILITY DATA SHEET (CONTINUED)

BUS NO. __________ DATE __________ TEST RUN NO. __________

MILEAGE AT START OF TEST __________

Step 10. Maneuvers

	0 to maximum Speed WOT Acceleration	Cruise for 3 Minutes	Deceleration to Stop in 12-15 Seconds	Idle in Neutral for 20 Seconds
Hesitation				
Stumble				
Surge				
Backfire				
Idle Roughness				
Number of Stalls				

Step 11. Maneuvers

	0 to maximum Speed WOT Acceleration	Cruise for 3 Minutes	Deceleration to Stop in 12-15 Seconds	Idle in Neutral for 20 Seconds
Hesitation				
Stumble				
Surge				
Backfire				
Idle Roughness				
Number of Stalls				

BUS DRIVEABILITY DATA SHEET (CONTINUED)

BUS NO. ____________ DATE ____________ TEST RUN NO. ____________

MILEAGE AT START OF TEST ____________

Step 12.

Time: __________________

Temperature, deg F: __________________

Steps 13 thru 16. (No data required)

Steps 17 and 18. Hot Start-up Data with Accessories OFF

Initial Start Cranking Time, sec.: __________

Second Cranking, sec.: __________

Third Cranking, sec.: __________

Fourth Cranking, sec.: __________

Step 19. Lights **ON**, check box ☐

Steps 20 and 21. Idle in "Neutral"

Idle Roughness in "Neutral" ________ Number of Stalls: ________

Total Cranking Time, sec: ________

Step 22. Idle in "Drive"

Idle Roughness in "Drive" ________ Number of Stalls: ________

Total Cranking Time, sec: ________

BUS DRIVEABILITY DATA SHEET (CONTINUED)

BUS NO. ____________ DATE ____________ TEST RUN NO. ____________

MILEAGE AT START OF TEST ____________

Step 23. Maneuvers

	0-20 mph WOT Acceleration	Cruise for 30 Seconds	Deceleration to Stop in 5 Sec.	Idle in Drive for 10 Sec.
Hesitation				
Stumble				
Surge				
Backfire				
Idle Roughness				
Number of Stalls				

Step 24. Maneuvers

	0 to maximum Speed WOT Acceleration	Cruise for 3 Minutes	Deceleration to Stop in 12-15 Seconds	Idle in Neutral for 5 Minutes
Hesitation				
Stumble				
Surge				
Backfire				
Idle Roughness				
Number of Stalls				

Step 25.

Time: ____________________

Temperature, deg F: ____________________

APPENDIX D

ACCELERATION AND GRADEABILITY TEST PROCEDURE AND DATA SHEETS

Introduction

This test will be performed on three methanol demonstration buses and three diesel control buses. The objective is to compare the acceleration and gradeability of the six buses and to determine whether the acceleration rates of any of the buses change as a result of time or a change in air temperature.

Test Fuels

The diesel control buses will use the same fuel as that used by other diesel buses in revenue service. The methanol demonstration buses will use the same fuel as the methanol buses use in revenue service.

Test Vehicles

Both the three methanol demonstration and three diesel control buses will be selected at random from the operating demonstration and control fleets. The same buses will be tested twice with a six-month interval. All test vehicles will have thorough mechanical inspections before the tests, but shall not have any engine or drive train maintenance beyond that typical for the other buses at the demonstration site. The buses to be tested will be loaded to 150 pounds per seat position.

Test Location and Temperatures

The test will be performed at a site selected by the transit agency. The most important site characteristics are that it be level, smoothly paved, dry, free of interference from other traffic, and permit wide open throttle acceleration to 55 mph with a safe stopping distance. The target temperatures for these tests are maximum and minimum local temperatures at the demonstration site. Therefore, one series of tests should be performed in July or August and another in January or February.

Test Personnel

The test personnel will include an experienced driver and a support person who will be responsible for data collection.

Test Instrumentation

The test instrumentation will include a fifth wheel with a strip chart that records velocity versus time. An event marker switch will be installed on the accelerator pedal so elapsed time from first pedal depression to any speed can be obtained. A thermometer, hygrometer, anemometer, and watch are also required.

Definitions

Test Run: Operation of the bus through all steps described in the Test Procedures.

Wide Open Throttle (WOT): "Floorboard" acceleration from stop to 55 mph. Rate at which the throttle is depressed will be as fast as possible without producing tire squeal or appreciable slippage.

Test Procedure and Data Recording

Step 1. Record all of the information describing the test on attached Bus Acceleration Data Sheet.

Step 2. Start bus. Air conditioner and heater will be OFF. All lights will be ON. (no data required)

Step 3. Lift fifth wheel, accelerate at WOT to 40 mph, and cruise for 15 miles. (no data required)

Step 4. Bring bus to a stop and idle engine for three minutes in "Neutral". During the idle, the data collector will lower the fifth wheel and prepare recorder for start. Identify bus number, date, run number, and data collector on the chart.

Step 5. Begin record chart travel and WOT acceleration. Accelerate to 55 mph and hold speed for a few seconds, and then coast down to below 10 mph. Stop recorder. Record wind direction and wind speed.

Step 6. Turn bus around for return run and repeat Steps 4 and 5. Record data as in Step 5.

Step 7. Turn bus around for second run in initial direction. Repeat Steps 4 and 5 and record data as in Step 5.

Step 8. Turn bus around for return run and repeat Steps 4 and 5 and record data as in Step 5.

Step 9. Record bus number, date, run number, and data collector on the strip chart.

Step 10. Bring engine to full stall rpm by simultaneously applying full throttle and service brake. Immediately release brake and permit WOT acceleration through 10 mph. Coast down to stop. Stop recorder. Record wind direction and wind speed.

Step 11. Turn bus around for return run and repeat Steps 9 and 10.

Step 12. Record time and air temperature.

This completes the acceleration and gradeability test

TEST RESULTS

The acceleration test results will be an average of the four runs.

Speed Versus Time

MPH	Time, Sec.
0-10	________
0-20	________
0-30	________
0-40	________
0-50	________
0-55	________

The gradeability will be calculated for 7 mph and 44 mph.

BUS ACCELERATION AND GRADEABILITY DATA SHEET

BUS NO. ________ DATE ________ TEST RUN NO. ________

Step 1.

Transit Agency: ____________________

Time of Day: ____________ Temperature, deg F: ____________

Relative Humidity: ________

Driver: ____________ Data Collector: ____________

Track Description:

Type of Surface: ____________________

Slope %: ____________

Elevation, Ft.: ________

Steps 2 and 3. Air conditioning and heater OFF, all lights ON, check box ☐

Step 4. Record bus number, date, run number and data collector on the strip chart.

Step 5. Data consists of the Recorder chart that will provide information necessary to calculate gradeability and prepare a table similar to the following:

SPEED VERSUS TIME

0-10 mph	4.50 sec.
0-20 mph	9.12 sec.
0-30 mph	16.88 sec.
0-40 mph	27.88 sec.
0-50 mph	48.38 sec.
0-55 mph	63.62 sec.

BUS ACCELERATION AND GRADEABILITY DATA SHEET

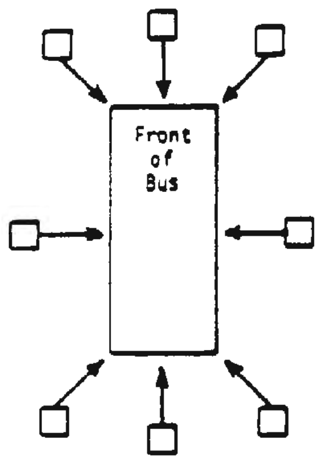
BUS NO. ________ DATE ________ TEST RUN NO. ________

Recorder chart labeled according to Step 4, check this square ☐

Wind Direction

Check one square

Wind Speed, mph: ____



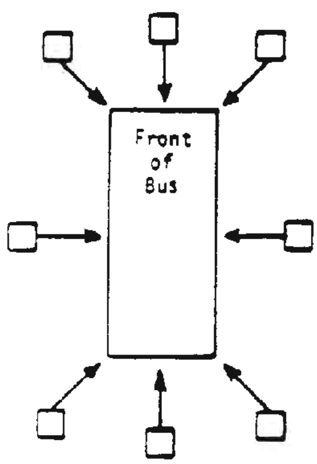
Step 6.

Recorder chart labeled according to Step 4, check this square ☐

Wind Direction

Check one square

Wind Speed, mph: ____



BUS ACCELERATION AND GRADEABILITY DATA SHEET

BUS NO. ________ DATE ________ TEST RUN NO. ________

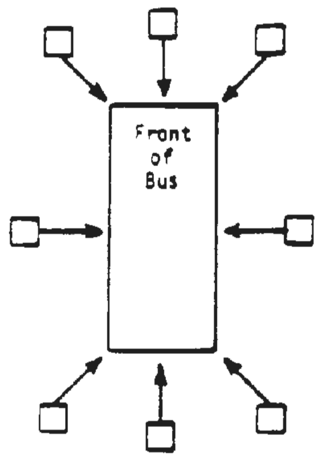
Step 7.

Recorder chart labeled according to Step 4, check this square ☐

Wind Direction

Wind Speed, mph: _____

Check one square



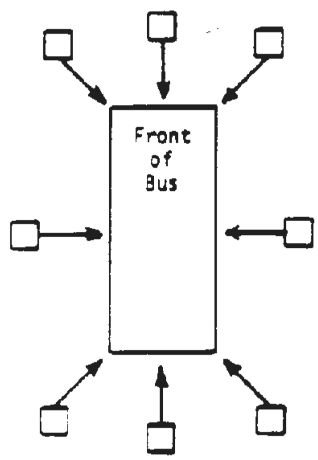
Step 8.

Recorder chart labeled according to Step 4, check this square ☐

Wind Direction

Wind Speed, mph: _____

Check one square



BUS ACCELERATION AND GRADEABILITY DATA SHEET

BUS NO. ________ DATE ________ TEST RUN NO. ________

Step 9. Record bus number, date, run number and data collector on the strip chart.

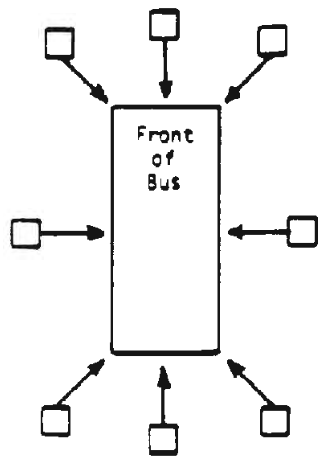
Step 10.

Recorder chart labeled according to Step 9, check this square ☐

Wind Direction

Wind Speed, mph: ____

Check one square



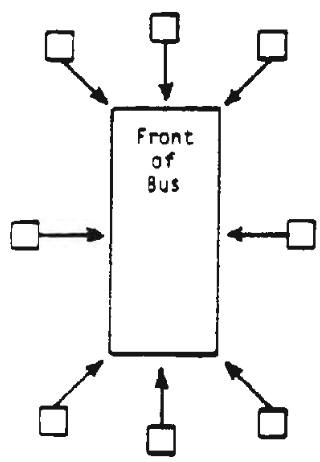
Step 11.

Recorder chart labeled according to Step 9, check this square ☐

Wind Direction

Wind Speed, mph: ____

Check one square



BUS ACCELERATION AND GRADEABILITY DATA SHEET

BUS NO. _________ DATE _________ TEST RUN NO. _________

Step 12.

Time: ___________ Air Temperature: ___________

This completes the acceleration and gradeability test

APPENDIX E

INTERIOR AND EXTERIOR BUS NOISE TEST PROCEDURES AND DATA SHEETS

APPENDIX E

INTERIOR AND EXTERIOR BUS NOISE TEST PROCEDURES AND DATA SHEETS

Transit Agency: ______________________________

Bus No.: ____________________ Date: ____________________

Time of Day: ____________________ Temperature, deg. F: __________

Driver: ____________________ Data Recorder: ______________

Introduction

The purpose of these four tests is to compare the noise levels of the methanol demonstration buses with the diesel control buses. These tests are structured to be simple to perform and are not intended to relate directly to SAE or regulatory tests which are more complex and difficult to perform. These tests were selected for their anticipated level of importance to a transit agency.

The procedure and data sheet for each test are combined under a single heading.

Test Vehicles

Both the three methanol demonstration and three diesel control buses will be selected at random from the operating demonstration and control fleets, respectively. The same buses will be tested twice with a six-month time interval. All test vehicles will have thorough mechanical inspections before the tests bus shall not have any engine or drive train maintenance beyond that typical for the other buses at the demonstration site. Each bus to be tested shall be empty (at curb weight) except for test personnel, not to exceed four persons, and the test equipment.

The test bus will be driven 15 miles at 40 mph immediately prior to the test to assure adequate warm-up of engine and fluids.

Test Location and Timing

The tests will be performed at a site selected by the transit agency. The site should be level, smoothly paved, and permit wide open throttle acceleration to 55 mph with a safe stopping distance. The most important site characteristics are a low background noise level and a flat open space free of reflecting surfaces such as hills, parked cars, buses, sign boards, buildings, etc., within 100 feet of the microphone or test bus. The site should comply as much as possible with that described in SAE J366b--Exterior Sound Level for Heavy Duty Trucks and Buses.

Test Personnel

The test personnel will include an experienced driver and staff required to operate the test instruments and record data.

Test Instrumentation

The test instrumentation shall include a sound level meter and associated equipment with the capacity to discern ± 0.1 dB(A). A watch, hygrometer, anemometer, and thermometer are also required.

Definitions

Test Run: Operation of the bus through all steps described in the Test Porcedures.

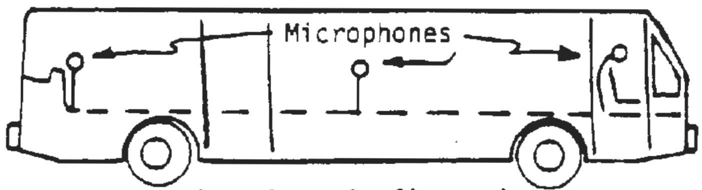
Wide Open Throttle (WOT): "Floorboard" acceleration from stop to 55 mph. Rate at which the throttle is depressed will be as fast as possible without producing tire squeal or appreciable slippage.

Curb Weight: Vehicle weight with all equipment installed and fuel tank filled to nominal capacity.

INTERIOR NOISE TEST

Procedure

A microphone shall be placed at the driver position, center of the bus and rear of the bus in plane at the height of a seated passenger as shown in the sketch below. Sound level will be recorded at each of these positions in the bus at idle, 35 mph cruise, and 55 mph cruise with windows closed. Measurements will be made with the bus empty and with all bus accessories, including maximum air conditioning if A/C equipped, or maximum heat, on and off.

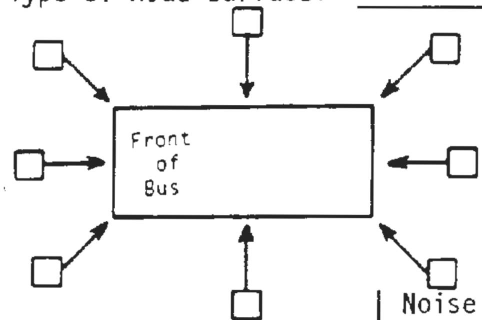


Microphone Configuration

Test Data

Bus No.: ______________ Date: ______________

Type of Road Surface: ________________________



Wind Direction,
Check One

Wind Speed: _____ mph

Air Temperature: _____ F

Relative Humidity: _____ %

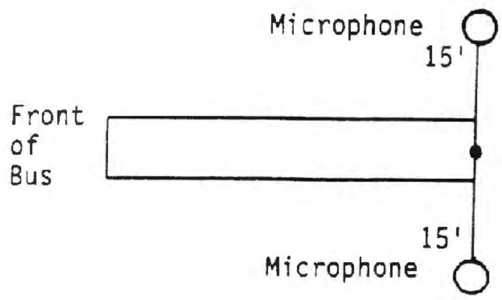
	Noise Measurements with Accessories ON.	Noise Measurements with Accessories OFF.
	Noise Level in Decibels, dB(A).	Noise Levels in Decibels, dB(A).
	Front Center Rear	Front Center Rear
Idle		
35 mph (cruise)		
55 mph (cruise		

EXTERIOR IDLE NOISE TEST

Procedure

This stationary test should be performed with all lights **ON**, A/C and heater **OFF**, and the bus idling with transmission in "**NEUTRAL**".

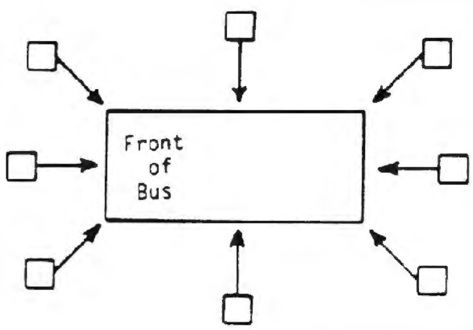
The microphones shall be mounted perpendicular to the bus centerline at a distance of 15 feet from the centerline of the bus at its rear bumper and four feet above the ground as shown in the sketch.



Test Data

Bus No.: ____________ Date: ____________

Type of Road Surface: ____________________



Wind Direction,
Check One

Wind Speed: _____ mph

Air Temperature: _____ F

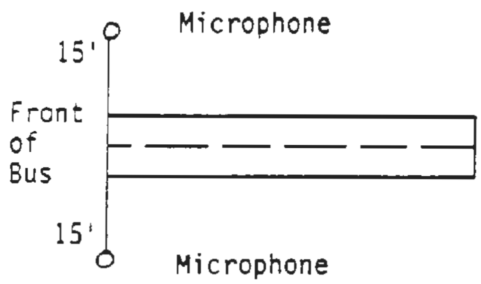
Relative Humidity: _____ %

Noise Level in Decibels, dB(A) with all Accessories ON	
Left	Right

EXTERIOR PULL-AWAY NOISE TEST

Procedure

The microhpones shall be mounted perpendicular to the bus centerline a distance of 15 feet from the centerline of the bus at the very front end and four feet above the ground as shown in the sketch. The bus will be accelerated at wide open throttle and the highest noise level will be recorded. The vehicle will be empty. Sound levels will be recorded on both sides of the vehicle. Three replications will be made.

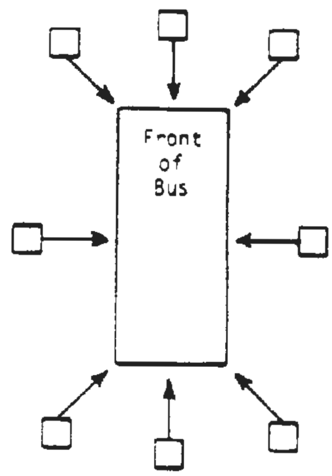


Test Data

Bus No.: ______________ Date: ______________

Type of Road Surface: ______________________

Run #	Left	Right
1		
2		
3		
Average		



Wind Direction,
Check One

Wind Speed: _____ mph

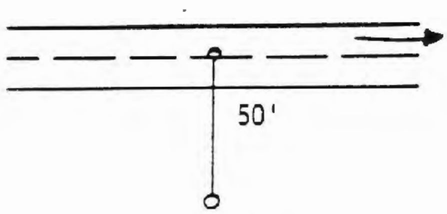
Air Temperature: _____ F

Relative Humidity: _____ %

PASS-BY AT CONSTANT SPEEDS TEST

Procedure

The microphone will be located 50 feet from the centerline of the vehicle path as shown in the sketch and 4 feet above the plane of the ground. The highest noise level will be measured as the bus passes by at constant speeds of 20 and 30 miles per hour. The vehicle shall be empty. Three replications at each speed will be made.

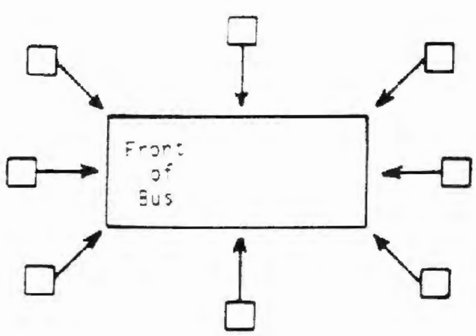


Test Data

Bus No.: ______________ Date: ______________

Type of Road Surface: ________________________

Sound Levels in Decibels, dB(A) 20 mph				30 mph			
1	2	3	Average	1	2	3	Average



Wind Direction,
Check One

Wind Speed: _____ mph

Air Temperature: _____ F

Relative Humidity: _____ %