Test Results on a Mercedes-Benz 220D Diesel Sedan Equipped with a Comprex Pressure Wave Supercharger

August 1975

Technology Assessment and Evaluation Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Environmental Protection Agency

Background

The Environmental Protection Agency receives information about many systems which appear to offer potential for emission reduction or fuel economy improvement compared to conventional engines and vehicles. EPA's Emission Control Technology Division is interested in evaluating all such systems, because of the obvious benefits to the Nation from the identification of systems that can reduce emissions, improve economy, or both. EPA invites developers of such systems to provide complete technical data on the system's principle of operation, together with available test data on the system. In those cases for which review by EPA technical staff suggests that the data available show promise, attempts are made to schedule tests at the EPA Emissions Laboratory at Ann Arbor, Michigan. The results of all such test projects are set forth in a series of Technology Assessment and Evaluation Reports, of which this report is one.

The conclusions drawn from the EPA evaluation tests are necessarily of limited applicability. A complete evaluation of the effectiveness of an emission control system in achieving performance improvements on the many different types of vehicles that are in actual use requires a much larger sample of test vehicles than is economically feasible in the evaluation test projects conducted by EPA. For promising systems it is necessary that more extensive test programs be carried out.

The conclusions from the EPA evaluation test can be considered to be quantitatively valid only for the specific test car used; however, it is reasonable to extrapolate the results from the EPA test to other types of vehicles in a directional or qualitative manner i.e., to suggest that similar results are likely to be achieved on other types of vehicles.

The Diesel engine has long been recognized as a vehicle powerplant capable of achieving excellent fuel economy. It also has inherently low gaseous emissions. Because of these qualities EPA is interested in the Diesel for use in light duty vehicles. As the domestic automotive industry does not produce anything but conventional gasoline engine powered automobiles, it was necessary to obtain Diesel powered test vehicles from foreign manufacturers. Report no. 75-21 by the Technology Assessment and Evaluation Branch summarizes the results of the emission characterizations of several Diesel vehicles.

One drawback of the Diesel engine has been its lower power-to-weight ratio compared to the conventional gasoline engine. For a given engine weight Diesels routinely have only about 60% of the power output of gasoline engines. The Diesel powered vehicles covered in report 75-21 had less horsepower than their gasoline engine powered counterparts. The vehicle weight-to-horsepower ratio for the cars tested was in the range of 40 to 45 lb/hp, which was considerably higher than the 25 to 30 lb/hp ratio average of vehicles produced in the United States. This lack of power by domestic standards could be an obstacle to achieving customer acceptance in the United States.

Supercharging is one method of increasing a Diesel's power output. Daimler-Benz has investigated supercharging and has recently reported[1] its experience with a relatively new type of device: the Comprex pressure wave supercharger developed by Brown-Boveri of Switzerland. Daimler-Benz and Brown-Boveri have permitted EPA to test the Comprex supercharged 220D Mercedes-Benz developed in their investigation. This report presents the results of our tests on that vehicle. Also included for comparative purposes are the results of similar tests on a standard 1975 Mercedes-Benz 240D.

<u>System Description</u>

For those readers unfamiliar with the mode of operation of the Comprex pressure wave supercharger, the following description from the Daimler-Benz paper is included:

> MODE OF OPERATION - Figure 1 shows the general arrangement and the mode of operation of the Comprex on the engine.
>
> The crankshaft of the engine (a) drives the cell wheel (b) of the Comprex via a V-belt drive (c), the multiplication ratio being constant. The ambient air sucked in at (f) is compressed in the Comprex and flows, highly compressed (e), into the engine. The hot high-pressure exhaust gas (d), which flows from the engine after combustion, transmits a large proportion of its energy within the Comprex to the air and flows into the exhaust system at (g).
>
> The Comprex supercharging system is based on the direct exchange of pulses between the exhaust gas, which is under increased pressure, and the fresh air using controlled pressure waves. In detail the process is shown in Figure 2.

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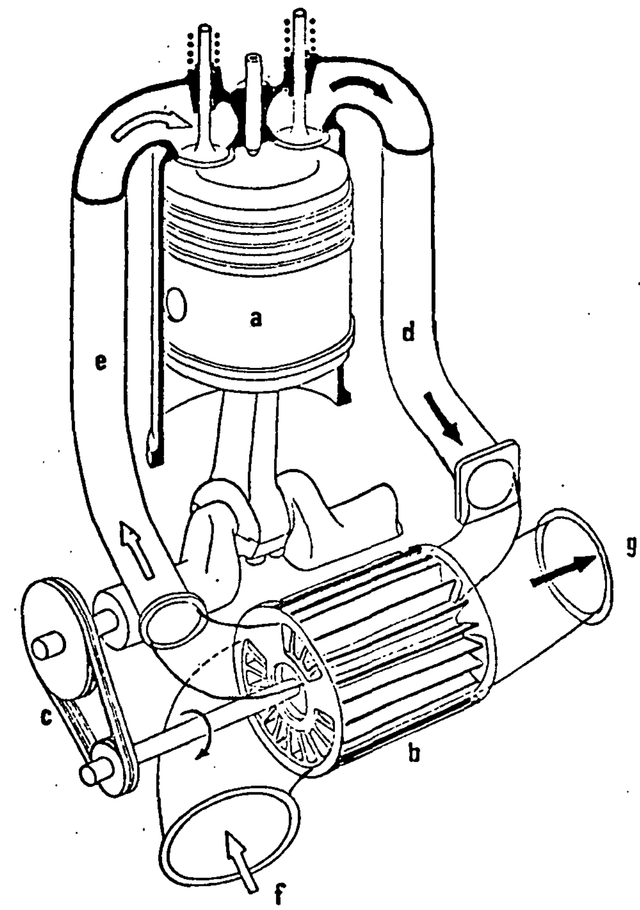
[1] E. Eisele, H. Hiereth and H. Polz, "Experience with Comprex Pressure Wave Supercharger on the High-Speed Passenger Car Diesel Engine," Paper 750334, presented at SAE Congress, Detroit, February 1975.

Pressure Wave Machine COMPREX®

Supercharging Application



a	*Engine*	d	*high pressure exhaust gas*	*HPG*
b	*cell wheel*	e	*high pressure air*	*HPA*
c	*belt drive*	f	*low pressure air intake*	*LPA*
		g	*low pressure exhaust*	*LPG*

BBC SkHTLT 5306 1973

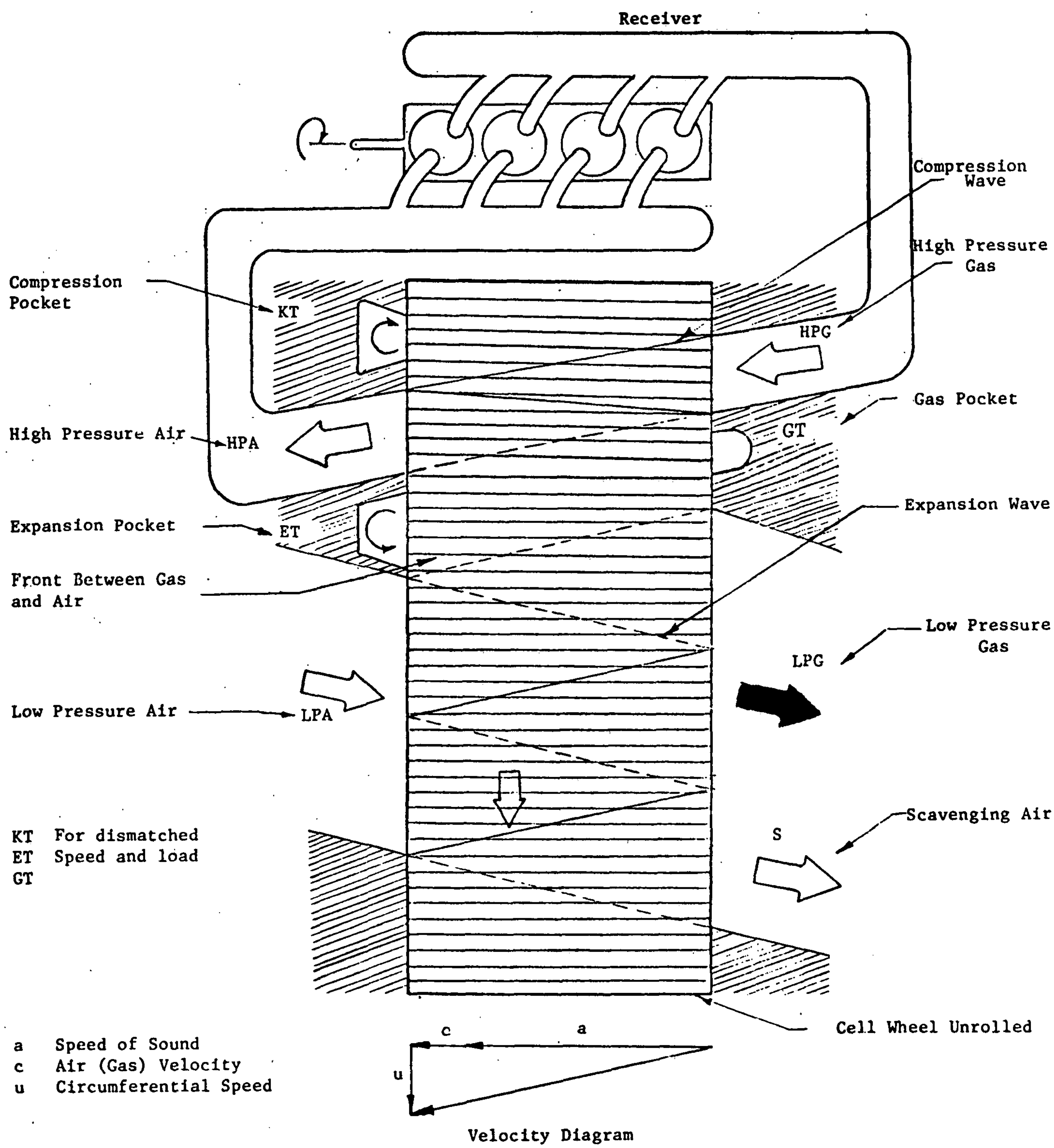
Figure 1

The exhaust gases of the individual cylinders are collected in the receiver, thus smoothing the exhaust pulses of the individual cylinders. The exhaust gases (HPG), which are under increased pressure, flow from the receiver into the cells of the cell wheel. Since these cells are filled with fresh air (LPA), the exhaust gases expell this air. Compression is produced by a pressure wave which propagates in the static air at sound velocity and causes an increase in pressure and an acceleration of the air column in the cell. In this way energy is directly transmitted from the exhaust gas to the intake air.

When the pressure wave reaches the high-pressure air side (HPA) of the cell wheel, the cell must be connected with the boost air manifold to the engine. The correct sequence of the cells, that is, the flow position of the cells, is achieved by the revolving cell wheel. In order to prevent the flow being disturbed by the reflected pressure waves, the inlet port of the exhaust gas is closed when the cell is turned further. For the same reason, the connection with the boost air manifold is also interrupted one wave sequence later.

The correct choice of the opening timing point on the low pressure exhaust gas side (LPG) enables the exhaust gases, which are still under pressure in the cell, to be completely expelled into the exhaust. The resulting depression wave allows fresh air to flow into the cell from the low-pressure air side (LPA). Part of the fresh air serves only to cool and completely scavenge the cells. As soon as the cell is completely refilled with fresh air, the process is repeated.

The circumferential velocity of the cell wheel and the sonic speed of the gases have a decisive influence on the pressure wave process with respect to its function. If cell wheel speed and engine load are completely unmatched, this process would be disturbed and consequently the pressure wave supercharger would no longer function. For this reason so-called pockets (KT, ET, and GT) are additionally arranged in the side walls beside the cell wheel. These are the functional prerequisites for using the Comprex as a supercharger on an internal combustion engine, and especially on a passenger car diesel engine with its wide speed and load ranges.



Receiver
Compression Wave
High Pressure Gas
Compression Pocket
KT
HPG
Gas Pocket
GT
High Pressure Air
HPA
Expansion Wave
Expansion Pocket
ET
Front Between Gas and Air
Low Pressure Gas
LPG
Low Pressure Air
LPA
Scavenging Air
S
KT For dismatched
ET Speed and load
GT
Cell Wheel Unrolled
c
a
u
a Speed of Sound
c Air (Gas) Velocity
u Circumferential Speed
Velocity Diagram

Figure 2

Because the Comprex was originally designed for truck Diesel engines, the Cx125 unit was about 50% heavier and 35% longer than one optimally designed for the higher speed 220D engine. The gross dimensions and weight of the Cx125 are given in the vehicle identification sheet of the 220D Comprex (Table 1).

The Comprex was belt driven from the engine in a manner similar to common accessories, with a Comprex-to-engine speed ratio of 4.5:1. As this resulted in a speed range of the Comprex 50% higher than encountered with truck engines, internal modifications of the Comprex were required. Adaptation of the engine to accommodate the supercharger also necessitated modifications. Briefly these included the following: increasing the compression ratio from 21:1 to 22:1; modification of the prechamber to minimize pumping losses of the higher quantity of fuel and air; additional cooling passages in the cylinder head; piston redesign; addition of spray nozzles in the crankcase for continuous oil spray cooling of the piston head bottoms; crankshaft strengthening by salt bath nitriding treatment and rolling of crank pin fillets; fuel injection pump plungers were increased in size to provide increased fuel delivery; injection nozzle opening pressure was increased; the governor was modified to conform to the altered injection quantity characteristics for full load.

Most of the above modification would also be required for more conventional superchargers providing a similar degree of supercharging. The Comprex has approximately 100% supercharging above 3500 rpm at full load. The exhaust and intake manifolds were replaced by a boost air manifold and an exhaust gas receiver respectively. Because the Comprex requires the lowest possible flow resistance in the intake and exhaust systems, their redesign was necessary to minimize pressure drops while handling approximately twice the normal flow rates. Compounding the design problems of the intake and exhaust system is the requirement for noise silencing, since the high speed rotation of the Comprex cell wheel produces a characteristic siren type noise above 1000 Hz. For the air intake, adequate noise damping was not entirely achieved due to the pressure drop requirement and space limitations of the engine compartment.

During cold starts the Comprex does not work well and must be bridged by an intake air bypass. A solenoid operated flap valve in the boost air manifold separates the high pressure air section of the Comprex from the engine. When this flap valve is closed air is drawn into the engine through vacuum-controlled spring-loaded check valves located in two tubes connecting the air intake to the boost air manifold at a location between the flap valve and the engine. Above 500 rpm the solenoid operated flap valve is open and the boost air pressure supplied by the Comprex closes the bypass valves.

Figure 3 is a photograph of the Comprex supercharged 220D and the standard 240D. Figure 4 and 5 are photos of the respective engine compartments of the 240D and 220D, identifying various components of the two systems. These two photos give an indication of the difference in complexity and packaging necessitated by the installation of the Comprex. Vehicle descriptions of the 220D Comprex and 240D are given in Tables 1 and 2.

Figure 3. 220D Comprex (left) 240D (right)

Test Description

Both vehicles were tested for gaseous emissions, fuel economy and performance. The emissions testing consisted of the 1975 Federal Test Procedures ('75 FTP) as described for Diesel vehicles in the Federal Register of August 7, 1973; the EPA Highway Cycle (HWC), described in the EPA Recommended Practices for Conducting Highway Fuel Economy Tests; and steady state driving modes of idle, 15, 30, 45, and 60 miles per hour. All of these tests were conducted on a chassis dynamometer and employed the Constant Volume Sampling (CVS) procedure. Per the Federal Register, hydrocarbon emissions were measured by continuous analysis of the diluted exhaust by a heated flame ionization detector (HFID), and carbon monoxide, carbon dioxide, and oxides of nitrogen were analyzed from the bag samples. Fuel economy for the above tests were determined by the carbon balance method. In most cases duplicate runs were made for each test on each vehicle.

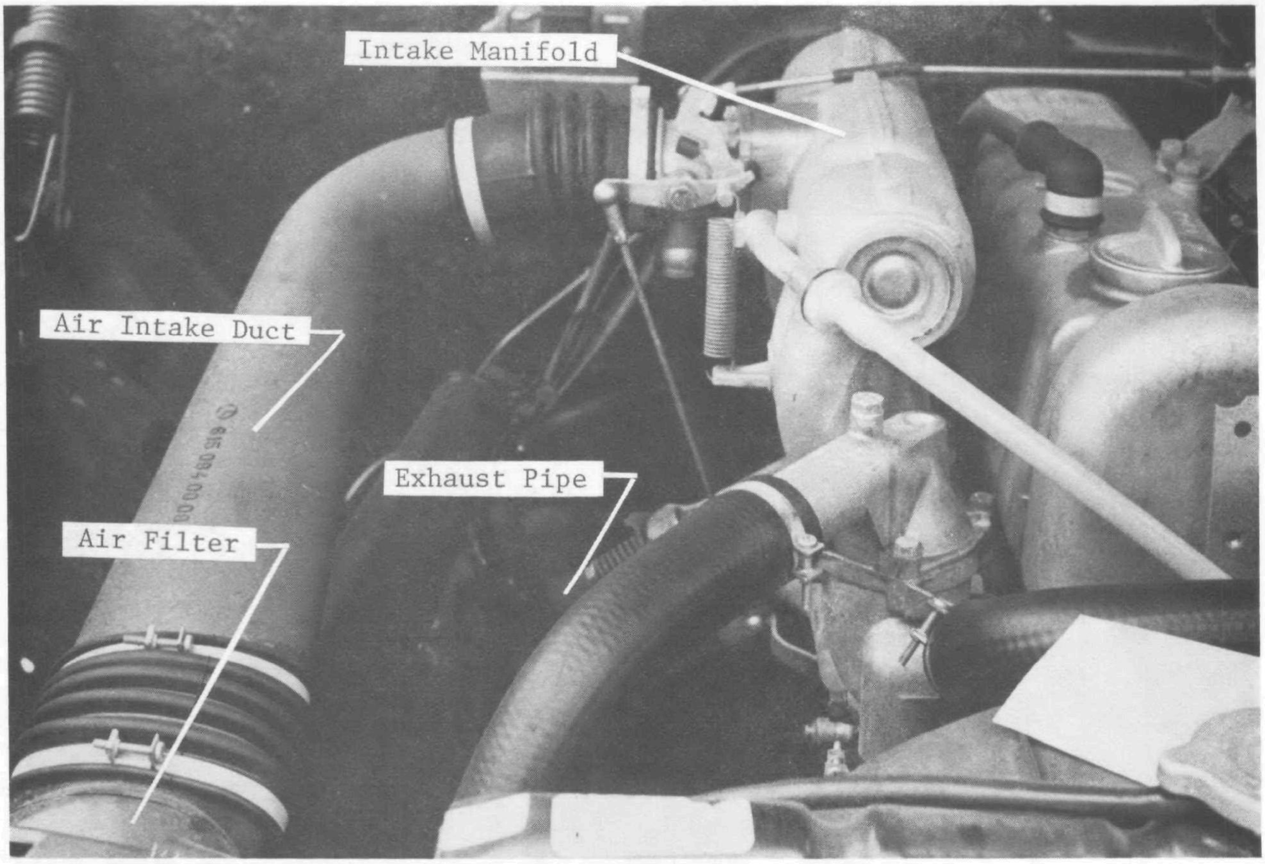


Figure 4. Engine Compartment of 240D

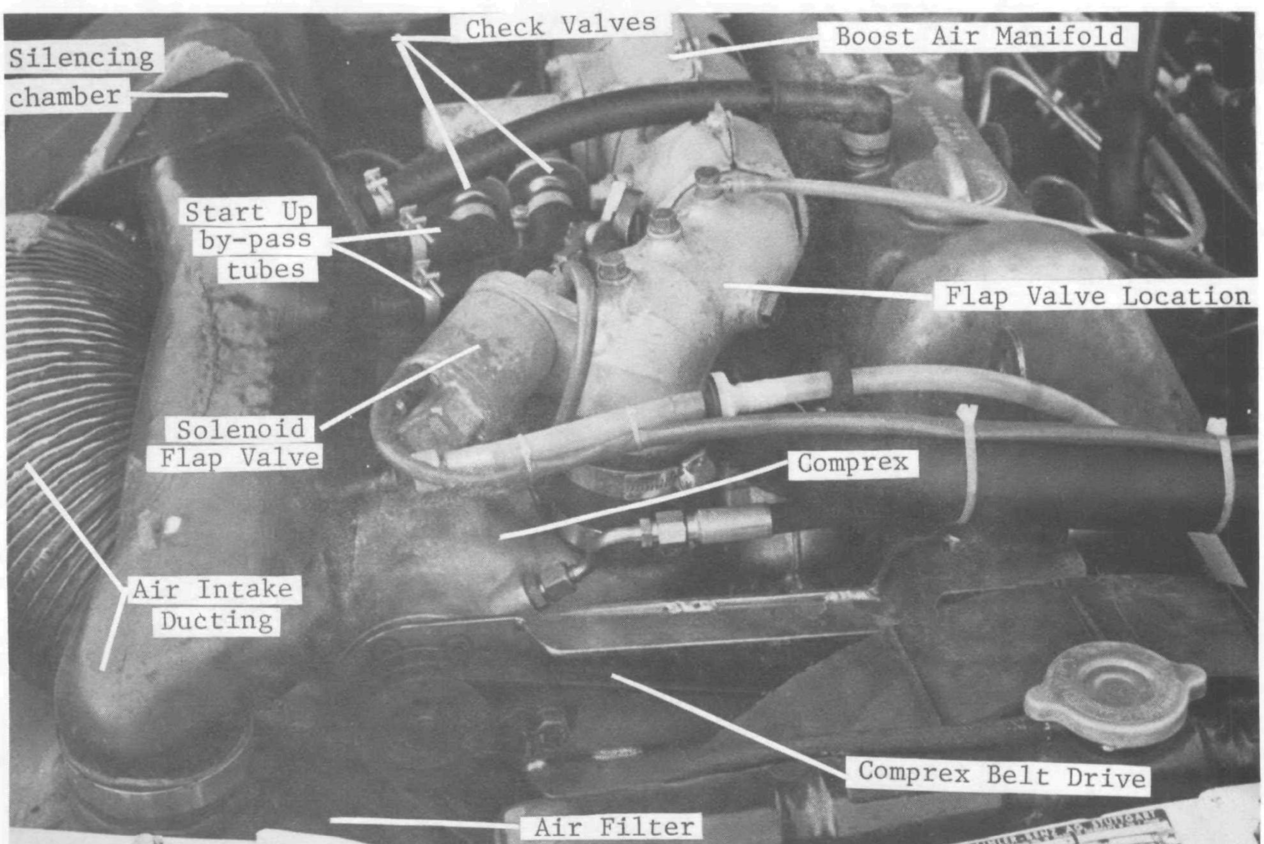


Figure 5. Engine Compartment of 220D Comprex

Performance was measured by a speed-time trace of full accelerator depression acceleration from 0 to 60 mph on the chassis dynamometer. Shifting was done at speeds yielding the best overall acceleration time. Driveability characteristics that were apparent in the driving cycles were reported. Diesel Fuel #2 was used for all tests. The starting procedure for the 240D was conducted according to the owners manuals. The 220D Comprex, due to special glow plugs, required a longer preglow time (a minimum of 45 seconds) before cranking.

Results

The zero to sixty mph acceleration times were 18.0 and 25.5 seconds respectively for the 220D Comprex and 240D. Figure 6 is a comparison of the speed versus time traces of those accelerations. The greater acceleration rates of the 220D Comprex throughout the speed range are an indication of the quick response time of the Comprex during acceleration. This is an advantage over turbine driven superchargers which do not provide high boost pressures as quickly as the Comprex device because of a time lag which results as the turbine accelerates itself and the compressor to the high rotational speeds required to provide full boost. Turbosuperchargers are not able to continuously remain at the high rotational speeds they require for the generation of high boost pressures because inadequate exhaust energy is available during light-load or no-load conditions. The Comprex supercharger has no inertia induced lag as it is directly driven by the engine. Direct drive of centrifugal compressors of the type used in turbosuperchargers is not considered practical because of the high power consumption that would be required at low loads. With the Comprex pressure-wave device, however, the parasitic losses at steady state conditions are minimal.

Also shown on Figure 6 are acceleration curves for typical mid-sized gasoline powered cars with V-8 and six cylinder engines. The acceleration performance of the Comprex equipped car is similar to that of the gasoline cars powered by six cylinder engines.

Table 3 gives the '75 FTP Composite results; individual bag results are given in Appendix I. Both vehicles had similar emission levels. While the 220D comprex's average hydrocarbon emissions of 0.26 grams/mile were roughly 25% greater than that of the 240D they were still well within even the 1978 Federal Statutory level of 0.41 grams/mile. Similarly, the 220D Comprex's average carbon monoxide emissions of 1.34 grams/mile exceeded that of the 240D by approximately 15%; but were still well below the 1978 Federal Statutory level of 3.4 grams/mile. For oxides of nitrogen, the Comprex, at 1.4 grams/mile, averaged 10% less than the 240D, and was below the 1977 Federal NOx level of 2.0 grams/mile. The

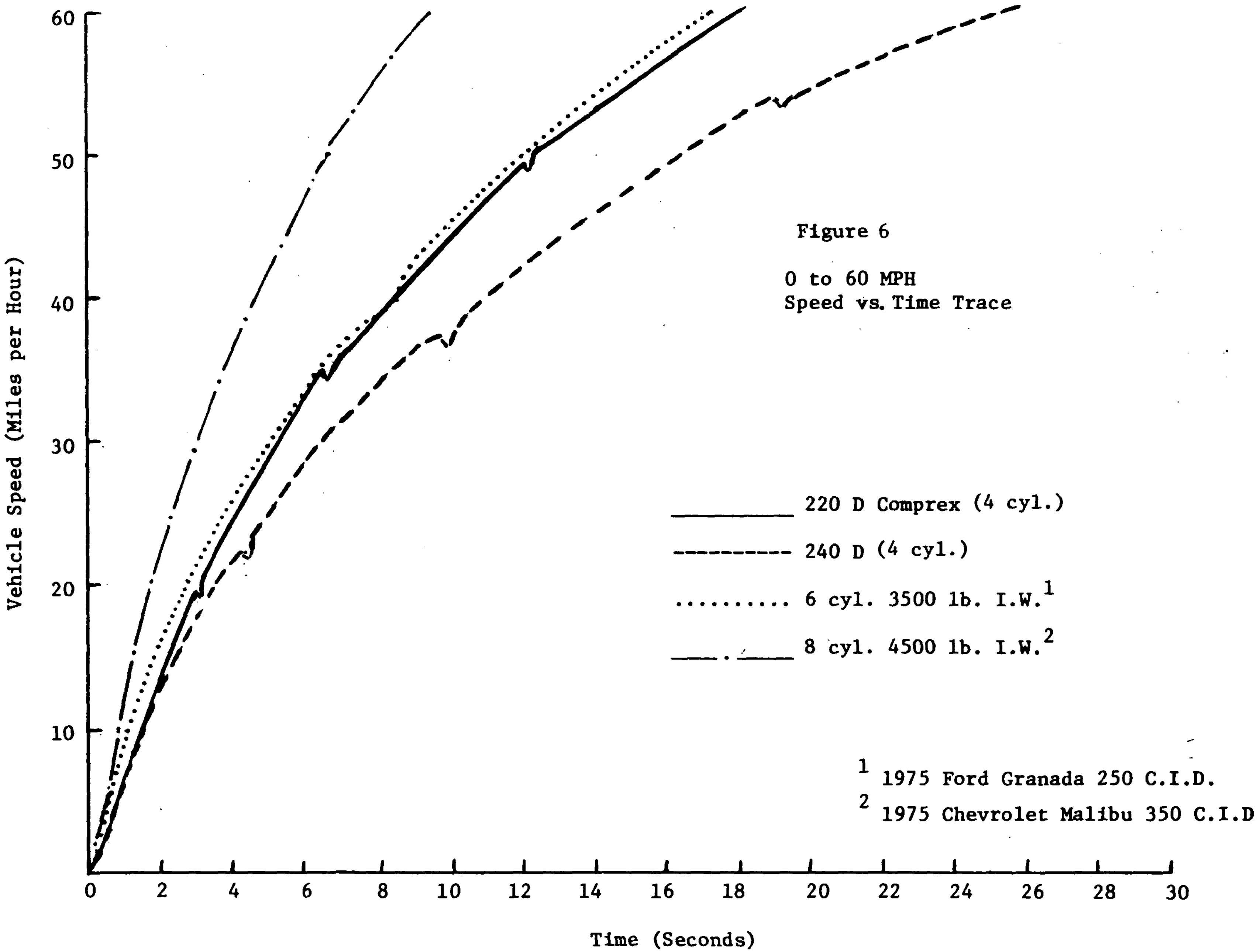


Figure 6

0 to 60 MPH
Speed vs. Time Trace

Table 1

TEST VEHICLE DESCRIPTION

Chassis model year/make - Comprex supercharged 1974 Mercedes-Benz 220D
Emission control system - Engine Modification (RFDV)

Engine	
type	4 stroke Pre-chamber Diesel, overhead camshaft, in-line 4 cylinder
bore x stroke	3.43 in. x 3.64 in. (87.0 mm x 92.4 mm)
displacement	134 CID (2197 cc)
compression ratio	22:1
maximum power @ rpm	88.5 bph (66 kW) @ 3800 rpm
fuel metering	high pressure fuel injection, in-line pump
fuel requirement	Diesel Fuel #2
Drive Train	
transmission type	4 speed manual
final drive ratio	3.46:1
Chassis	
type	4 door sedan, front engine, rear drive
tire size	175 SR 14
curb weight	3307 lbs (1500 kg)
inertia weight	3500 lbs (1590 kg)
passenger capacity	5
Emission Control System	
basic type	Engine modification (Reverse Flow Damping Valve)
additional features	Supercharged by a Cx125 Comprex pressure wave supercharger with Comprex-to-engine drive ratio of 4.5:1
	Cx125 Comprex:
	Length . . . . 13.82 in. (351 mm)
	Diameter . . . . 6.50 in. (165 mm)
	Weight . . . . 28.6 lb. (13 kg)

Table 2

TEST VEHICLE DESCRIPTION

Chassis model year/make - 240D - 1975 Mercedes-Benz
Emission control system - Engine Modification (RFDV)

Engine

type	4 stroke Pre-chamber Diesel, overhead camshaft, in-line 4 cylinder
bore x stroke	3.58 in. x 3.65 in. (91.0 mm x 92.5 mm)
displacement	146.5 CID (2400 cc)
compression ratio	21:1
maximum power @ rpm	62 bhp (46 kW) @ 4000 rpm
fuel metering	high pressure fuel injection, in-line pump
fuel requirement	Diesel Fuel #2

Drive Train

transmission type	4 speed manual
final drive ratio	3.69

Chassis

type	4 door sedan, front engine, rear drive
tire size	175 SR 14
curb weight	3190 lb. (1450 kg)
inertia weight	3500 lb. (1590 kg)
passenger capacity	5

Emission Control System

basic type	Engine Modification
additional features	RFDV (Reverse Flow Damping Valve)

Table 3
1975 FTP Composite Results

Mass Emissions in grams per mile (grams per kilometre) — Fuel Economy in miles per gallon (litres per 100 kilometres)

Vehicle	HC	CO	CO_2	NOx	Fuel Economy
Mercedes	0.23	1.35	408	1.39	24.8
220 D Comprex	(0.14)	(0.84)	(254)	(0.86)	(9.49)
	0.29	1.34	403	1.39	25.1
	(0.18)	(0.83)	(250)	(0.86)	(9.37)
Average	0.26	1.34	406	1.39	25.0
	(0.16)	(0.84)	(252)	(0.86)	(9.43)
Mercedes	0.21	1.14	413	1.57	24.5
240D	(0.13)	(0.71)	(257)	(0.98)	(9.60)
	0.125*	1.17	406	1.53	24.9
	(0.08)*	(0.73)	(252)	(0.95)	(9.45)
Average	0.21+	1.16	410	1.55	24.7
	(0.13)+	(0.72)	(254)	(0.96)	(9.52)
1976 Federal Emission	1.5	15.0		3.1	
Standard	(0.93)	(9.32)		(1.93)	
1977 Federal Emission	1.5	15.0		2.0	
Standard	(0.93)	(9.32)		(1.24)	
1978 Federal Statutory	.41	3.4		0.4	
Emission Standard	(0.25)	(2.1)		(0.25)	

* Not Hot FID
\+ Non Hot FID value not included

lower level of NOx produced by the 220D Comprex in spite of its higher combustion temperatures and pressure may be due to the exhaust gas recirculation effect of the Comprex. As exhaust gas is in actual contact with incoming air, in the Comprex cell wheel a certain amount of mixing results in some exhaust being pumped back into the engine.

The 75 FTP fuel economies of the two Diesels were almost identical at 25 miles per gallon. The Highway Cycle fuel economies and composite Urban - Highway fuel economies are given in Table 4. (Detailed results of the Highway Cycles, including gaseous emissions, are given in Appendix II). For the Highway Cycles, the 220D Comprex at 34.3 miles per gallon was almost 2 miles per gallon better than the 240D. Figure 7 is the comparison of the two Diesels' '75 FTP fuel economies with those of the gasoline powered 1975 model year light duty vehicles certified for sale in the 49 states and California. The three curves on this figure represent the maximum, minimum and sales weighted average fuel economies versus inertia weight of these 1975 vehicles. The two Diesels' fuel economies were higher than the fuel economy range of the 1975 cars. Figure 8 is a similar comparison for the Highway Cycle fuel economies. Again the fuel economies of the 240D and 220D Comprex exceeded the fuel economy range for their 3500 inertia weight class by a wide margin.

Complete results of the steady state driving modes are shown in Appendix III. Although not tested in 4th gear at 30 mph, it is expected that the 220D Comprex fuel economy would have been roughly 25% higher in top gear than in 3rd gear.

Both cars displayed good driveability. The 220D Comprex had noticeable smoke during start up and hard accelerations away from idle, while the 240D had nearly invisible exhaust under all modes observed. The 220D Comprex, with its characteristic high frequency whine, had higher interior and exterior noise levels. Its interior noise level was tolerable, but the exterior noise, particularly with the engine compartment hood open, was annoying at higher speeds. Detailed test results covering smoke, noise, odor and particulate emissions are yet to be obtained for these cars by EPA contractor Southwest Research Institute.

Conclusions

The 220D Comprex demonstrated the ability of the Comprex supercharger to significantly improve Diesel engine performance. The 30% decrease in the 0-60 mph acceleration time over the standard 240D is

Table 4

Fuel Economies of the 220D Comprex and Standard 240D
in miles per gallon (litres per 100 kilometres)

	220D Comprex		240D	
Average '75 FTP Fuel Economy	25.0	(9.43)	24.7	(9.52)
Highway Cycle Fuel Economies	34.8	(6.76)		
	33.8	(6.96)	32.2	(7.31)
	34.2	(6.88)	32.8	(7.17)
Average	34.3	(6.86)	32.5	(7.24)
Average Urban-Highway Fuel Economy*	28.5	(8.26)	27.7	(8.50)

* Urban-Highway Fuel Economy = 1/[.55(1/'75 FTP F.E.) + .45(1/Hwy F.E.)]

Figure 7

1975 FTP Fuel Economy of 220D Comprex and 240D Diesels vs. 1975 Gasoline Powered Certification Cars

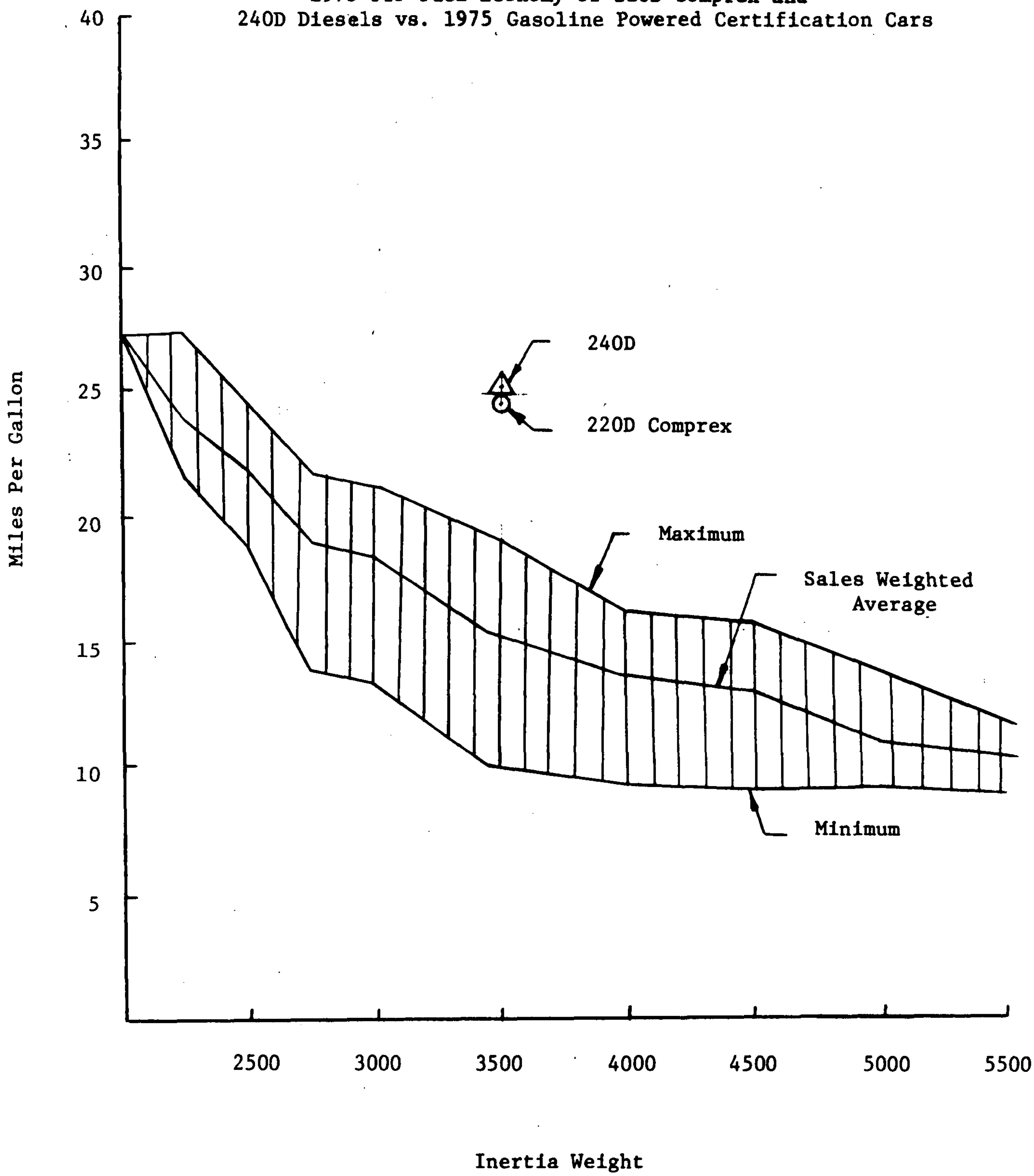
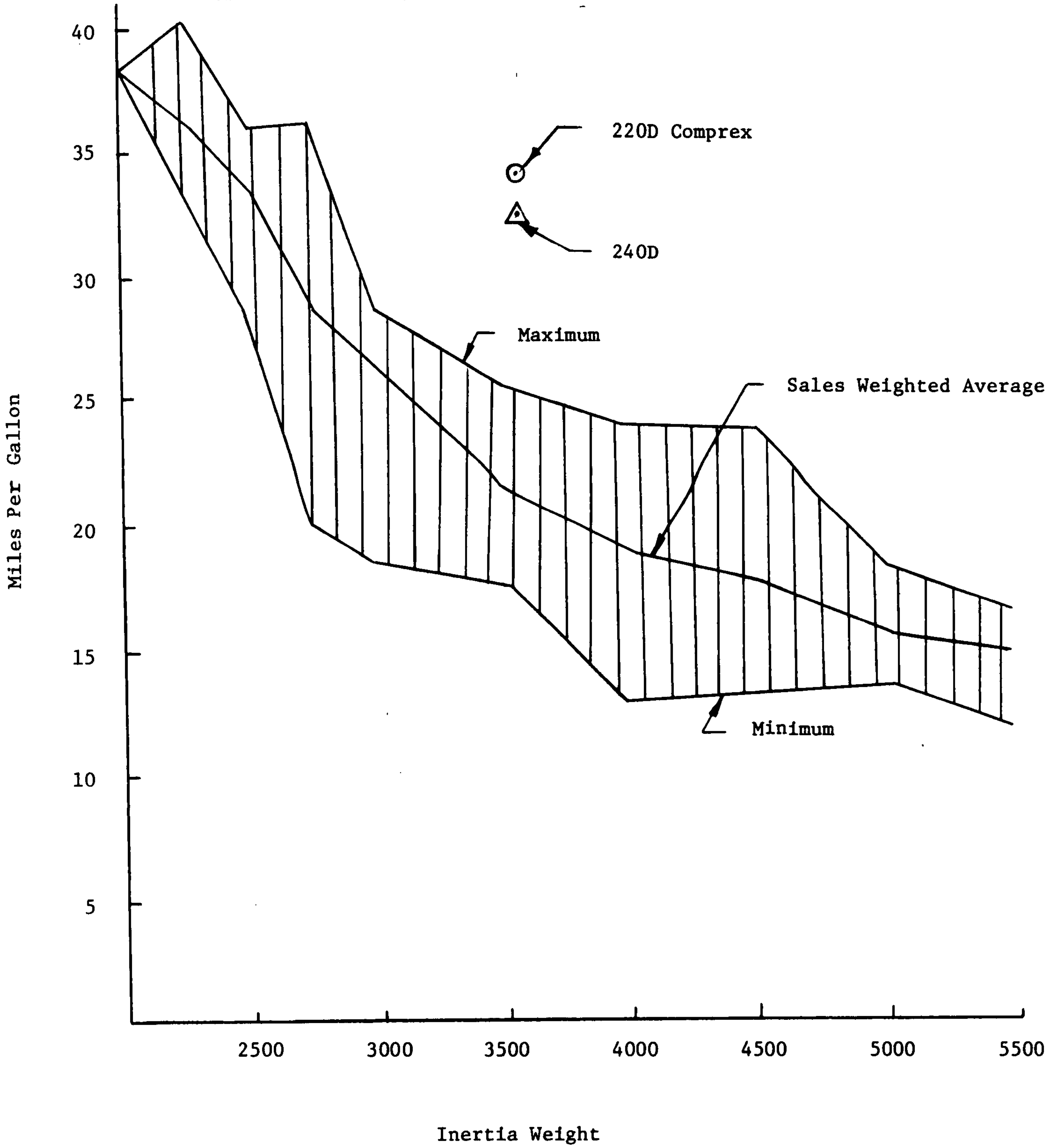


Figure 8

Highway Cycle Fuel Economy of 220D Comprex and
240D Diesels vs. 1975 Gasoline Powered Certification Cars



impressive particularly when it was achieved with no loss in the characteristically good Diesel fuel economy. With the exception of a 25% increase in hydrocarbons, the gaseous emissions were nearly the same as those of the 240D. The emissions of both cars were well below the 1977 Federal levels.

The 220D Comprex, as tested, was a low mileage experimental system with uncertain durability. A Comprex specifically designed for the smaller high speed engine, and an engine completely redesigned to accommodate the supercharging should be capable of acceptable reliability. Whether or not the added weight, bulk, noise silencing, and complexity can be resolved in an economically viable system, however, remains to be seen.

Further improvements over the prototype Comprex-equipped vehicle tested in the areas of noise control and transient smoke emission seem desirable. An investigation into the potential for lower NOx emissions with a Comprex-equipped engine also appears to be in order.

Appendix I

1975 Federal Test Procedure Individual Bag Results
Mass Emissions in Grams per Mile Fuel Economy in Miles per Gallon

TEST NO.	BAG NO.	HC	CO	CO_2	NOx	FUEL ECONOMY	BARO. P. "HG	TEMP °F DRY	TEMP °F WET	RELATIVE HUMIDITY
Mercedes 220D Comprex										
16-9062	1	.21	1.40	416	1.39	24.3	28.83	76.0	60.0	38%
	2	.27	1.41	422	1.39	24.0				
	3	.18	1.20	376	1.38	26.9				
16-9085	1	.28	1.36	424	1.43	23.9	29.15	76.0	59.0	35%
	2	.33	1.40	416	1.42	24.3				
	3	.21	1.19	363	1.31	27.8				
Mercedes 240D										
16-9239	1	.22	1.19	424	1.50	23.9	28.69	75.0	61.0	44%
	2	.23	1.22	424	1.63	23.9				
	3	.17	.95	386	1.51	26.3				
15-9215	1	.14*	1.17	423	1.56	23.9	29.05	76.5	60.0	37%
	2	.22	1.27	414	1.53	24.5				
	3	.16	.99	380	1.50	26.7				

* Not Hot FID

Appendix II

'75 Highways Fuel Economies
Mass Emissions, Grams Per Mile
Fuel Economy, Miles Per Gallon

TEST TYPE	HC	CO	CO_2	NOx	FUEL ECONOMY	BARO. P. "HG	TEMP DRY	TEMP WET	RELATIVE HUMIDITY	TEST NO.
Mercedes 220D Comprex	0.12	0.77	291	1.21	34.8	28.87	76.0	63.0	55%	15-9124
	0.11	0.77	300	1.19	33.8	28.83	76.0	60.0	49%	16-9062
	0.13	0.77	297	1.23	34.2	29.15	76.0	59.0	46%	16-9085
Average	0.12	0.76	296	1.21	34.3					
Mercedes 240D	0.09	0.65	316	1.45	32.2	28.69	75.0	61.0	52%	16-9239
	0.09	0.68	310	1.44	32.8	29.05	76.5	60.0	49%	15-9215
Average	0.09	0.66	313	1.45	32.5					

APPENDIX III

Steady State Driving Modes Results

Mass Emissions Grams Per Mile   Fuel Economy Miles Per Gallon

	Speed	Gear	Emissions HC	Emissions CO	Emissions CO_2	NO_x	Fuel Economy	Baro. P. "HG	Temp. Dry	Temp. Wet	Hum.	Test No.
Mercedes 220D Comprex	0	N	3.24^{+}	8.76^{+}	190^{+}	10.86^{+}	3.85*	29.0	75.0	61.0	52%	15-9140
	15	2	0.35	1.60	385	1.25	26.3	29.0	75.0	61.0	52	15-9140
	30	3	0.23	1.17	279	0.69	36.2	29.0	75.0	61.0	52	15-9140
	45	4	0.11	0.70	257	0.74	39.5	29.00	74.5	60.5	52	15-9141
	60	4	0.14	0.89	320	1.68	31.6	29.00	74.5	60.5	52	15-9141
	0	N	4.44^{+}	8.52^{+}	191^{+}	10.20^{+}	4.35*	28.90	75.0	60.0	50	16-9101
	15	2	0.44	1.44	476	1.26	26.5	28.90	75.0	60.0	50	16-9101
	30	3	0.24	0.98	707	0.72	35.7	28.90	75.0	60.0	50	16-9101
	45	4	0.21	0.69	271	0.78	37.3	28.90	77.0	60.0	48	16-9102
	60	4	0.26	0.89	344	1.75	29.4	28.90	77.0	60.0	48	16-9102
Mercedes 240D	0	N	0.996^{+}	6.72^{+}	146^{+}	9.6^{+}	5.78*	28.85	78.0	61.0	49	15-692
	15	2	0.25	1.56	366	2.32	27.6	28.85	80.0	61.5	49	15-732
	30	4	0.07	0.48	220	2.06	46.2	28.85	80.0	62.0	50	15-731
	45	4	0.11	0.40	265	0.67	38.2	28.85	84.0	63.0	49	15-658
	60	4	0.05	0.56	343	1.88	29.6	28.85	84.0	63.0	49	15-730
	0	N	2.16^{+}	7.2^{+}	152^{+}	6.12^{+}	5.56*	29.2	76.0	58.5	45	16-9390
	15	2	0.20	1.43	370	1.17	27.3	29.2	76.0	58.5	45	16-9390
	30	3	0.19	0.97	290	1.01	34.8	29.2	76.0	58.5	45	16-9390
	45	4	0.42	0.66	269	1.11	37.6	29.2	76.0	58.0	45	16-9391
	60	4	0.33	0.62	361	1.80	28.1	29.2	76.0	58.0	45	16-9391

$^{+}$Grams/hour

*Hours/gallon