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PARATRANSIT VEHICLE TEST AND EVALUATION
Volume V: Noise Tests

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JUNE 1978

FINAL REPORT

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Prepared for

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16. Abstract

The vehicles presently available for paratransit service do not cover the full spectrum of required characteristics necessary for public transportation. Therefore, specifications were developed by the U.S. Government for a vehicle specifically for use in paratransit service which combines a number of desirable features without compromising important performance parameters. Prototype vehicles were manufactured for the Government by two different manufacturers (ASL Engineering and Dutcher Industries) according to these specifications. Dynamic Science, Inc. was selected by the Government to conduct an independent series of tests and evaluations of the two prototype paratransit vehicles. The testing and evaluation program was structured to provide performance data on the prototypes as compared to a baseline vehicle (Chevrolet Nova). The program consisted of five separate test series: 1) Ride Comfort and Quality; 2) Acceleration and Interior Measurements; 3) Handling; 4) Fuel Economy; and 5) Noise. The results of the program are documented in a five-volume technical report, and each volume corresponds to one of the individual test series.

This volume (Volume V) presents the test procedures and results of the noise tests conducted on the two paratransit prototype vehicles and the baseline test vehicle. The test series measured external vehicle noise during acceleration, constant speed, and stationary at idle conditions. Interior noise at each of the passenger locations and in the driver's compartment was also measured under the above conditions.

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PREFACE

This final report, Volume V, summarizes the noise testing on the Paratransit Evaluation and Testing Contract. The program was structured to provide performance data on the prototypes compared to a baseline vehicle that will be used to upgrade future redesigns.

The program was conducted by Dynamic Science, Inc. under Contract DOT-TSC-1241 with the Transportation Systems Center (TSC) of Cambridge, Massachusetts for the Urban Mass Transportation Administration. The contract was technically managed by Mr. Jim Kakatsakis and Mr. Joe Picardi of TSC.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

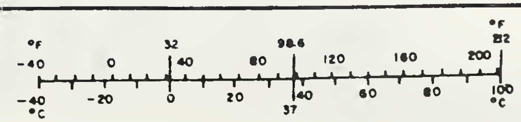


TABLE OF CONTENTS

TABLE OF CONTENTS (CONTD)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONTD)

LIST OF TABLES

LIST OF TABLES (CONTD)

1.0 INTRODUCTION

The paratransit mode of transportation provides an alternative between transit in privately owned and operated vehicles and scheduled mass transit systems. Paratransit includes such systems as dial-a-ride, taxi, and jitney service. It is of vital importance to people without individual cars or ready access to regular mass transit and to people of limited mobility. The vehicles presently available for paratransit service, however, do not cover the full spectrum of required characteristics. They are slightly modified versions of vehicles designed for different purposes. As such, they are not as efficient in their operation nor as easy to enter and exit as is desirable in this type of transportation.

Therefore, the Urban Mass Transportation Administration (UMTA), working through the Transportation Systems Center (TSC), developed specifications for a vehicle specifically for use in paratransit which combines a number of desirable features without compromising important performance parameters. Prototype vehicles were manufactured for UMTA by two different manufacturers (ASL Engineering and Dutcher Industries) according to these specifications. The primary features of the vehicles are a low pollution, quiet, efficient propulsion system combined with a body designed for the comfort and convenience of both the passengers and driver. The vehicles include provisions for easy ingress and egress for the general public as well as the elderly and handicapped, including the easy ingress/egress and accomodation of a wheelchair passenger.

Dynamic Science, Inc. was selected by UMTA to conduct an independent series of tests and evaluations of the two prototype paratransit vehicles (PTV). These tests were designed to provide additional information on the ride quality and comfort, fuel economy, performance and handling characteristics of the two vehicles. A compact passenger car (Chevrolet Nova) was utilized as a baseline test vehicle throughout the test series to furnish comparative data for the evaluations.

The paratransit vehicle testing and evaluation program consisted of six major tasks. The first task consisted of initial vehicle inspection, test preparation, and driver familiarization efforts conducted upon delivery of the vehicles to the Dynamic Science test facility. The remaining five tasks consisted of conducting and evaluating the results of five separate test series. These series were:

- Ride Comfort and Quality Test Series which measured the ride characteristics of the test vehicles to determine if and how well they satisfy accepted standards of ride quality.
- Acceleration and Interior Measurement Test Series which determined the acceleration characteristics and available interior space of the vehicles in order to evaluate their suitability for urban paratransit use.
- Handling Test Series which determined the steering and handling characteristics of the PTVs and allowed their characteristics to be compared with those of the baseline test vehicle.
- Fuel Economy Test Series which obtained fuel economy data for the PTVs under actual road conditions with various driving cycles.
- Noise Test Series which measured the acoustic noise generated by the vehicles and the noise environment inside the passenger and driver compartments.

The Paratransit Test and Evaluation Program is documented in five separate volumes as follows:

Volume 1. Ride Comfort and Quality Tests

Volume 2. Acceleration and Interior Measurement Tests

Volume 3. Handling Tests

Volume 4. Fuel Economy Tests

Volume 5. Noise Tests.

This volume (Volume 5) presents the test procedures and results of the noise tests conducted on the two PTV prototypes and the baseline test vehicle.

2.0 TEST DESCRIPTION

2.1 TEST OBJECTIVES

This noise test series was designed to measure the acoustic noise generated by the two Paratransit Vehicle prototypes and the baseline vehicle and also to measure the noise environment inside the passenger and driver compartments. The tests were used to determine what the noise levels of the Paratransit Vehicles were, how closely they came to the originally specified goals for PTV noise characteristics, and how they compared to the standard production baseline vehicle and the recommended standards set forth in SAE Standard J986a and J994a.

2.2 TEST DESIGN

The testing consisted of two major parts. The first part measured the external noise generated by the vehicle under three different operational conditions:

- Accelerating from 30 mph to maximum rated engine speed (not to exceed 55 mph) per SAE Standard J986a.
- Constant speed, passing at 15, 30, and maximum speed (not to exceed 55 mph) using the same procedure and measurement techniques as specified in SAE J986a.
- Stationary, with engine idling and in neutral gear. A 360-degree survey was made around the perimeter of the vehicle at a 5- and 10-foot radius with the sound level meter/microphone located 4 feet above the ground level. Instrumentation and general measurement techniques were as specified in SAE J994a.

The second part of the testing measured the interior noise in each of the primary and wheelchair passenger locations as well as in the driver's compartment. The microphone was located at or near the normal head location in each of the seat areas. The noise levels at these four locations (the passenger, wheelchair passenger, and driver locations) were measured under the following conditions:

- Accelerating from 0 to 45 mph at wide-open throttle, using the instrumentation and general recommendations in SAE J986a and SAE J336a.
- Accelerating from 30 mph to the maximum engine speed (not to exceed 55 mph).
- Constant speed conditions of 15 mph, 30 mph, and maximum speed (not to exceed 55 mph).
- Stationary, with engine idling and in neutral gear.

2.3 SCOPE OF TEST SERIES

The noise test series is presented in Table 1. The test series consisted of five types of exterior noise tests and six types of interior noise tests for each test vehicle. The conditions of the exterior noise tests were identical with five of the interior types of tests and therefore these tests were run concurrently. The noise test series for each vehicle consisted of 164 noise measurements taken during 41 test runs.

TABLE 1. NOISE TEST SERIES

Test Conditions	Test Runs	Measurements Per Test Run	Total Measurements
1 acceleration	8	2 interior	16
1 acceleration	8	2 interior 1 exterior	16 8
3 steady state velocities	24	2 interior 1 exterior	48 24
1 stationary	1	4 interior 48 exterior	4 48
TOTALS: 6 Test Conditions	41		164

3.0 TEST VEHICLES

The test vehicles consisted of two prototype paratransit vehicles (one manufactured by ASL Engineering and the other by Dutcher Industries) and one baseline vehicle (Chevrolet Nova). These vehicles are shown in Figure 1.

3.1 ASL PARATRANSIT VEHICLE

The ASL PTV (Figure 2) is a front engine, front drive vehicle which can accommodate a maximum of five seated passengers or two seated passengers plus a wheelchair. Ingress/egress is accomplished through remotely operated sliding doors on each side of the vehicle. An electrically powered loading ramp may be extended on the right side of the vehicle to permit unassisted ingress and egress for wheelchair passengers.

The driver's compartment is separated from the passenger compartment by a bullet-resistant partition. An intercom system is provided for communication between the two compartments. All seating positions are equipped with belt restraints and a restraint system is also provided to fasten the wheelchair securely to the vehicle.

3.2 DUTCHER PARATRANSIT VEHICLE

The Dutcher PTV (Figure 3) is a rear engine, rear drive vehicle which also accommodates five seated passengers or two seated passengers plus a wheelchair. Hydraulically actuated bifold doors on each side of the vehicle permit passenger ingress and egress. An electrically powered loading ramp extending on the right side of the vehicle allows wheelchair ingress and egress.

Figure 1. Test Vehicles Left-to-Right: Dutcher PTV, ASL PTV, Chevrolet Nova.

Figure 2. ASL Paratransit Vehicle.

Figure 3. Dutcher Paratransit Vehicle.

As in the ASL PTV, the Dutcher PTV contains a driver compartment which is completely separated from the passenger compartment by a transparent partition. Communication between passengers and driver is accomplished through an intercom system. Restraints are provided for all seating positions and for the wheelchair.

3.3 BASELINE TEST VEHICLE

The baseline test vehicle which was used for comparative evaluation of the PTV test results was a 1977 Chevrolet Nova 6. The criteria for the selection of the baseline vehicle were:

- Compact Size
- 4-Door Passenger Car
- 6-Cylinder Engine
- Automatic Transmission
- Air Conditioning System
- Radial Tires
- Weight, Width, and Length Comparable to the Paratransit Vehicle
- Mileage Less Than 5000 Miles.

The Nova was selected because it fulfills all of the above requirements and, in addition, is more prevalent and more commonly known than any of the other vehicles which met the criteria.

3.4 COMPARISON OF BASIC VEHICLE CHARACTERISTICS

The basic test vehicle characteristics are listed in Table 2. The characteristics of the two PTV vehicles are similar in most instances. The major differences between the two vehicles lie in the engine location/drive configuration and in the front-to-rear weight ratio (1.59 for the ASL and 0.60 for the Dutcher).

TABLE 2. BASIC TEST VEHICLE CHARACTERISTICS

Vehicle Parameter	ASL PTV	Dutcher PTV	Nova (Baseline)
1. Dimensions			
Height (in.)	70.8	80.1	55.1
Width (in.)	72.5	72.8	73
Length (in.)	184	172.5	197.1
Wheelbase (in.)	108.3	106.8	111.4
Track			
- Front (in.)	63.4	63.5	61
- Rear (in.)	63.2	61.9	59.3
2. Weight			
Curb Weight (lb)	3510	3021	3450
- Front Rear Ratio	1.59	0.60	1.23
3. Minimum Turning			
Diameter (ft)	37.5	33.8	40.2
4. Engine			
Location	Front	Rear	Front
No. of Cylinders	4	4	6
Displacement ($in.^3$)	114.5	120.3	250
Horsepower	95	86	110
Compression Ratio	8:1	7.6:1	8.25:1
5. Transmission			
Automatic/Manual	Automatic	Automatic	Automatic
No. of Forward Speeds	3	3	3
6. Brakes			
Power/Manual	Power	Manual	Power
Front	Disc	Disc	Disc
Rear	Drum	Drum	Drum
7. Tire Size	ER78-14	Front BR78-13 Rear ER78-14	FR78-14
8. Steering			
Power/Manual	Power	Manual	Power
Type	Rack & Pinion	Rack & Pinion	Standard
9. Drive			
Front/Rear	Front	Rear	Rear
Ratio	4.11	4.57	2.73
10. Fuel Capacity (gal)	15	15	21

4.0 TEST FACILITIES

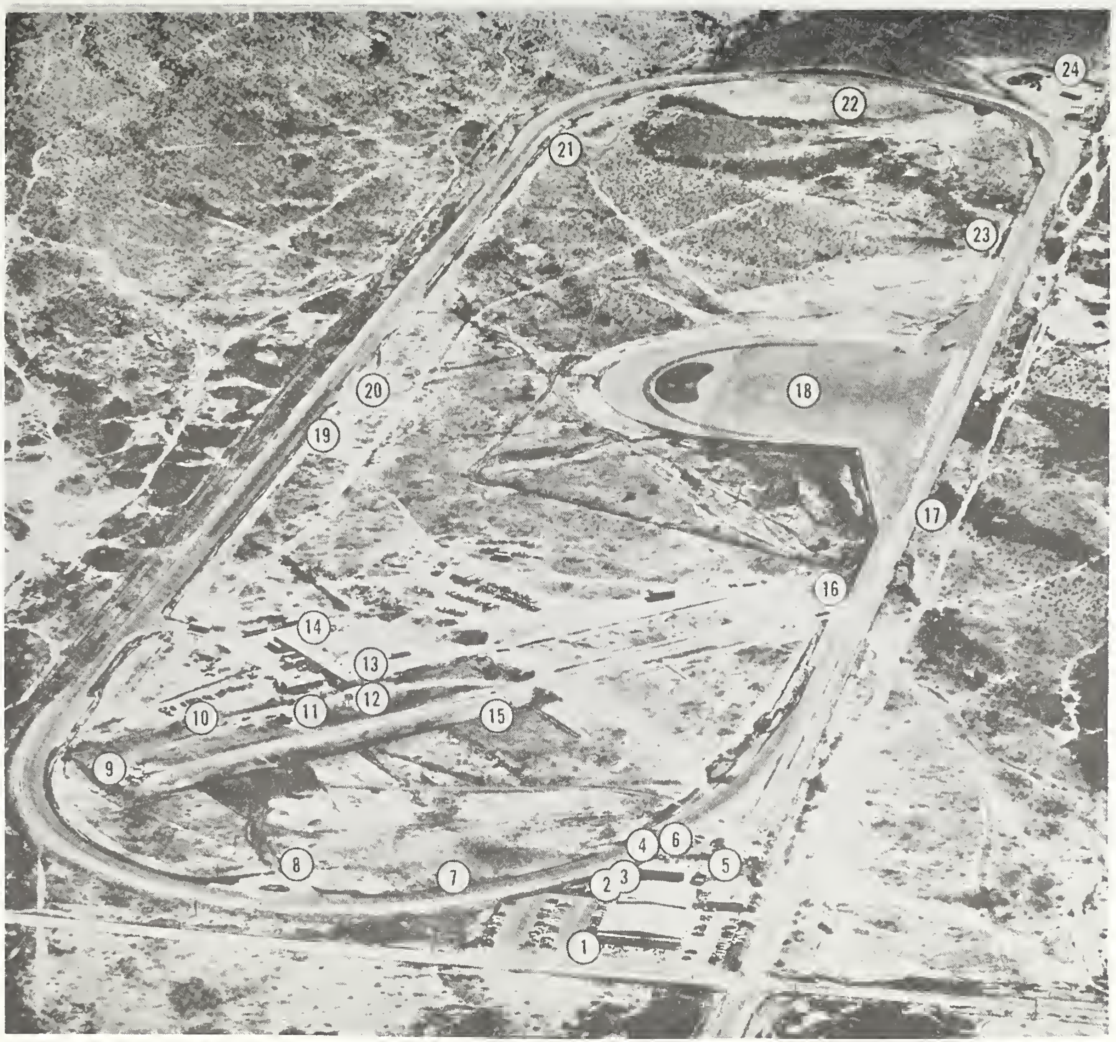
All of the Paratransit Vehicle testing was done at the Dynamic Science Deer Valley Facility. Figure 4 presents an overall aerial view of this facility.

The skid pad area (Item 18) together with sections of the two-mile oval (Item 17) were used for the conduct of the noise tests of the PTVs and baseline vehicle. The skid pad is a large flat (runout less than 0.25 inches in ten feet) asphalt area that adjoins a straight section of the two-mile oval. The pad has a maximum width of 600 feet and length of 600 feet.

The adjacent section of the oval track is made of asphaltic concrete with no perceptible bumps or dips. The pavement slope is maintained at ±1 percent. Banked curves are provided at the ends of the straightaway which permit top speeds in excess of 60 mph. The area is free of obstructions and provides a low ambient noise level.

The stationary testing was conducted on the skid pad and the vehicle-in-motion noise testing was performed on the lead-in area between the skid pad and test track. These locations provided the necessary level, open space free of large reflecting surfaces located within 100 feet of either the vehicle path or the microphone.

The in-motion test course and microphone position was laid out as shown in Figure 5 and marked with highway cones. The region within 100 feet of either the vehicle path or microphone position was inspected for any unusual sound absorption/deflection qualities. In particular, the area between the microphone and vehicle path and all along the vehicle path had to be free of extraneous debris such as gravel.



1. ENGINEERING/ADMINISTRATION CENTER
2. MECHANICAL/INSTRUMENTATION SHOPS
3. DUMMY CALIBRATION LABORATORY
4. GARAGE/MAINTENANCE SHOP
5. ENVIRONMENTAL CHAMBER
6. STATIC CRUSH FACILITY
7. TWO-MILE OVAL
8. TURNAROUND (TYPICAL OF TWO)
9. BARRIER IMPACT FACILITY
10. DROP TOWER/SLED TEST FACILITY
11. CENTRAL DATA ACQUISITION AND CONTROL STATION
12. PENDULUM FACILITY
13. NONMETALLICS LABORATORY
14. TEST SERVICE FACILITY
15. VEHICLE-TO-VEHICLE TEST FACILITY
16. ROLLOVER TEST FACILITY
17. RIDE QUALITY COURSE
18. SKID PAD
19. HIGH AND LOW SKID NUMBER BRAKING LANES
20. SALT WATER TROUGH
21. BELGIAN BLOCK
22. PARKING BRAKE TEST RAMP
23. PULL-OFF AREA (TYPICAL OF THIRTEEN)
24. BALLISTIC TEST RANGE

Figure 4. The Dynamic Science Deer Valley Facility.

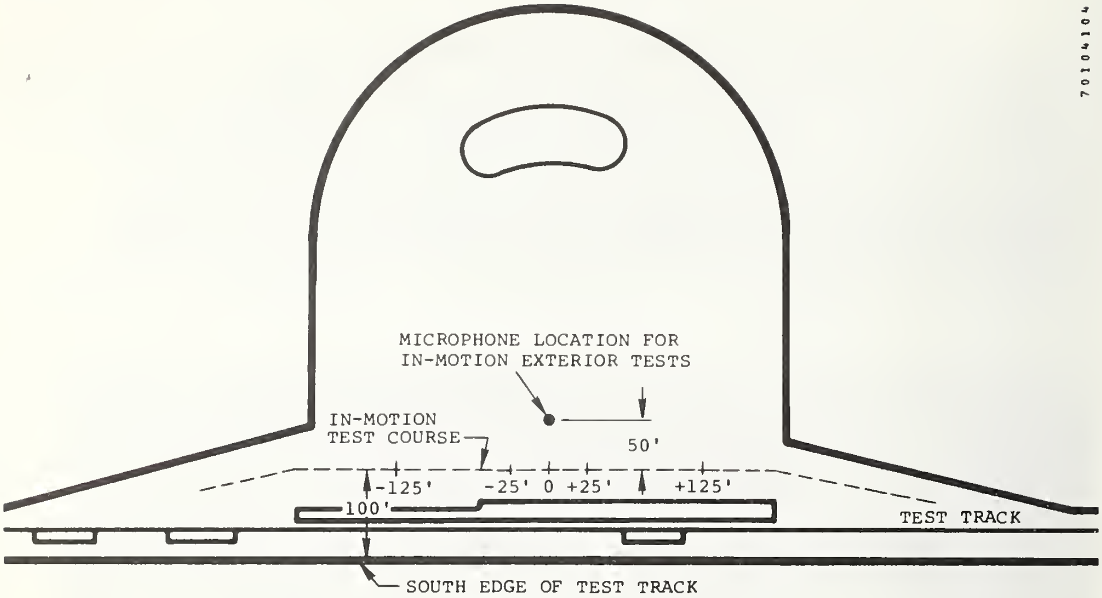


Figure 5. Facility Configuration for In-Motion Exterior Noise Tests.

The stationary test position was located on the skid pad per Figure 6 and the test area laid out with surface chalk marks as shown in Figure 7. The marks placed around the stationary test position at 15° intervals aided the positioning of the external microphone. The 6-1/2' to 8-1/2' distance marks along the centerline helped center the test vehicles directly over the test spot. The area within 50 feet of either vehicle or microphone positions was inspected for debris or unusual qualities.

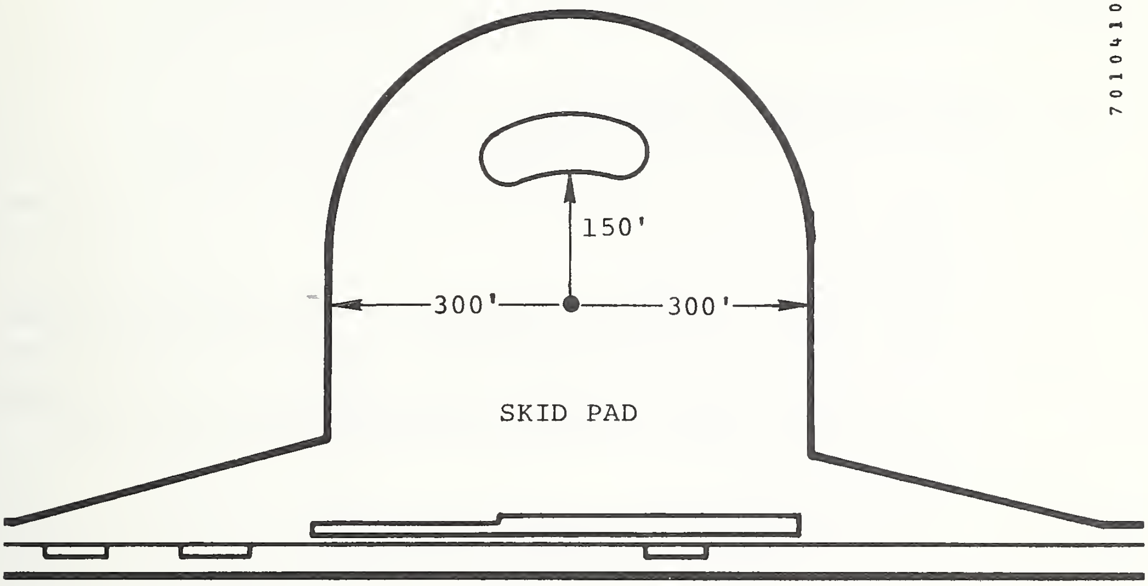


Figure 6. Stationary Noise Test Location.

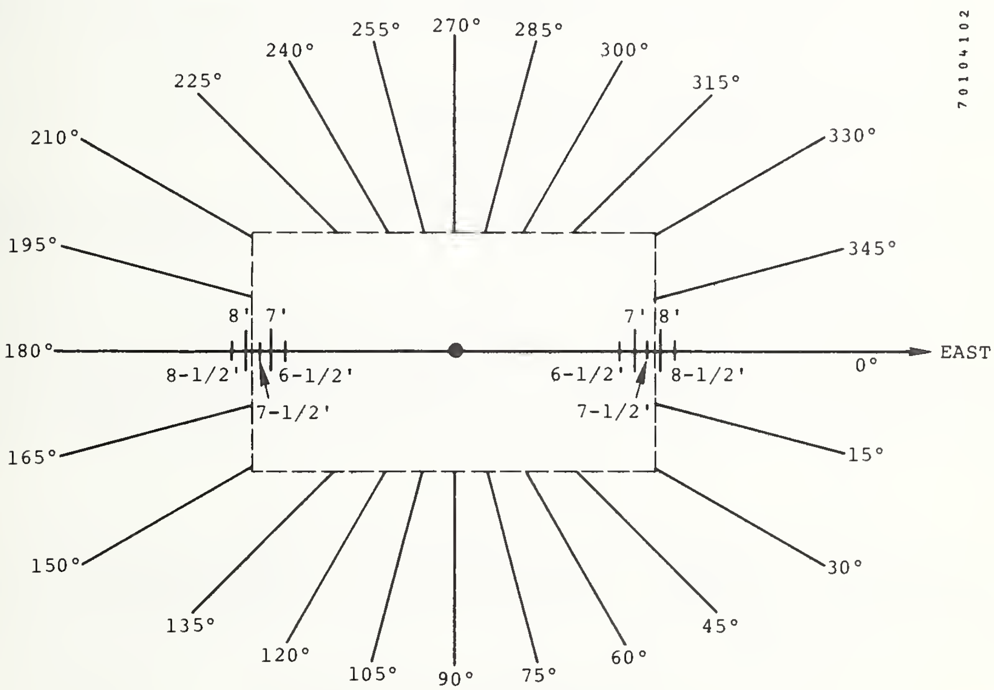


Figure 7. Stationary Test Position Layout.

5.0 TEST PROCEDURES

5.1 TEST INSTRUMENTATION

5.1.1 Required Measurements

The primary variables to be measured during the testing were:

1. Vehicle velocity.
2. The highest external noise levels generated by the vehicles during the test series.
3. The highest internal noise levels at the following four locations within the vehicles during the test series (see Figure 8):
   - Driver's location - D_1
   - Left rear seat passenger location - P_1
   - Right rear seat passenger location - P_2
   - Wheelchair passenger location in PTVs - P_{3W}
   - Right front passenger location in baseline vehicle - P_3.

5.1.2 Instrumentation Specifications

Table 3 presents the specifications for the instrumentation used in the noise testing.

A Labeco fifth wheel was used to measure vehicle velocity. The output of the fifth wheel was inputted into a Labeco DD-1.1 speedometer for visual display of velocity at the driver's location.

One precision sound level meter (B & K 2203) with matching microphone was used for the exterior noise measurements. It was set up as follows:

- Vehicle Stationary-at-Idle test condition - microphone mounted vertically upward, four feet above ground level and moved on five and ten foot perimeters in 15-degree increments around vehicle.

- All Exterior-in-Motion test conditions - microphone mounted vertically upward, four feet above ground level and located 50 feet from the centerline of the vehicle path.

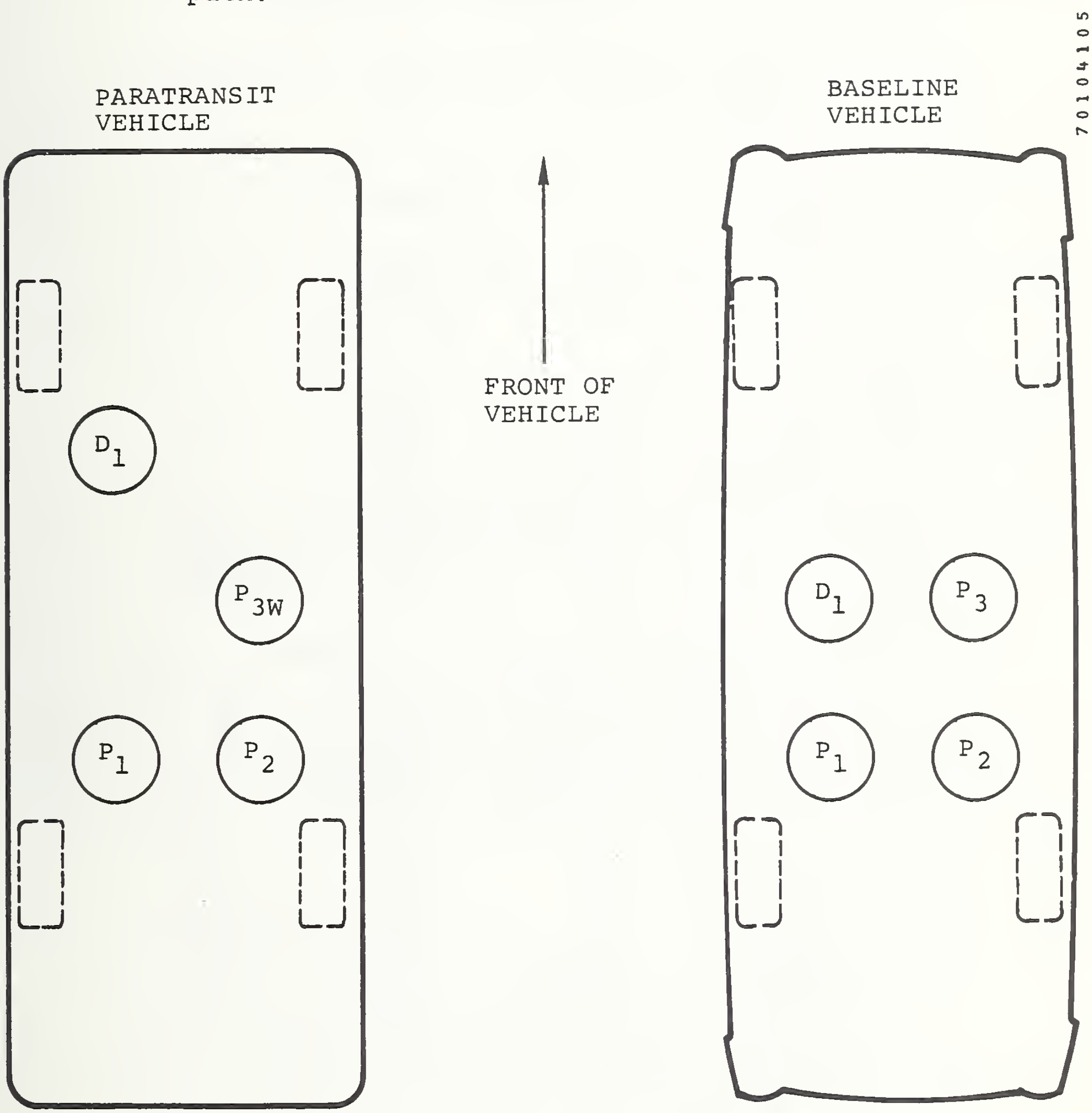


Figure 8. Interior Noise Measurement Locations.

TABLE 3. NOISE INSTRUMENTATION LIST

Measurement	Type of Transducer	Manufacturer and Model	Full-Scale Range	Full-Scale Transducer Accuracy	Quantity	Remarks
Vehicle Velocity	Fifth Wheel	Labeco TT481 With DD-1.1 Readout	100 mph	.5% FS	1	
Sound Level	Precision Sound Level Meter	B&K Model 2209 with 4134 Micro-phone	36 to 150 dBA 2Hz to 18KHz	±.5dB	1	Meets all requirements of ANSI S1.4-1971, Type 1 precision sound level meter.
Sound Level	Precision Sound Level Meter	B&K Model 2203 with 4134 Micro-phone	39 to 154 dBA 10 Hz to 18kHz	±.5dB	2	Meets all requirements of ANSI S1.4-1971, Type 1 precision sound level meter.
Sound Level Meter	Sound Level Calibrator	B&K Model 4220 Pistonphone	124dB Constant 250Hz	±.2dB	1	

Two precision sound level meters (B & K 2203 and B & K 2209) with matching microphones were used for the interior noise measurements and monitored two locations during each run. Since data on all four interior locations was required, each interior run was performed twice.

All meters were set for fast response and the A-weighting network.

5.1.3 Calibration Procedures

The following physical tests were performed to check the calibration of the instruments:

- The fifth wheel was spun up using the calibration motor. The tire pressure was adjusted to obtain proper calibration value.
- All sound level meters were calibrated with their respective microphones using the sound level calibrator and the procedures specified in the B & K Instruction Handbook.

The fifth wheel was calibrated prior to each day's testing. The sound level meters were calibrated before and after each series of test runs. In addition, the interior sound level meters were recalibrated every time they were repositioned inside the vehicle.

5.1.4 Data Acquisition

Noise level data were read directly from the sound level meters by the interior and exterior test monitors and were recorded after each test run on Test Data Log Sheets. The interior test monitor occupied the right rear passenger seat.

5.2 VEHICLE PREPARATION

The test vehicles were prepared by placing test dummies in the passenger seats of the vehicles and installing the instrumentation listed in Table 3.

The passenger loading for the two PTVs during all tests consisted of two rear seated and one wheelchair passenger. All tests for the baseline vehicle had two passengers in the rear seat and one passenger in the front right seat. Passengers were uninstrumented Alderson VIP-50 anthropomorphic dummies with close-fitting underwear, except that the passenger in the right rear seat of all vehicles for all tests was a test monitor whose physical characteristics were as close to 50th percentile as possible.

Microphone positions were established at the four interior occupant locations as follows:

- Driver (D_1) and left rear seat passenger (P_1) - microphone supported vertically downward from ceiling, motion restricted, and positioned so as to be reasonably aligned with and approximately 6 inches laterally to the right of the occupant's right ear.
- Right rear seat passenger (P_2) and baseline vehicle right front seat passenger (P_3) - microphone supported vertically downward from ceiling, motion restricted, and positioned so as to be reasonably aligned with and approximately 6 inches laterally to the left of the occupant's left ear.
- Wheelchair passenger (P_{3W}) - microphone supported vertically downward from ceiling, motion restricted, and positioned so as to be reasonably aligned with and approximately 6 inches laterally from the occupant's ear towards the center of the vehicle.

The fifth wheel installation and its accompanying visual readout are shown in Figures 9 and 10. Typical microphone installations are shown in Figures 11 and 12. The sound level meters were hand held by the interior test monitor.

5.3 TEST CONDUCT

5.3.1 General Test Conditions

The exterior and interior noise tests were run according to the conditions listed in Tables 4 and 5. During all but one of the six test conditions (Test 6 in the interior noise tests), interior noise measurements were made simultaneously with the external noise measurements.

The engine temperature was held within the normal operating range throughout each run. A one-minute cooling-off period with engine at idle in neutral was required between acceleration runs. Measurements were made only when wind speed was below 10 mph. Vehicle windows and vents were in the fully closed position and all accessories were off.

Detailed descriptions of the individual test conditions are given in the following paragraphs.

5.3.2 Test Condition Number 1 - Accelerating from 30 mph to Maximum Rated Engine Speed

This test was made up of eight test runs along the course illustrated in Figure 5.

From an approach speed of 30 mph, wide open throttle was established when the front of the vehicle reached a line 25 feet before the line through the microphone normal to the vehicle path. The lowest transmission gear or range was used such that the front

Figure 9. Fifth Wheel Installation on ASL PTV.

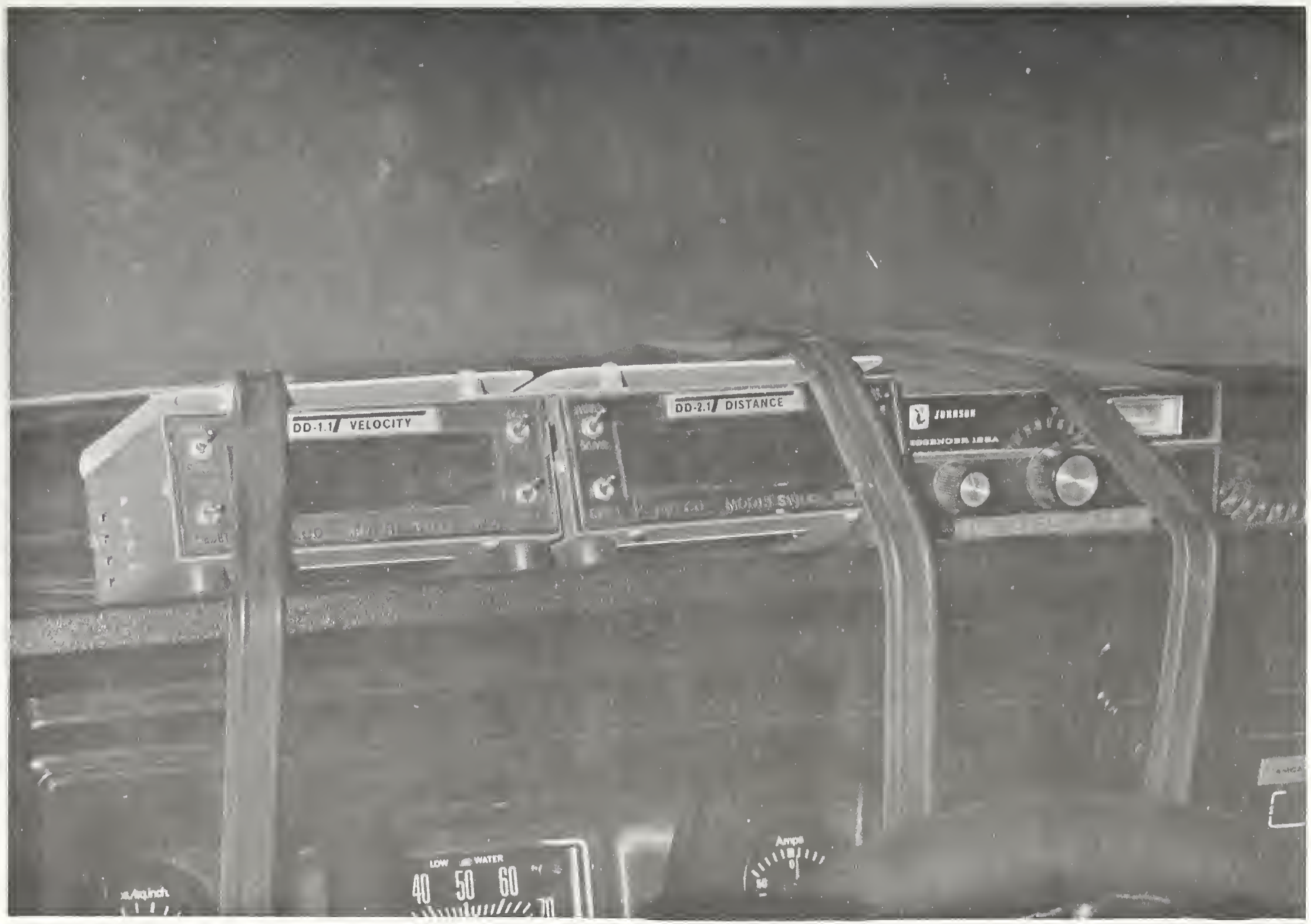


Figure 10. Fifth Wheel Readout Inside ASL PTV.

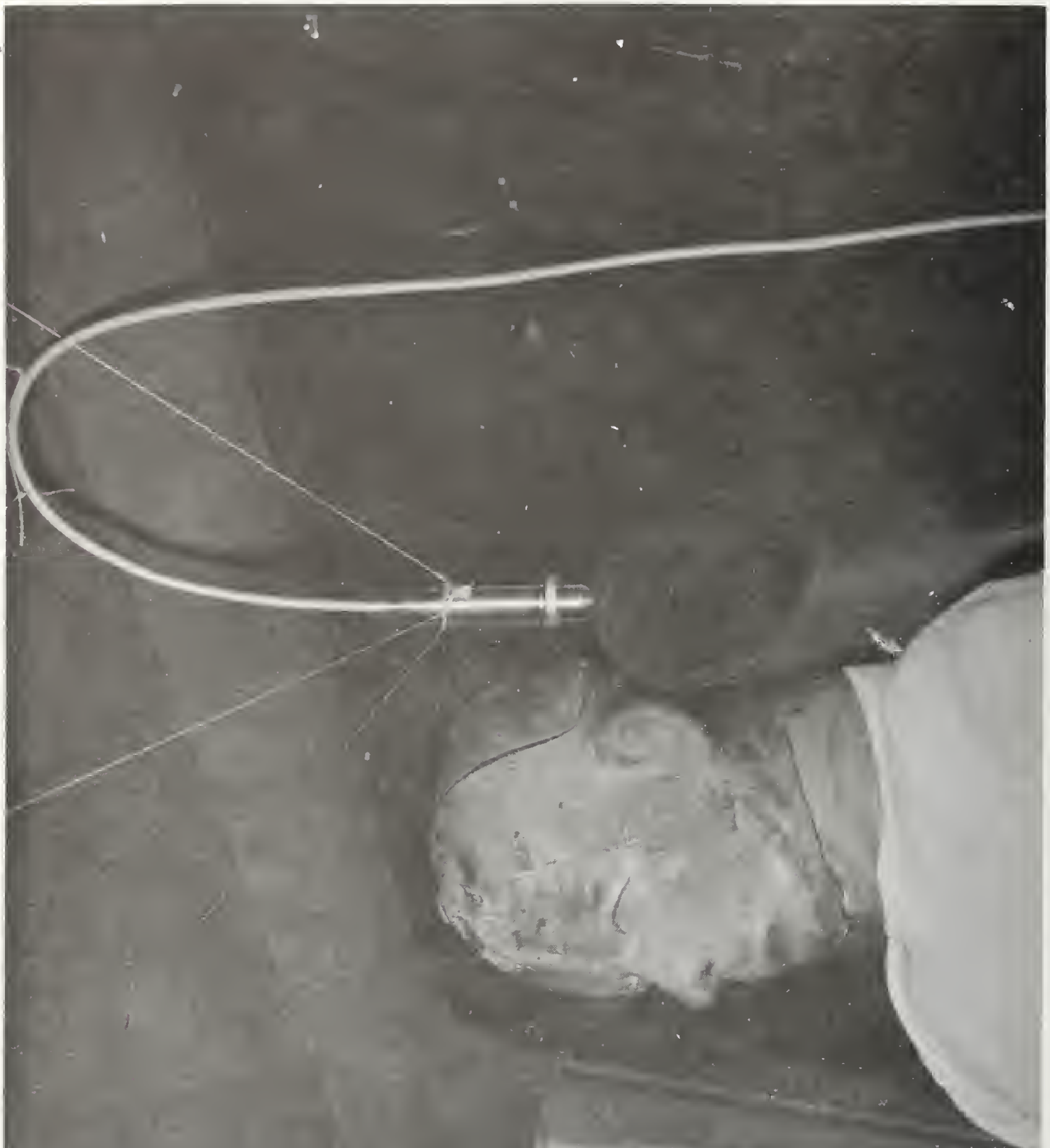


Figure 11. Microphone Placement Near Wheelchair Passenger in Dutcher PTV.

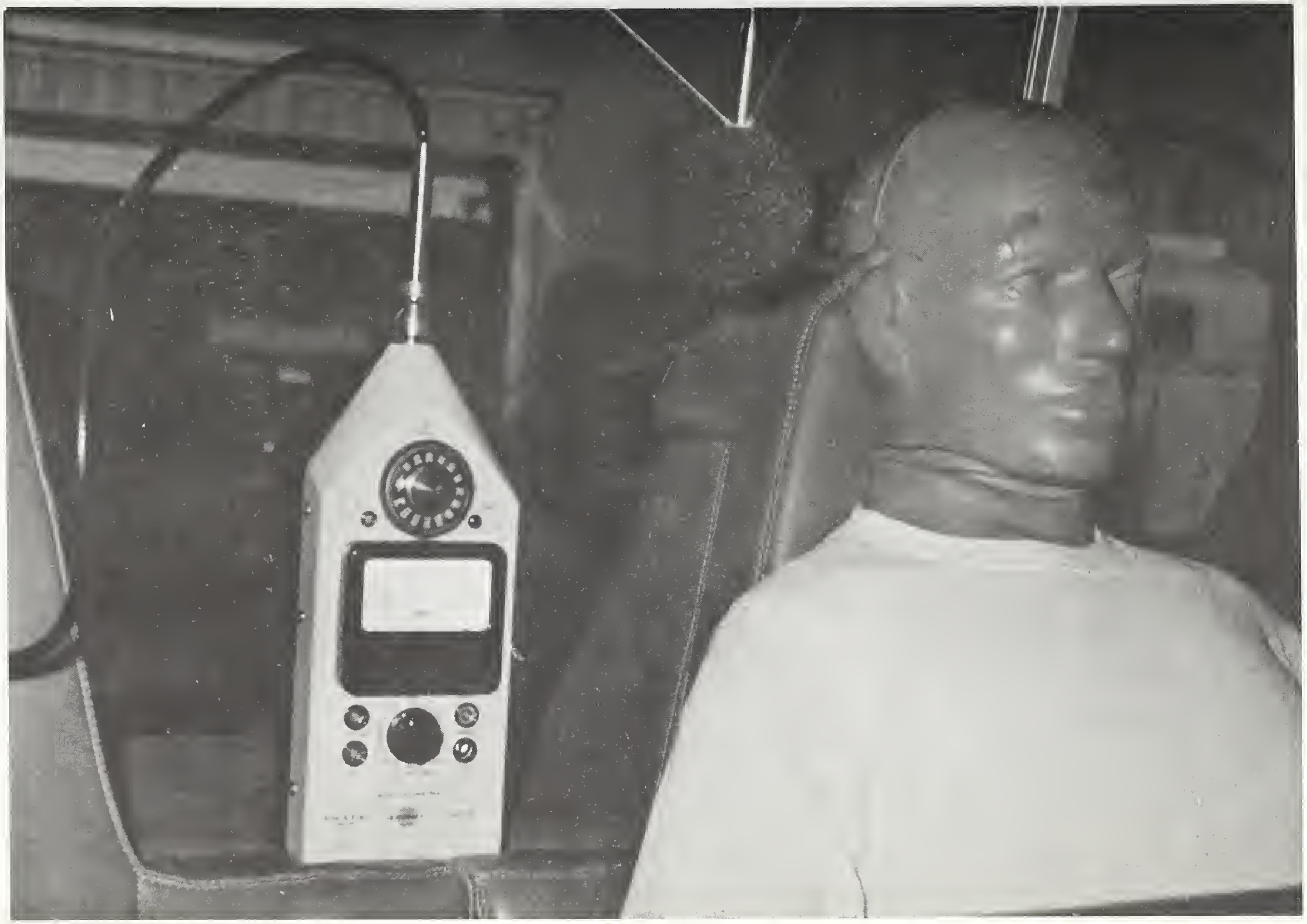


Figure 12. Microphone Placement Near Rear Seat Passenger in Dutcher PTV.

TABLE 4. EXTERIOR NOISE TEST MATRIX

Test No.	Test Description	No. of Runs	No. of Vehicles
1	Accelerating from 30 mph to maximum rated engine speed*	4 Right and 4 Left	3
2	Constant Speed, Passing at 15 mph*	4 Right and 4 Left	3
3	Constant Speed, Passing at 30 mph*	4 Right and 4 Left	3
4	Constant Speed, Passing at 55 mph*	4 Right and 4 left	3
5	Stationary, with Engine Idle in Neutral (survey every 15° at 5' and 10' perimeters)**	2 Perimeters x 24 Positions	3

*Per SAE J986a.
**Per SAE J994a.

of the vehicle reached or passed a line 25 feet beyond the microphone line when maximum rpm was reached. The throttle was then closed enough to prevent further acceleration and the test continued until the vehicle reached a line 125 feet beyond the microphone line.

The exterior microphone was set up 50 feet from the centerline of the vehicle path at a height of four feet above the ground plane and pointed vertically upward (see Figures 13 and 14). The test runs were conducted with the vehicle traveling west and east alternately so that measurements were obtained on the sound levels for each side of the vehicle. Two interior locations were

TABLE 5. INTERIOR NOISE TEST MATRIX

Test No.	Test Description	No. of Runs*	No. of Vehicles
1	Accelerating from 30 mph to maximum rated engine speed	8**	3
2	Constant Speed - 15 mph	8**	3
3	Constant Speed - 30 mph	8**	3
4	Constant Speed - 55 mph	8**	3
5	Stationary, with Engine Idle in Neutral	1***	3
6	Accelerating from 0 to 45 mph	8	3

*Two of the four occupants monitored during each run.
**These runs are concurrent with exterior noise tests.
***This run is concurrent with exterior noise survey.

measured during the first four runs and then the microphones were repositioned to monitor the remaining two positions on the final four runs.

5.3.3 Test Condition Number 2 - Constant Speed at 15 mph

This test was also made up of eight test runs along the course shown in Figure 5. A constant speed of 15 mph was established along the course and the maximum exterior and interior noise levels were obtained while the vehicle traversed the region from 100 feet before the exterior microphone position to 100 feet after the microphone position.

Microphone placement, run directions, and interior measurements were identical to those of Test Condition Number 1.

Figure 13. Test Setup for Vehicle-in-Motion Exterior Noise Measurements (View Facing South).

Figure 14. Test Setup for Vehicle-in-Motion Exterior Noise Measurements (View Facing North).

5.3.4 Test Condition Number 3 - Constant Speed at 30 mph

This test was run exactly like Test Condition Number 2 except that a constant speed of 30 mph was used.

5.3.5 Test Condition Number 4 - Constant Speed at 55 mph

This test was conducted exactly like Test Condition Number 2 and Number 3 except that a constant speed of 55 mph was used.

5.3.6 Test Condition Number 5 - Stationary-at-Idle

With the vehicle stationary-at-idle, in neutral, with all doors, windows, and vents closed and accessories off, the maximum steady state exterior noise levels were determined at 15-degree intervals on a 5-foot and 10-foot perimeter around the vehicle as illustrated in Figure 7 (Section 4.0). The first position tested was 5 feet from the front bumper and along the 0-degree axis. Subsequent measurements were taken in a clockwise direction at 5 feet out from the vehicle along the 15-degree radial markers. Upon completion of the 5-foot perimeter analysis, the exterior microphone was repositioned and recalibrated for the 10-foot perimeter analysis. Measurements were then taken around the 10-foot perimeter following the same procedure as for the 5-foot perimeter.

The steady state maximum interior noise levels at two of the four occupant positions were determined by an interior test monitor during the 5-foot perimeter exterior noise test. The interior microphones were then repositioned and recalibrated and the noise level of the remaining two passenger positions were obtained during the 10-foot perimeter exterior noise tests.

5.3.7 Test Condition Number 6 - Accelerating from 0 to 45 mph

Only interior measurements of maximum sound levels at the four occupant locations were obtained for this test condition.

The test was made up of eight test runs along the course laid out in Figure 5. Starting points were established and marked at each end of the course such that the vehicle was able to accelerate from a stationary position with wide open throttle and obtain 45 mph without deviating from a straight line. The driver accelerated the vehicle with wide open throttle until reaching 45 mph. He then signaled the interior test monitor and maintained 45 mph for several seconds prior to decelerating. Interior sound level meters were observed by the test monitor while the vehicle was accelerating. The highest sound level indicated during the portion of the run up to 45 mph was recorded.

The test runs were conducted with the vehicle traveling west and east alternately.

After the first four runs, the interior microphones were repositioned and recalibrated in order to obtain data on the other two passenger locations during the final four test runs.

5.4 PROBLEMS ENCOUNTERED DURING TESTING

Problems and failures are to be expected in the normal operation of prototype vehicles. Several minor problems occurred with the PTV prototypes during the noise tests.

The ASL prototype was very hard to start when cold. The prototype vapor locked two times during testing after it had been sitting at idle. The vehicle was taken to an Audi dealer for fuel system repairs to eliminate these problems. (The ASL PTV was powered by a 1975 Audi 100LS engine.)

In addition, the door opening system developed a problem on the ASL prototype, preventing the closing of the left passenger door. Problems also developed with the Dutcher prototype's hydraulic system which prevented the opening of its passenger doors. Both systems were repaired by personnel from the respective prototype manufacturers.

6.0 TEST RESULTS

6.1 EXTERIOR NOISE TESTS

The sound levels measured during the exterior noise tests of the three vehicles are summarized in Table 6. The measurements presented for the in-motion tests (Test Types 1-4) are the average of the two highest readings which were within 2 dB of each other. The stationary test measurements presented in Table 6 (Test Type 5) are the highest measurements recorded anywhere along the perimeter line.

TABLE 6. SUMMARY OF EXTERIOR NOISE TEST RESULTS

Test Type	Location	Nova (Baseline) (dBA)	ASL PTV (dBA)	Dutcher PTV (dBA)
1	Right Side	70.50	74.75	80.50
	Left Side	73.25	77.75	80.25
2	Right Side	52.25	55.75	59.25
	Left Side	54.25	55.75	59.50
3	Right Side	59.00	60.25	66.75
	Left Side	60.00	60.50	67.00
4	Right Side	66.75	69.50	72.25
	Left Side	68.75	70.00	74.75
5	5-ft Perimeter	68.50	72.00	74.50
	10-ft Perimeter	65.50	68.50	71.50

Notes: Test 1: Accelerating from 30 mph to maximum rated engine speed.
Test 2: Constant speed, passing at 15 mph.
Test 3: Constant speed, passing at 30 mph.
Test 4: Constant speed, passing at 55 mph.
Test 5: Stationary, with engine idle, in neutral.

A comparison of the maximum noise levels of the vehicles with the PTV design goals and the limit recommended in SAE Standard J986a is presented in Table 7. (The maximum levels for Test Type 1-4 are the readings from the loudest side of the vehicle.)

Test Type	Nova (Baseline) (dBA)	ASL Prototype (dBA)	Dutcher Prototype (dBA)	PTV Design Goal (dBA)	SAE Standard (dBA)
1	73.25	77.75	80.50	76	86
2	54.25	55.75	59.50	63	--
3	60.00	60.50	67.00	63	--
4	68.75	70.00	74.75	76	--
5	68.50	72.00	74.50	62	--

TABLE 7. COMPARISON OF EXTERIOR NOISE TEST RESULTS

Notes: Test 1: Accelerating from 30 mph to maximum rated engine speed.
Test 2: Constant speed, passing at 15 mph.
Test 3: Constant speed, passing at 30 mph.
Test 4: Constant speed, passing at 55 mph.
Test 5: Stationary, with engine idle, in neutral.

Table 7 shows that the Nova baseline car was quieter than either of the two PTV prototypes in all of the exterior tests. The Dutcher PTV was somewhat noiser than the ASL prototype in all tests. Neither of the two prototypes met the PTV design goals for the acceleration test (Test Type 1) or the stationary at idle test (Test Type 5), although both vehicles were well under the acceleration test limits recommended by SAE J986a.

The results of the constant speed noise tests are presented graphically in Figure 15. This figure shows that all three vehicles met the PTV design goals for the constant speed tests with one exception. The Dutcher prototype noise level at 30 mph was 4 dBA higher than the design goal.

The noise measurements recorded for the stationary, at idle tests for the Nova, ASL and Dutcher vehicles are presented in Tables 8, 9, and 10 respectively. Graphical representations of these data are shown in Figures 16, 17, and 18. These figures show that the noise levels of all three vehicles did not diminish

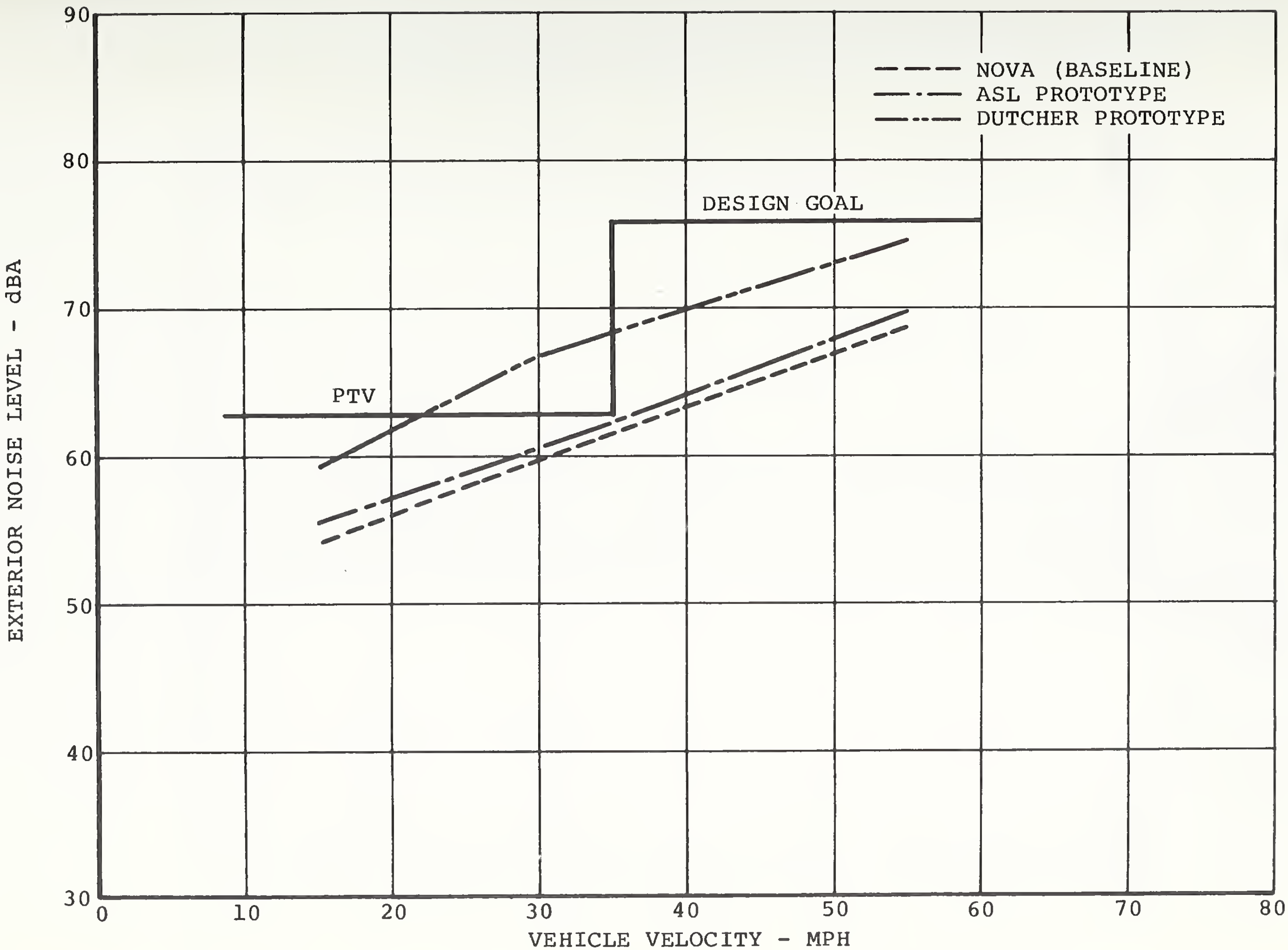


Figure 15. Comparison of Exterior Noise Levels Versus Velocity.

TABLE 8. RESULTS OF STATIONARY NOISE TESTING FOR THE NOVA (BASELINE)

Exterior Measurement		
	Noise Level	
Radial Angle	5-Foot Perimeter	10-Foot Perimeter
0°	68.5	65.5
15	68.5	65.0
30	67.5	64.0
45	67.0	63.5
60	65.5	63.0
75	65.5	61.5
90	65.0	61.5
105	63.5	61.5
120	63.0	61.0
135	62.5	60.0
150	59.0	58.0
165	56.5	55.0
180	56.5	53.0
195	56.0	54.0
210	60.0	58.5
225	62.0	60.5
240	64.0	61.5
255	64.5	61.0
270	65.0	62.0
285	66.0	62.5
300	66.5	63.0
315	67.5	64.0
330	68.0	65.0
345	68.5	65.0

TABLE 9. RESULTS OF STATIONARY NOISE TESTING FOR THE ASL PROTOTYPE

Exterior Measurement		
	Noise Level	
Radial Angle	5-Foot Perimeter	10-Foot Perimeter
0°	72.0	68.5
15	70.5	68.0
30	70.5	68.5
45	67.5	65.0
60	68.0	65.5
75	69.0	61.5
90	64.5	62.5
105	65.5	61.5
120	64.0	61.5
135	64.0	61.5
150	62.5	61.5
165	62.0	59.5
180	61.5	59.0
195	62.0	59.5
210	64.5	61.5
225	66.0	62.0
240	66.0	63.0
255	66.5	63.0
270	66.0	63.0
285	66.5	64.0
300	67.5	65.0
315	68.5	66.0
330	70.0	67.0
345	71.5	68.0

TABLE 10. RESULTS OF STATIONARY NOISE TESTING FOR THE DUTCHER PROTOTYPE

Exterior Measurement		
	Noise Level	
Radial Angle	5-Foot Perimeter	10-Foot Perimeter
0°	62.5	60.5
15	61.5	61.5
30	63.0	62.0
45	66.5	65.0
60	66.5	64.5
75	67.5	66.5
90	69.5	67.5
105	70.0	68.0
120	72.0	70.5
135	72.5	70.5
150	73.5	71.0
165	73.0	70.0
180	74.5	70.5
195	73.5	69.5
210	74.0	71.5
225	73.5	71.0
240	70.5	70.5
255	70.5	68.5
270	70.5	67.0
285	69.0	67.0
300	68.5	66.0
315	69.0	65.5
330	65.5	63.0
345	63.0	61.5

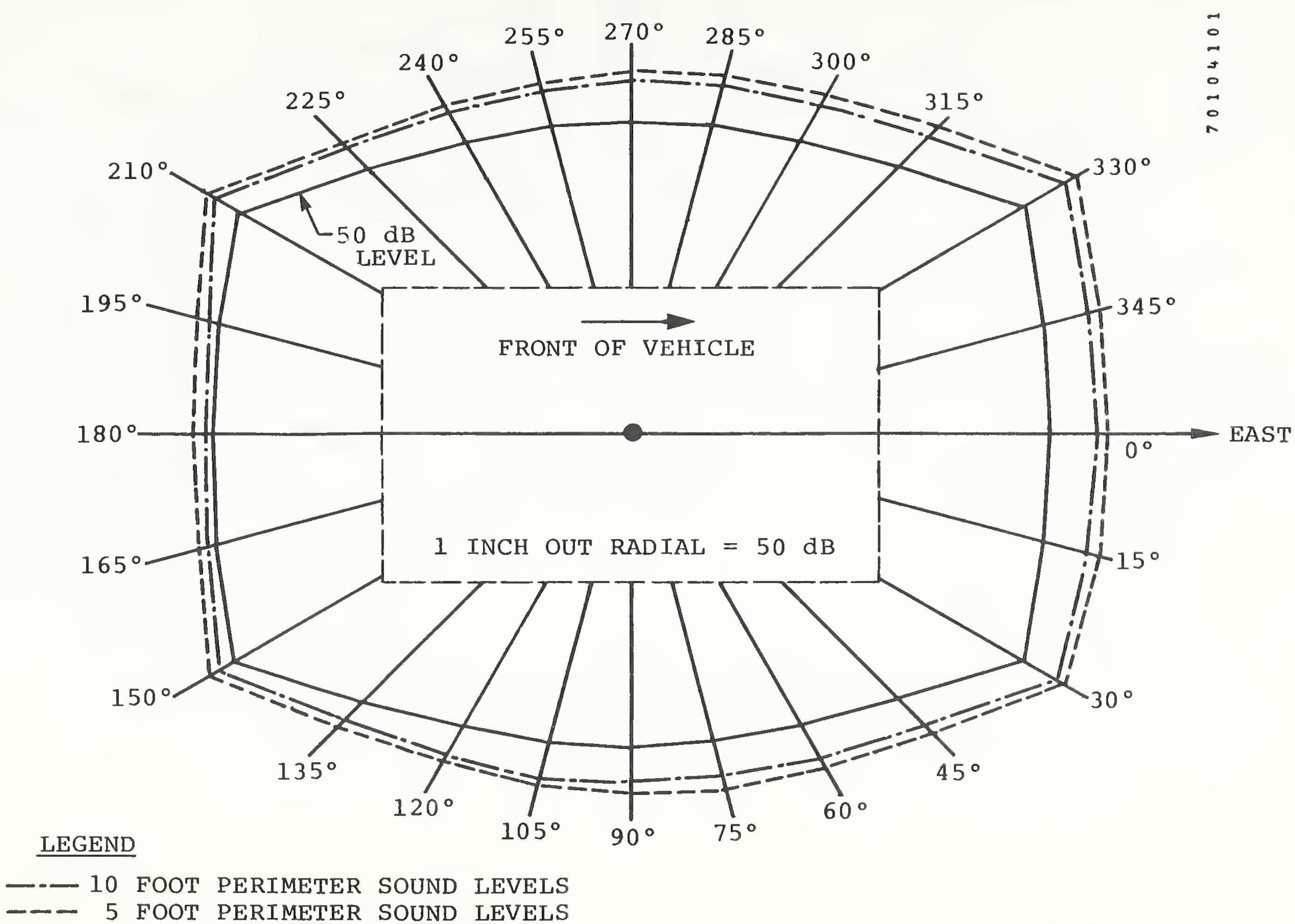


Figure 16. Exterior Perimeter Noise Patterns for the Nova (Baseline).

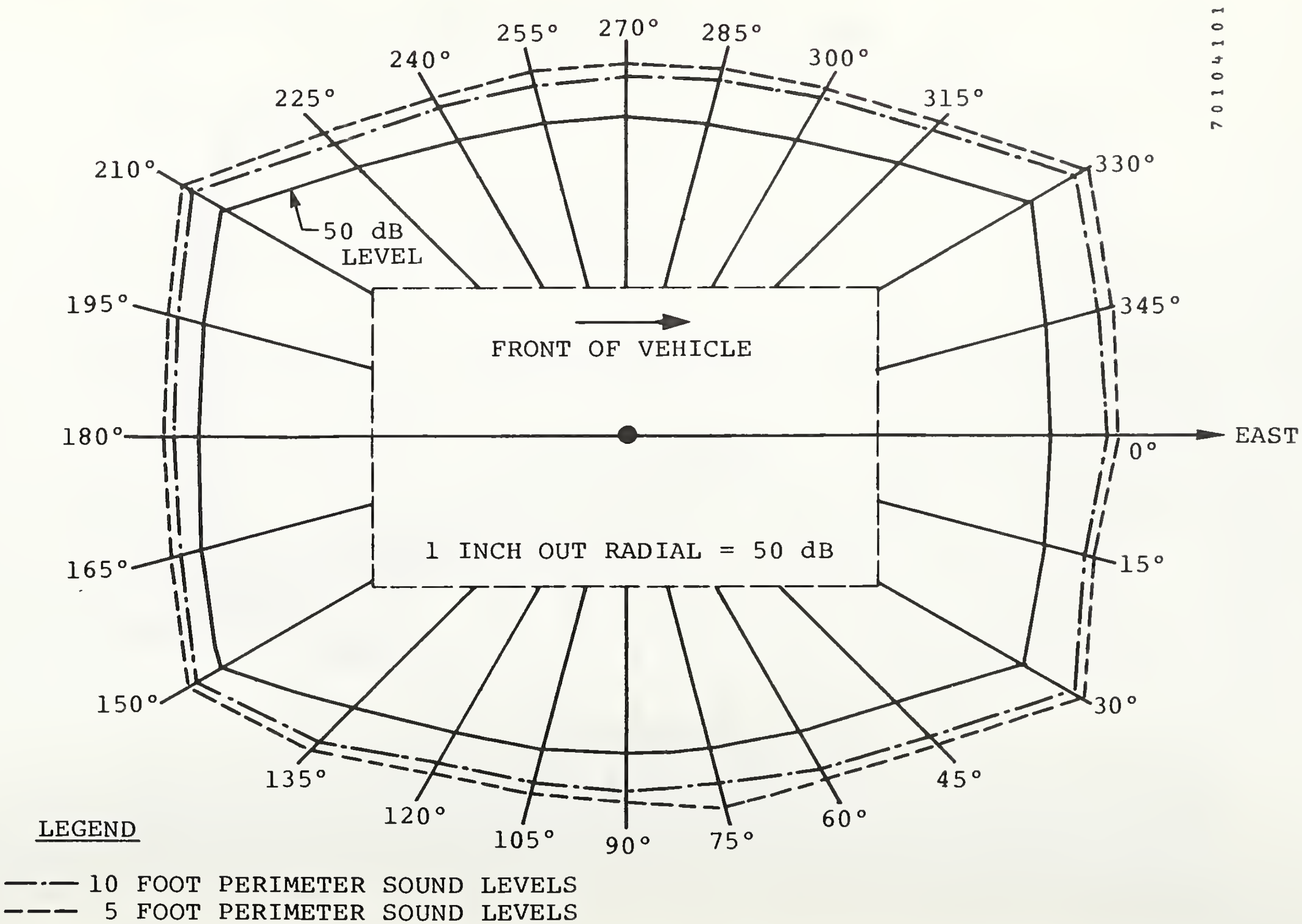


Figure 17. Exterior Perimeter Noise Patterns for the ASL Prototype.

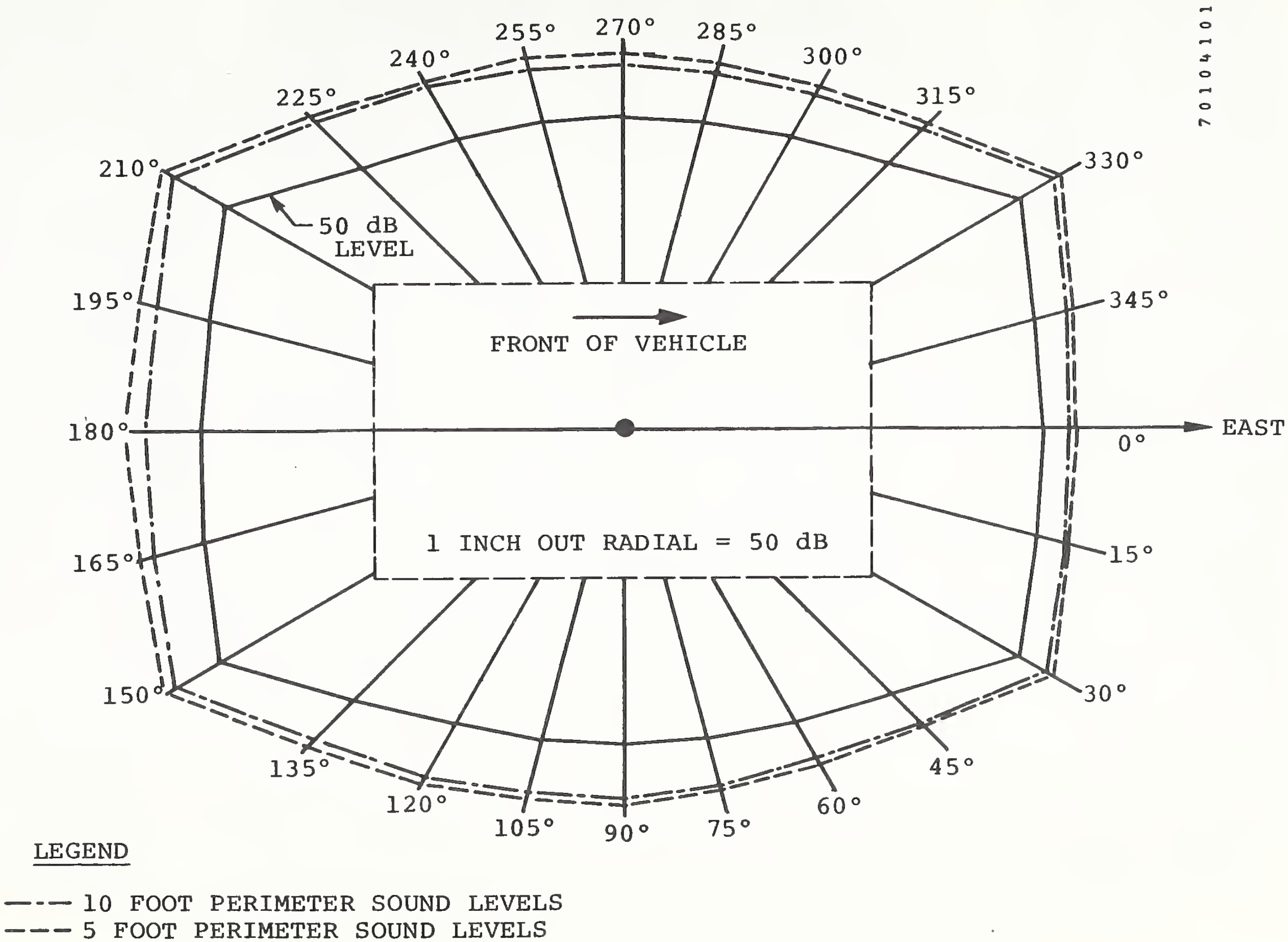


Figure 18. Exterior Perimeter Noise Patterns for the Dutcher Prototype.

more than 3 to 4 dBA in moving from the 5-foot to the 10-foot perimeter line.

The noise patterns of all three vehicles are compared at the 5-foot and 10-foot perimeter lines in Figures 19 and 20 respectively. These figures show that the noise patterns of the Nova and the ASL prototype are quite similar, with the ASL being somewhat noisier than the Nova at the rear of the vehicle. As might be expected, the rear-engine Dutcher is noisier at the rear and quieter at the front than are the Nova and ASL.

6.2 INTERIOR NOISE TESTS

The results of the interior noise tests are listed in Table 11. Although there are some variations in noise levels inside each vehicle, most passenger and driver positions levels in a particular vehicle were within 4 to 5 dBA of each other with the exception of the levels in the ASL prototype during Test Type 1. During this acceleration test, the driver's noise level was consistently 10 dBA or more higher than any of the passenger positions.

The maximum interior noise levels of the three vehicles are presented in Table 12. As with the exterior noise levels, the Nova was quieter than either of the two PTV prototypes. The Dutcher was somewhat noisier than the ASL vehicle. Neither of the two prototypes met the PTV low-speed or high-speed design goals, although the ASL did meet the low-speed goal during the stationary, at idle test.

The maximum interior noise levels for the constant speed tests (Test Types 2-4) are shown graphically in Figure 21. In addition to showing the relative noise levels of the three vehicles, this figure also shows that the increase in noise level with increasing velocity rises at a slightly higher rate in the two PTV prototypes than it does in the baseline Nova.

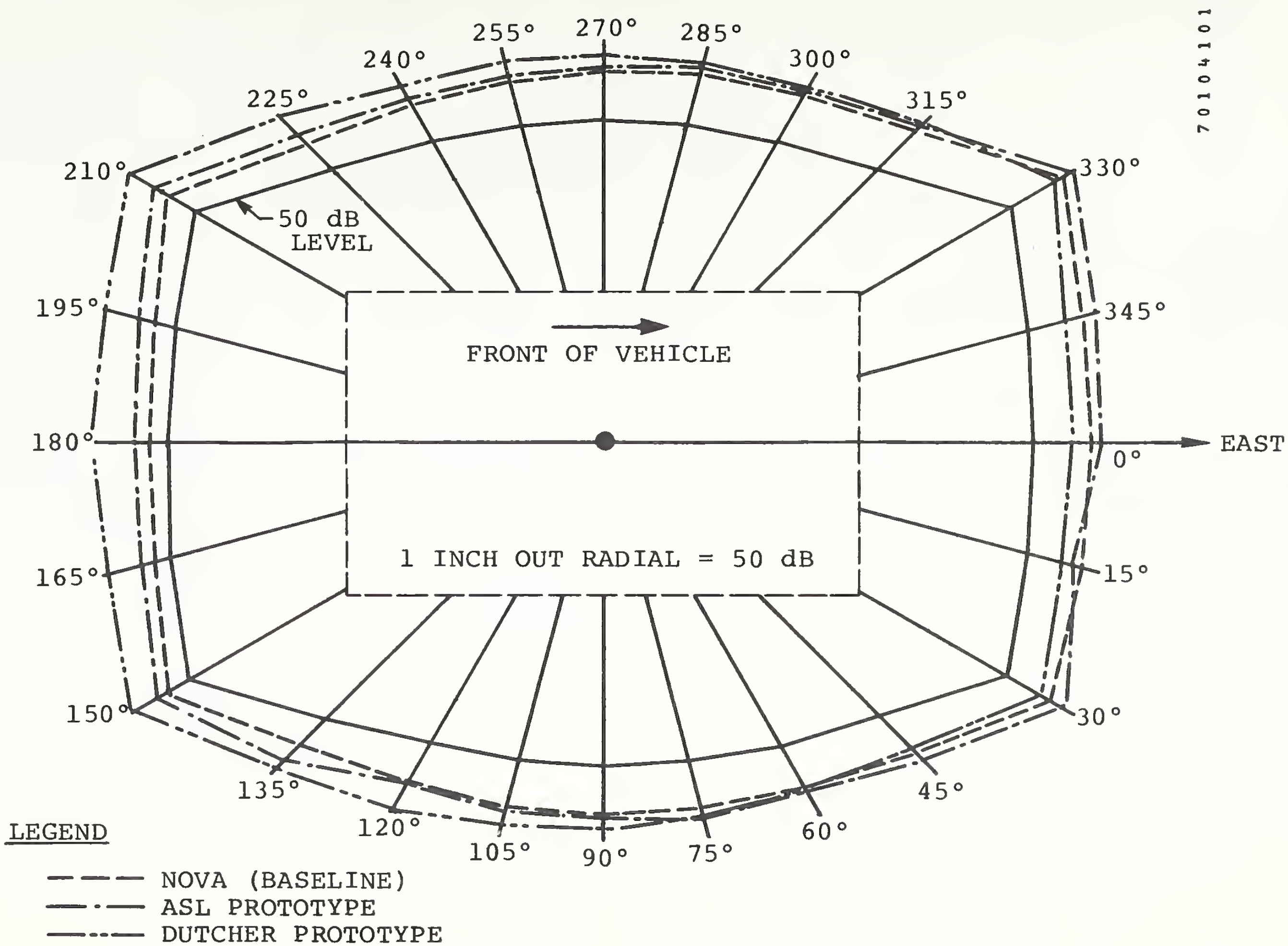


Figure 19. Comparison of Exterior Perimeter Noise Patterns at 5-foot Perimeter Line.

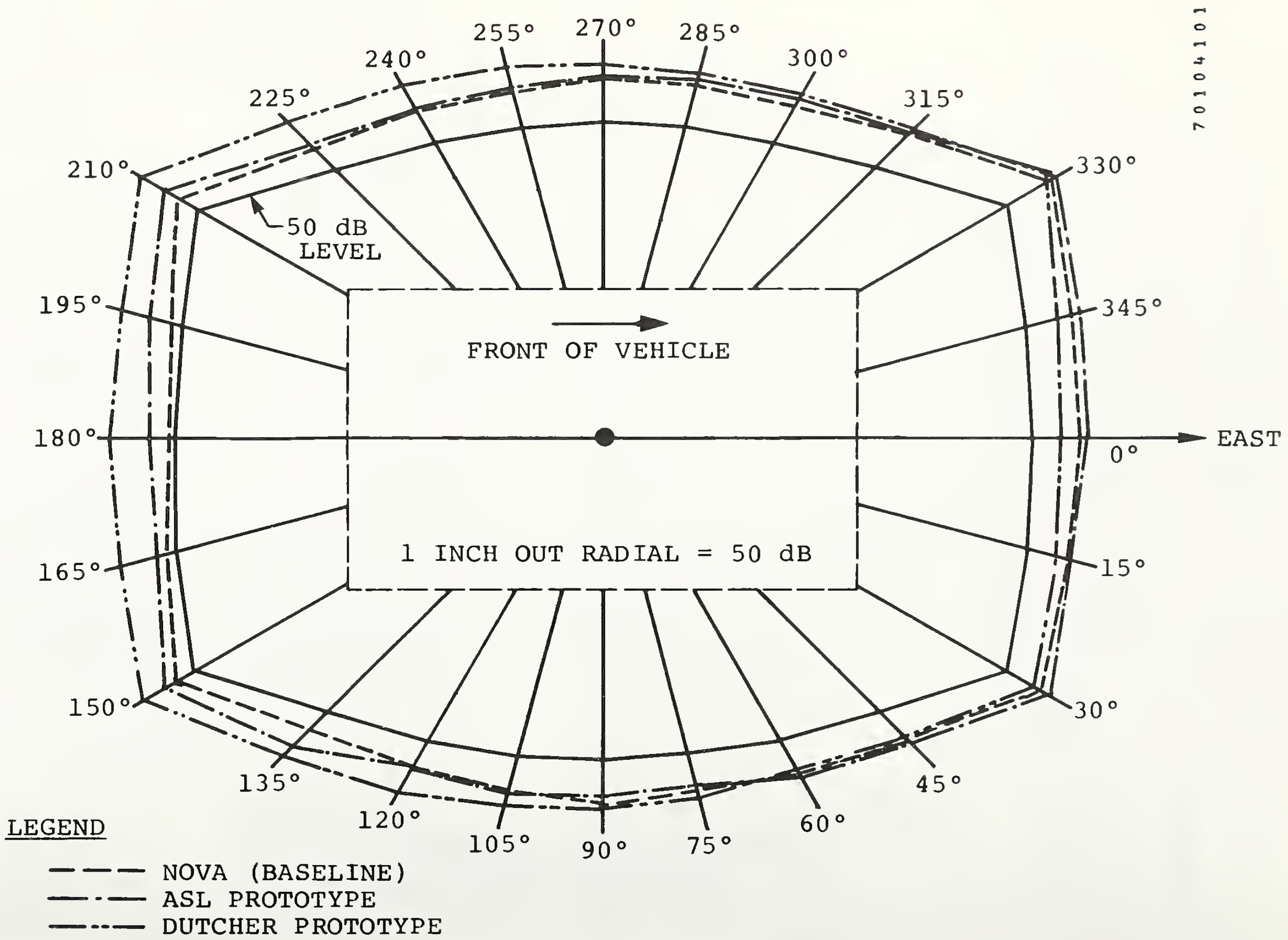


Figure 20. Comparison of Exterior Perimeter Noise Patterns at 10-foot Perimeter Line.

Test Type	Occupant	Nova (Baseline) (dBA)	ASL Prototype (dBA)	Dutcher Prototype (dBA)	PTV Design Goal (dBA)
TABLE 11. RESULTS OF INTERIOR NOISE TESTS					
1	P_1	78.00	78.00	89.00	76
	P_2	76.00	77.50	89.00	76
	P_3/P_{3w}	72.25	79.25	89.00	76
	D_1	71.75	89.25	84.25	76
2	P_1	60.25	63.50	68.50	65
	P_2	59.75	62.00	67.75	65
	P_3/P_{3w}	56.50	65.50	69.25	65
	D_1	56.25	66.25	65.25	65
3	P_1	65.25	66.50	73.75	65
	P_2	64.50	65.75	73.50	65
	P_3/P_{3w}	63.25	69.25	74.50	65
	D_1	63.25	69.25	72.00	65
4	P_1	71.75	76.50	81.00	76
	P_2	71.75	76.00	81.00	76
	P_3/P_{3w}	69.00	77.00	84.25	76
	D_1	69.75	79.50	78.00	76
5	P_1	50.50	62.00	66.50	65
	P_2	52.50	59.50	66.00	65
	P_3/P_{3w}	48.50	64.50	66.50	65
	D_1	50.00	63.00	62.50	65
6	P_1	75.50	76.00	87.00	76
	P_2	76.00	76.50	89.50	76
	P_3/P_{3w}	72.00	77.50	88.00	76
	D_1	72.50	81.50	84.25	76

Notes: Test 1: Accelerating from 30 mph to maximum rated engine speed.
Test 2: Constant speed, 15 mph.
Test 3: Constant speed, 30 mph.
Test 4: Constant speed, 55 mph.
Test 5: Stationary, with engine idle, in neutral.
Test 6: Accelerating from 0 to 45 mph.

P_1 = Left Rear Passenger; P_2 = Right Rear Passenger; P_3 = Right Front Passenger

P_{3w} = Wheelchair Passenger; D_1 = Driver

TABLE 12. COMPARISON OF MAXIMUM INTERIOR NOISE LEVELS

Test Type	Nova (Baseline) (dBA)	ASL PTV (dBA)	Dutcher PTV (dBA)	PTV Design Goal (dBA)
1	78.00	89.25	89.00	76
2	60.25	66.25	69.25	65
3	65.25	69.25	74.50	65
4	71.75	79.50	84.25	76
5	52.50	64.50	66.50	65
6	76.00	81.50	89.50	76

Notes:
Test 1: Accelerating from 30 mph to maximum rated engine speed.
Test 2: Constant speed, 15 mph.
Test 3: Constant speed, 30 mph.
Test 4: Constant speed, 55 mph.
Test 5: Stationary, with engine idle, in neutral.
Test 6: Accelerating from 0 to 45 mph.

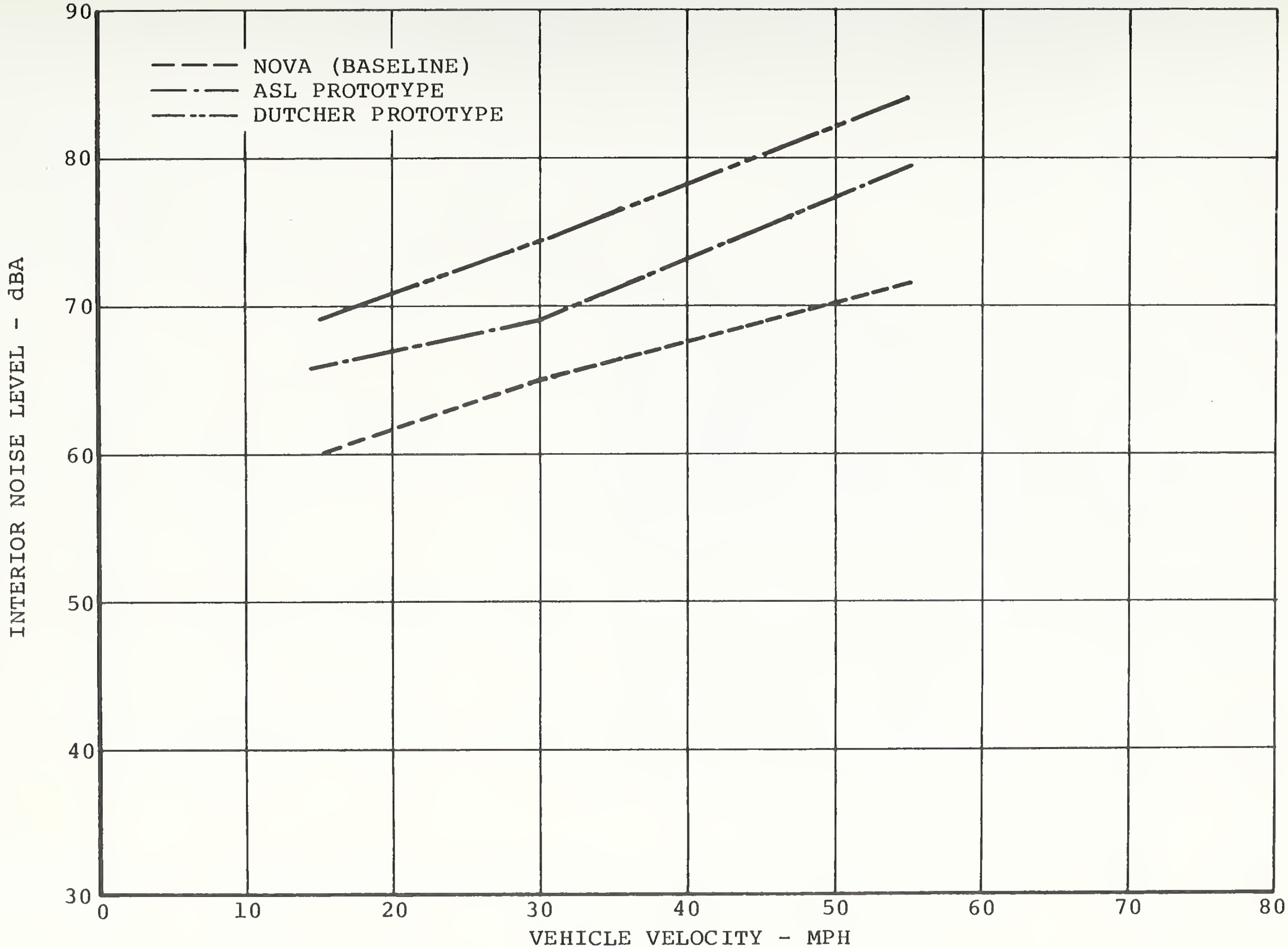


Figure 21. Comparison of Interior Noise Levels Versus Velocity.

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