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Technical Report

Evaluation of Fuel Economy, Exhaust Emissions and Performance of a Sequentially Fuel-Injected High Compression Methanol-Fueled 1.5 L Engine in a Light-Duty Diesel Vehicle

by

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NOTICE

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I. Background of Engine Development Work

Various properties of methanol fuel have been investigated which specifically relate to its suitability as a fuel for use in conventional light-duty engines. The poor self-ignition characteristics, i.e., low cetane number of methanol fuel indicates that it is not easily utilized in Diesel engines. Conversely, methanol's high octane quality implies it is fairly suitable for application in spark-ignited engines. The octane number of methanol is significantly higher than that of current commercial gasolines and methanol lends itself for use in engines having relatively high compression ratios with inherent thermal efficiency advantages over current gasoline-fueled engines. Methanol also has good lean burn properties which offer further advantages in terms of thermal efficiency and low exhaust emissions when used in a spark-ignited engine.

In recent years, several research organizations have worked on the development of engine concepts capable of successfully utilizing high compression ratios for optimized methanol combustion. Ricardo Consulting Engineers, plc. have developed the HRCC (High Compression Ratio, Compact Combustion chamber) engine which, by specific design of the combustion chamber, permits the use of a high compression ratio (with a relatively low fuel octane requirement) together with the ability to successfully utilize lean mixtures or tolerate high levels of EGR. Both are important attributes with regard to fuel economy and exhaust emissions.

Considerations of the major performance characteristics of the HRCC combustion system and some of the properties of methanol fuel suggested that they complement each each other to a large extent. It therefore appeared that an HRCC unit was a promising basis for the development of an optimized engine for methanol use. In order to confirm this theory, a practical engine test program, aimed at investigating the potential performance, fuel economy and exhaust emissions of an HRCC engine when fueled with methanol, was carried out by Ricardo under contract with EPA.[1]*

This contract resulted in the production of a methanol-fueled High Compression Ratio, Compact Chamber (HRCC) engine in which air/fuel mixture strength was controlled using a simple carburetor and ignition timing was varied using a conventional distributor with vacuum advance. This engine showed considerable potential with regard to high thermal efficiency and low exhaust emissions. However, it was apparent that the relatively simple engine control system used imposed significant limitations on several aspects of engine performance.

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* Numbers in parentheses denote references listed at the end of the paper.

EPA initially attempted to test the engine on an engine dynamometer (as received) in order make an exact comparison to the Ricardo tests. This evaluation was performed under the direction of engineers in the Technical Support Staff with the aid of technicians in the heavy-duty test cell at MVEL. The details of this test program are included in Appendix A.[18] After this evaluation, it was envisioned that the engine would then be placed in the chassis of an Audi 5000 Diesel vehicle to compare the performance, fuel economy and exhaust emissions of the methanol and Diesel engines in the diesel vehicle on a chassis dynamometer.

Problems were experienced by the previous project team when it came to fitting the engine into a vehicle for chassis dynamometer testing purposes. The vehicle chosen was a three-year old 1980 Audi 5000 Diesel with a 5-speed transmission. The Audi is a 3250 lb IW vehicle, whereas the HRCC engine is based on a VW Rabbit powerplant which is normally fit into a 2500 lb IW vehicle. It was believed that the increased power output of the high compression HRCC (r_v = 13:1) would compensate for the lower power-to-weight ratio obtained by swapping a smaller engine into a larger vehicle. The objective was to compare the fuel economy of the methanol-fueled engine with the certification Audi Diesel fuel economy. Secondary objectives included the comparison of exhaust emissions and performance. A transmission adapter was fabricated to fit the transverse HRCC engine into the longitudinal Audi chassis. Though no documentation exists regarding the engine swap or attempted chassis dynamometer testing, it is believed that this effort was unsuccessful due to problems which occurred when the VW Rabbit flywheel was mated to the Diesel clutch. Proper clutch operation was never obtained. Additional complications may have occurred as a result of the engine's relatively simple control system and the vehicle never achieved acceptable power output for the FTP driving cycle.

The engine was then removed from the vehicle and shipped back to Ricardo for further development of the fuel management system to incorporate a sequential fuel injection system in place of the carburetor, and to provide mapped Microprocessor control of various Engine Control (MEC) parameters. This work was performed from October 1984 through September of 1986 under EPA Contract No. 68-03-1968.[9]

Under this contract, alternative ignition systems were initially investigated before the fuel metering system was modified. A Bosch/MEC ignition system was shown to result in similar performance compared with the original A.C. Delco ignition system and was adopted for the subsequent engine development program. This result showed only that the high energy ignition system previously used did not offer any significant advantage to the methanol engine concept.

Compared with the carbureted engine, the injected engine has a much reduced ignition requirement at part load by 6 to 10 degrees with reduced HC emissions and higher brake thermal efficiency. Some of these differences were evidently due to the mechanism of fuel preparation since the engine was shown to be sensitive to fuel injection rate and timing.

At full load the changes to mixture preparation, fuel distribution and intake manifold geometry led to a significant improvement in BMEP above 50 rev/s and an increase in brake thermal efficiency of 2.5 percent over the speed range. Volumetric efficiency is, however, some 5-10 percent lower at 20 to 40 rev/s because the manifold geometry favors high speed running.

Pre-ignition was encountered while running at optimum mixture strength above 60 rev/sec at full load. This caused slight damage which necessitated fitting a new piston. This was an unforeseen problem as test work with the carbureted engine had indicated that the engine could be over advanced by up to 10 degrees before encountering pre-ignition when BN-60Y sparking plugs were fitted. Richer mixtures were later used to prevent reoccurrence of pre-ignition.

The mixture strength for best economy without significant HC emissions penalty was generally found to be at an equivalence ratio of 0.7 and this mixture strength was used for the "best economy" maps. This equivalence ratio was the same as that established as optimum for the carbureted engine. Maldistribution and lack of adequate transient fueling control with the carburetor meant that this lean potential could not previously be utilized. This was not the case for the injected engine so that the full potential of the engine concept could be realized in the vehicle application. The result of this was a predicted fuel economy improvement of 18 percent (Audi/Injected/HRCC over VW/Carb/HRCC) despite the increase of vehicle weight from 2500 to 3250 lbs.

A second control strategy, using EGR and ignition timing retard, was identified to reduce the NOx emission level below that obtained with best economy and comply with the project objectives of less than 0.7 g/mi NOx. The control strategy optimization showed that NOx emissions could be reduced by 62 percent with an insignificant increase of HC emissions by selecting a suitable strategy for EGR, mixture strength, and ignition timing. This strategy increased predicted fuel consumption 6 percent (0.9 MPG). It was felt that the low vehicle power/weight ratio, which at about 43 kw/ton (58 hp/ton) is well below that typical of current gasoline engine vehicles at 50 to 60 kw/ton (67 to 80 hp/ton), combined with lean air/fuel mixtures, EGR and ignition retard would result in a vehicle concept whose driveability may be unsatisfactory. Without ignition retard, 1.07 g/mi NOx was achieved, and Ricardo developed this as a first cut at a reduced NOx strategy with driveability that was believed to be acceptable.

Simulation of engine transients was carried out on the test bed by actuation of the throttle lever between "stops." A smooth transition between engine loads was achieved by calibration of the MEC maps.[15] It was recognized that it was not possible to fully calibrate transient engine performance on the engine testbed and that further development of engine transients would be required when the engine was fitted into the vehicle by EPA.

The engine "cold start strategy" was set up to enable an unaided start to be achieved at an ambient temperature of 10°C (50°F). Tests could not be conducted at lower temperatures because the cell had no cooling facility. Initial strategies for warm-up compensation and modulation of EGR rate during the warm-up phase were also devised using testbed data and Ricardo experience gained from similar applications. Again, this area was recognized as one where further development would be required during the vehicle phase or as part of another test program.

The application of electronic sequential fuel injection and electronic engine management to the engine was successfully carried out during this second Ricardo project.

The effect of fuel injection was to improve the engine performance when compared to that previously obtained with the carbureted version of the engine. At full load, maximum BMEP increased by 6 percent and peak power output by 16 percent; however, some increased sensitivity to pre-ignition was evident. Under part load conditions brake thermal efficiency increased and HC emissions were reduced. The engine was noted to be sensitive to fuel injection characteristics such as fuel injection rate.

The part load vehicle calibration for best economy was carried out at a leaner mixture strength than that of the carbureted engine, 0.7 equivalence ratio, instead of 0.8 equivalence ratio due to improved mixture preparation and distribution with sequential fuel injection, as well as the sophisticated transient fueling control possible with the Ricardo MEC unit.

The two calibration strategies developed for the engine were entered as data to the Ricardo "CYSIM" drive cycle simulation computer program.[13] The vehicle details input to the cycle simulation program were those of the Audi 5000 vehicle. To supplement the comparison with the results predicted for the carbureted version of this engine when fitted to a VW Rabbit vehicle, a simulation of the Audi 5000 diesel-engined vehicle using Ricardo in-house data was also carried out. These results are summarized in Table 1 for the "FTP" driving cycle, but are really representative of hot-start FTP engine-out emissions.

Table 1

Predicted Hot-LA4 Results Using Ricardo CYSIM
Drive Cycle Simulation Program*

Vehicle/Engine/Strategy	HC (g/mi)	NOx (g/mi)	CO (g/mi)	Fuel Economy Meth. MPG	Fuel Economy Gas Equiv.	Accel. 0-50 (sec)	Time 30-50 (sec)
1. VW Rabbit/Carb/0.8 ER	1.61	2.07	1.17	13.85	28.61	--	--
2. VW Rabbit/Carb/EGR	1.35	0.98	1.75	14.76	30.49	--	--
3. VW Rabbit/Injected/ 0.7 ER	1.95	1.29	3.35	16.84	34.80	15.0	9.1
4. VW Rabbit/Injected/ EGR	1.70	0.59	8.77	16.48	34.05	15.0	9.1
5. Audi 5000/Injected/ 0.7 ER	1.92	1.75	3.37	16.30	33.68	18.0	11.0
6. Audi 5000/Injected/ EGR**	1.91	1.07	19.90	14.90	30.79	--	--
7. Audi 5000/Injected/ EGR+	1.82	0.67	14.52	15.40	31.82	18.0	11.0
8. Audi 5000/Injected/ EGR++	1.94	0.65	21.24	14.50	29.96	--	--
9. Audi 5000/Diesel/no EGR	0.11	2.15	--	--	32.85	22.9	14.4

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* Steady-state simulation--no cold start adjustment.
** Reduced NOx calibration without spark retard.
\+ Initial reduced NOx calibration with spark retard.
++ Final reduced NOx calibration with spark retard.

Notes:
VW Rabbit - 2500 lbs inertia weight.
Audi 5000 - 3250 lbs inertia weight.
0.8 ER = Best economy carbureted calibration.
0.7 ER = Best economy fuel-injected calibration.
EGR = Reduced NOx calibration (0.8 ER).

Both carbureted and fuel-injected HRCC engine "reduced NOx" strategies result in about 1.0 g/mi FTP NOx emissions if MBT ignition timings were used and again showed the fuel-injected engine to advantage in fuel economy despite the end weight differential. More directly comparable results, i.e., at the same simulated inertia weight, were carried out though the results are marginally representative since the change of vehicle weight requires a reoptimization of the engine control strategy since different engine speeds and loads are used.

The comparison with the simulated diesel-engined vehicle shows the Audi/Diesel to have low HC emissions but NOx emissions indicated that optimization of the control strategy and/or EGR would be required. A comparison of the fuel consumption showed the methanol concept to be favorable.

II. Diesel Vehicle Baseline Exhaust Emissions, Fuel Economy, Performance and Rated Power Output

After the engine development work under the second Ricardo contract was completed, it was decided to reinstall the engine in the Audi vehicle to determine whether the initial program objectives of comparing the methanol and Diesel engine exhaust emissions, fuel economy and performance could now be successfully performed.

The 1980 Audi 5000 was not cyclic tested in the as-received condition (as a Diesel) when it arrived at the Motor Vehicle Emission Laboratory prior to removal of the original Diesel engine. However, the vehicle was placed on the dynamometer for a few performance tests. These performance data consist of several 0-50 MPH and 30-50 MPH accelerations which are listed in Table 2. By comparison with Table 1 values, the actual acceleration times for the Audi/HRCC and Audi/Diesel combinations are quite a bit (5-6 seconds) faster than the performance predicted by the Ricardo simulations. However, as we shall see in a later section, the percent improvement in performance with the methanol engine over the Diesel baseline is essentially the same, roughly 22 percent, for both EPA tests and Ricardo simulations.

Cyclic emissions and fuel economy data for the Audi/Diesel were obtained from the 1980 Fuel Economy Program 49-State Test Car List (Gas Mileage Guide) as published in the August 27, 1980 Federal Register.[22] These data are listed in Table 3 and pertain to a 3,250 lb. ETW vehicle with a 121 in^3 in-line five-cylinder fuel-injected Diesel engine with a compression ratio of 23:1 and rated power of 67 HP. The Audi 5000 Diesel has front-wheel drive, a manual five-speed transmission, an axle ratio of 4.78 and an N/V ratio of 46.1.

No deterioration factors were applied to the exhaust emissions data to account for the fact that this vehicle was three years old when procured by EPA, and over six years old when evaluated with a methanol engine installed in it.

The vehicle condition prior to installation of the fuel-injected HRCC engine was quite poor since it had not been moved for three years and had acquired a substantial amount of rust from sitting dormant over three Michigan winters outside of the MVEL. Several parts were in need of repair and replacement and the vehicle required cleaning and maintenance from bumper to bumper.

Table 2

Audi 5000 Diesel Performance:
June 30, 1983 Acceleration Tests

Test Run	0-50 MPH (sec)	Test Run	30-50 MPH (sec)
1.	15.75	1.	9.0
2.	18.75	2.	8.5
3.	15.00	3.	9.5
4.	15.75	4.	9.5
5.	17.50	5.	9.0
Average	16.55	Average	9.1
Std. Dev.	1.535	Std. Dev.	0.42

* 30-50 MPH accelerations performed cruising at 30 MPH in third gear.

Table 3

1980 Audi 5000 Certification Diesel Emissions
and Fuel Economy (g/mi, MPG)

	FTP	HFET	
HC	0.405	0.162	
CO	1.330	0.460	
CO_2	371	236	
NOx	1.710	1.075	
MPG	27	43	Combined = 33

III. Diesel Vehicle Modifications and Engine Installation

The HRCC engine, as mentioned earlier, was installed in a 1980 Audi 5000 Diesel vehicle (VIN= 43A0131868). Prior to engine installation, however, a substantial number of vehicle and engine parts were procured or fabricated and various vehicle modifications needed to be made.

The goal of these efforts was to ensure that the test vehicle could be used both on the dynamometer for emissions tests and as a vehicle for operation on the road. The overall test program consisted of five distinct phases requiring significant coordination of in-house personnel and test facilities and extramural equipment and services. These five phases were: 1) parts procurement; 2) vehicle modifications; 3) engine installation; 4) baseline Audi/HRCC vehicle cyclic testing; and 5) transient fuel and EGR calibration optimization.

Neat methanol fuel was used for all chassis dynamometer testing of the engine/vehicle combination. The test fuel specifications are listed in Table 4.

Fitting a transverse engine into a vehicle originally designed for a longitudinal engine presented significant problems, particularly with a front-wheel drive vehicle (see Figures 1 and 2). The exhaust system for this configuration is completely different than VW Rabbit system and had to be fabricated based on Audi 4000 components.[16] Fortunately, the engine being installed was relatively small (4-cylinder, 1.5-liter VW Rabbit base engine) compared to the vehicle engine compartment designed for a 5-cylinder 2.0-liter Audi Diesel engine.[17] Engine compartment space was not expected to cause insurmountable problems. However, the front-end grille frame on the Audi had been cut away slightly indicating that extra space was necessary for the radiator when the carbureted version of the HRCC engine was installed in the Audi.

Since the Audi vehicle had been sitting outside MVEL without an engine for three years without ever being moved, some components acquired a significant amount of rust. The bell housing, transmission inlet shaft, and transaxle were scrubbed with steel wool, thoroughly cleaned and lubricated. The front tires were replaced and new front disc brake pads were installed. New engine mounts were fabricated and the alignment, fitting, and weight distribution of the engine, drivetrain and transmission was performed. Radiator mounting brackets were fabricated and installed and a hood scoop was fitted since the new engine configuration sat a little higher in the vehicle compartment with the new engine mounts and fuel injection components. The emergency brake was repaired and the hood release was attached.

Table 4

Methanol Test Fuel Specifications

Appearance	Clear, colorless, free from suspended matter and sediment
Relative Density 0/00 15.5/15.5°C	0.798 - 0.795
IBP°C	>64.5
95% Dist. Temp. (°C)	<65.25
FBP°C	<65.5
Water Content	<0.5 % by weight (measured - 571ppm)
Aldehydes and Ketones	<.015 % by weight, as acetone
Alkalinity	<.0005 % by weight, as ammonia
Acidity	<.003 % by weight, as formic acid
Sulfur and Sulfur Compounds	<.0001 % by weight, as sulfur
Composition % by weight:	
Carbon	37.5
Hydrogen	12.5
Oxygen	50.0
Octane quality (from literature):	
RON	104-114
MON	87-97
Stoichiometric air/ fuel ratio	6.46
Measured Calorific Value, kJ/kg	19940
Latent Heat of Vaporization kJ/kg (from literature)	1100

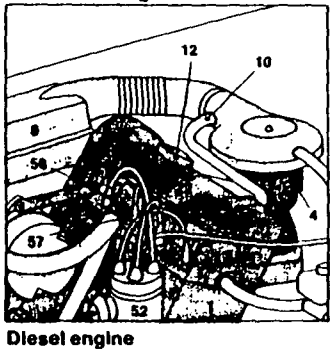
Major car components / Volkswagen

Front-drive transverse-engine cars

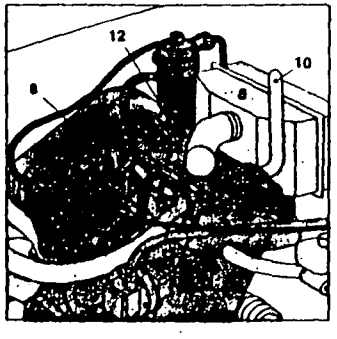
Rabbit, Scirocco, Pickup

ENGINE
1. Engine block
2. Cylinder head
3. Intake manifold
4. Carburetor
5. Fuel-injection distributor
6. Air cleaner
7. Fuel-injector lines
8. Fuel-injector nozzle
9. Gas pedal
10. PCV hose
11. Oil filter
12. Oil filler cap
13. Drive belt
14. Electric fan
15. Water pump
16. Radiator
17. Radiator cap
18. Upper radiator hose
19. Lower radiator hose
20. Exhaust pipe
21. Camshaft drive belt cover
22. Overhead camshaft cover

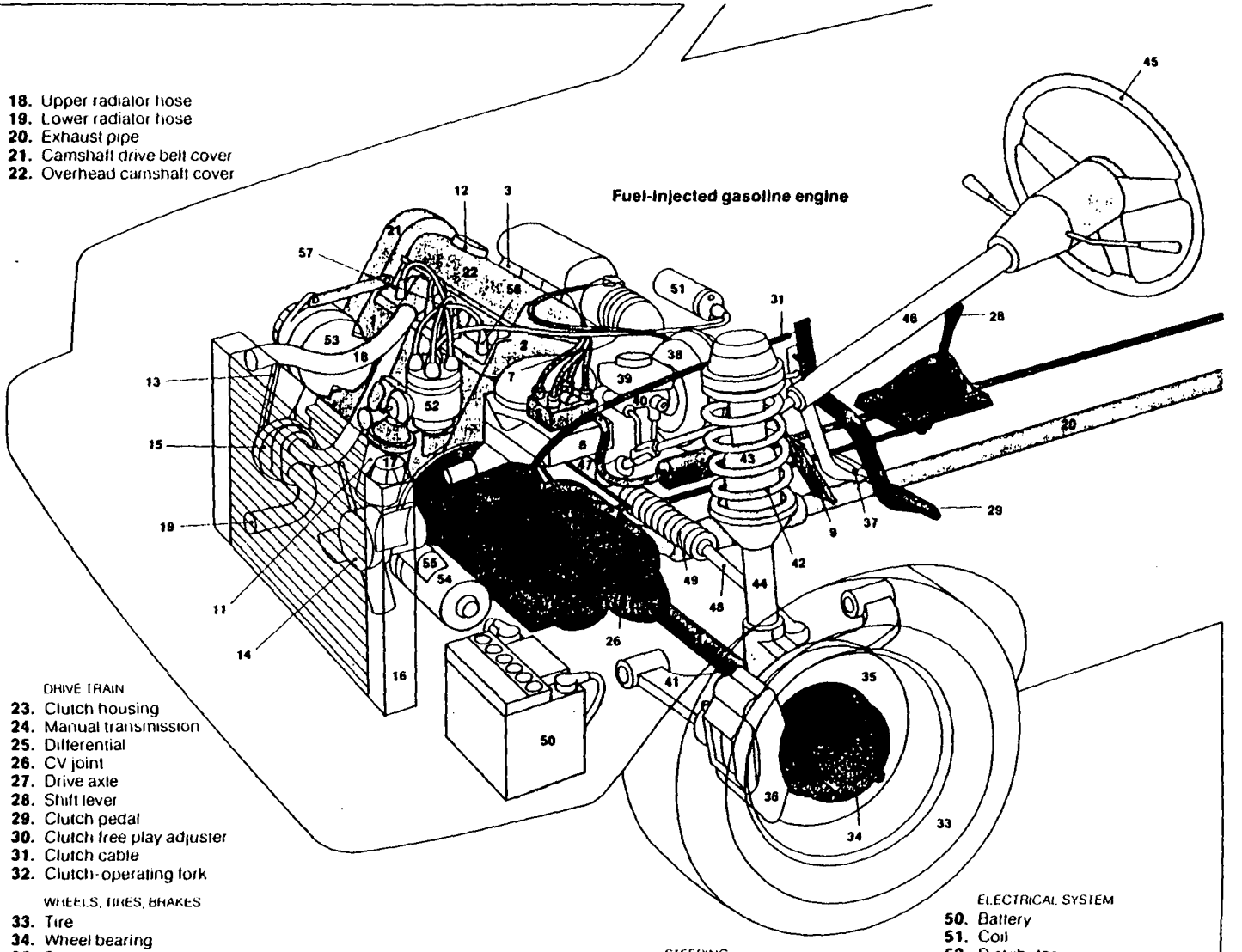
Carburetor engine



Diesel engine



Fuel-injected gasoline engine



DRIVE TRAIN
23. Clutch housing
24. Manual transmission
25. Differential
26. CV joint
27. Drive axle
28. Shift lever
29. Clutch pedal
30. Clutch free play adjuster
31. Clutch cable
32. Clutch-operating fork

WHEELS, TIRES, BRAKES
33. Tire
34. Wheel bearing
35. Brake disc
36. Brake caliper
37. Brake pedal
38. Brake vacuum booster
39. Brake fluid reservoir
40. Brake master cylinder

SUSPENSION
41. Lower A-arm
42. Coil spring
43. Shock absorber
44. MacPherson strut

STEERING
45. Steering wheel
46. Steering column
47. Rack and pinion assembly
48. Tie rod
49. Rubber boot

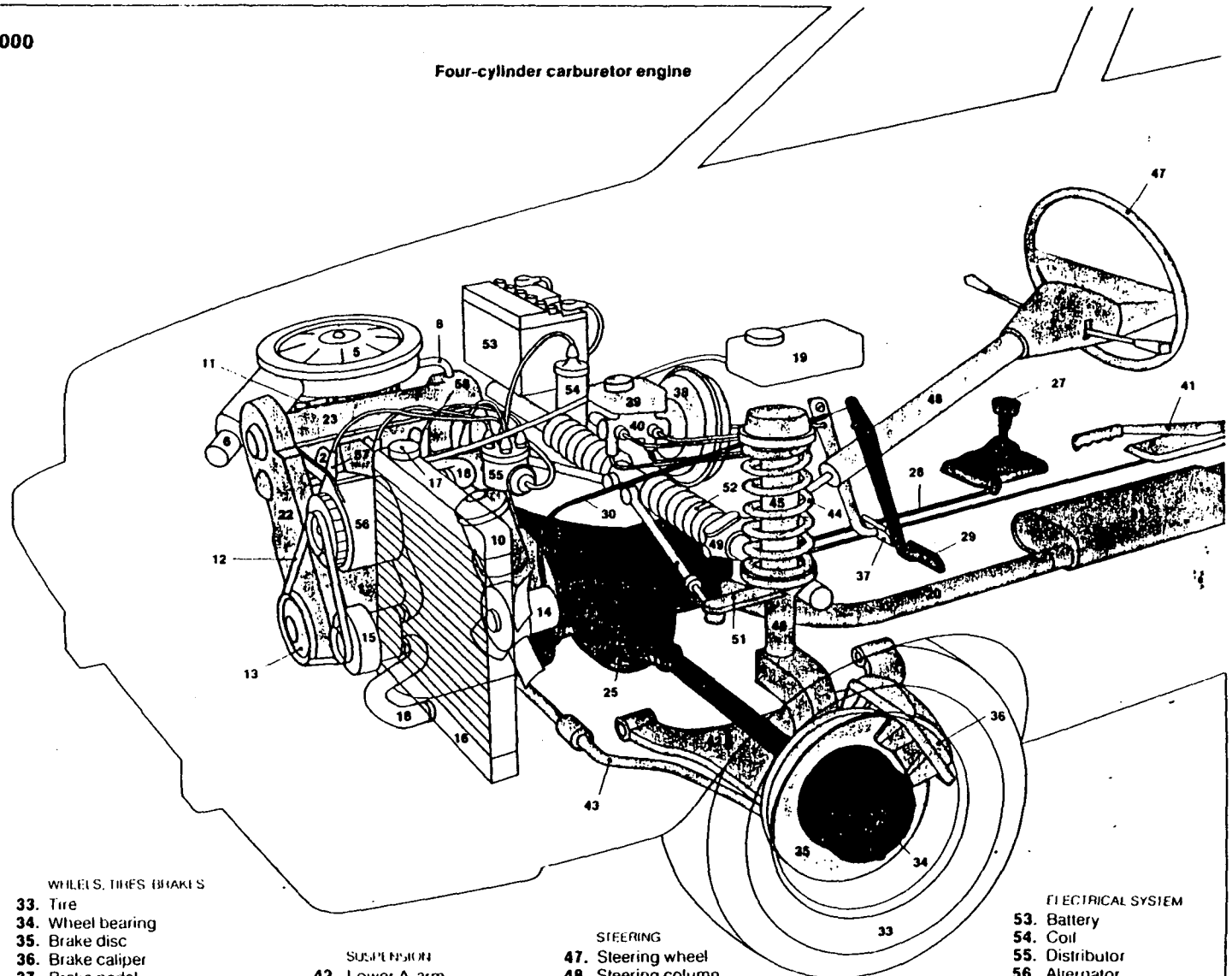
ELECTRICAL SYSTEM
50. Battery
51. Coil
52. Distributor
53. Alternator
54. Starter motor
55. Starter solenoid
56. Spark plug
57. Spark plug cables

Figure 2

Front-drive longitudinal-engine cars

VW Dasher; Audi Fox, 4000, 5000

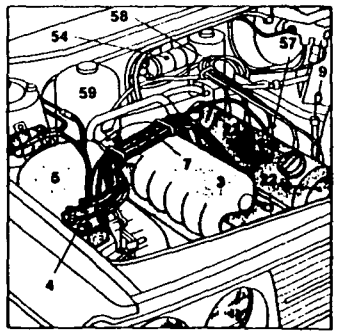
Four-cylinder carburetor engine



ENGINE
1. Engine block
2. Cylinder head
3. Intake manifold
4. Fuel-injection distributor
5. Air cleaner
6. Cool air duct
7. Fuel-injector lines
8. PCV hose
9. Oil dipstick
10. Oil filter
11. Oil filler cap
12. Drive belt
13. Crankshaft pulley
14. Electric fan
15. Water pump
16. Radiator
17. Radiator cap
18. Radiator hoses
19. Radiator overflow recovery tank
20. Exhaust pipe
21. Muffler
22. Camshaft drive belt cover
23. Overhead camshaft cover

DRIVE TRAIN
24. Clutch housing
25. CV joint
26. Drive axle
27. Shift lever
28. Shift linkage
29. Clutch pedal
30. Clutch cable
31. Clutch-operating fork
32. Transaxle

Five-cylinder fuel-injected engine



WHEELS, TIRES, BRAKES
33. Tire
34. Wheel bearing
35. Brake disc
36. Brake caliper
37. Brake pedal
38. Brake vacuum booster
39. Brake fluid reservoir
40. Brake master cylinder
41. Parking brake lever

SUSPENSION
42. Lower A-arm
43. Stabilizer bar
44. Coil spring
45. Shock absorber
46. MacPherson strut

STEERING
47. Steering wheel
48. Steering column
49. Rack and pinion assembly
50. Tie rod
51. Steering knuckle
52. Rubber boot

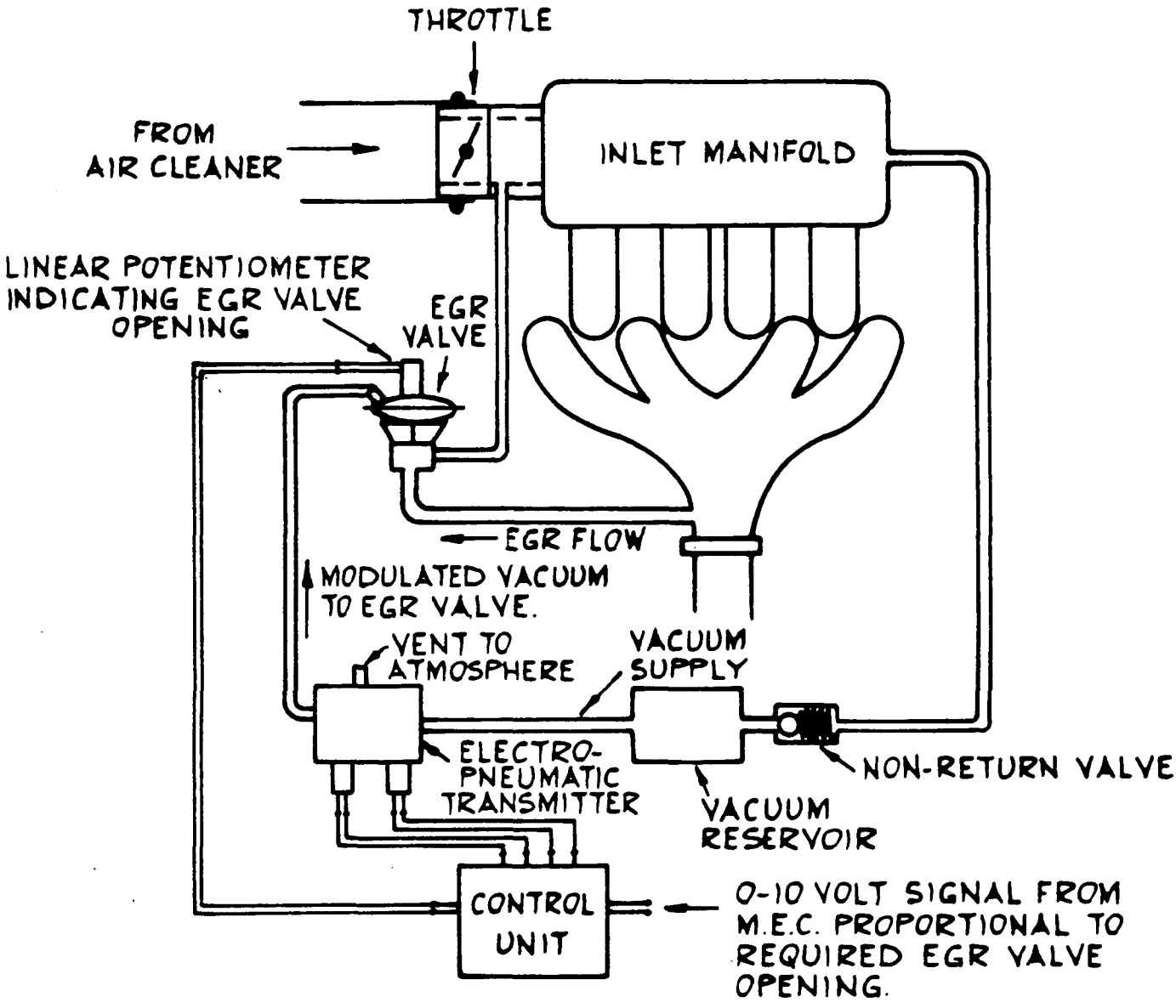
ELECTRICAL SYSTEM
53. Battery
54. Coil
55. Distributor
56. Alternator
57. Spark plug
58. Spark plug cables
59. Windshield washer reservoir

Engine installation required the measurement and fitting of several related components. A flywheel spacer plate was fabricated to align the Ricardo flywheel with the flywheel adaptor plate, bell housing, magnetic pickup and starter motor. The flywheel adaptor was machined to accept a slightly altered starter geometry to line up with the Ricardo flywheel teeth. A new pilot bearing was machined to match the main shaft from the transmission. A new throwout bearing was installed and the clutch slave piston was lengthened to allow the clutch to engage and disengage smoothly without loss of hyraulic fluid. All hydraulic systems were bled and fluids replaced. A new Bosch fuel pump, stainless steel fuel lines, fuel filters and pressure gauges were installed. Existing power steering and air conditioning system components were removed since they would not be needed for the Audi/HRCC test program. A methanol tolerant fuel cell was installed in the trunk.

After vehicle modifications were complete, and the engine was installed in the vehicle, all associated components were assembled and connected. The air inlet system needed to be rerouted to connect with the previous transverse engine configuration. A VW throttle cable was purchased and installed with a special pop fit terminal on the throttle to adapt it from automatic to a standard transmission configuration. Two adaptors were manufactured to fit the modified Audi 4000 exhaust manifold and head pipe through the engine compartment. A straight section in the exhaust pipe was fitted in case catalyst testing was to be performed after the engine-out emissions were baselined. A completely new wiring harness was installed to hook up all electrical connections. This allowed the Ricardo EGR and microprocessor engine controller (MEC) systems to be installed and tested for accurate operation (see Figures 3 and 4). Once these systems were set up and nominally functional, all other hoses, pipes, valves, sensors, belts and thermostats were hooked up. New fuses, a battery, spark plugs and wires, distributor cap and rotor and oil filter were all purchased locally and installed.

The MEC required many connections for various inputs and outputs. Inputs to the MEC include a throttle potentiometer, crank and camshaft pickups, exhaust gas and manifold charge thermocouples, and coolant and inlet air platinum resistance thermometers. MEC outputs include signals to the ignition module (distributor and coil), fuel injectors, the Pierburg EGR control unit and an ADM 11 video display terminal. The MEC unit itself was installed in the passenger compartment by removing the front passenger-side seat.

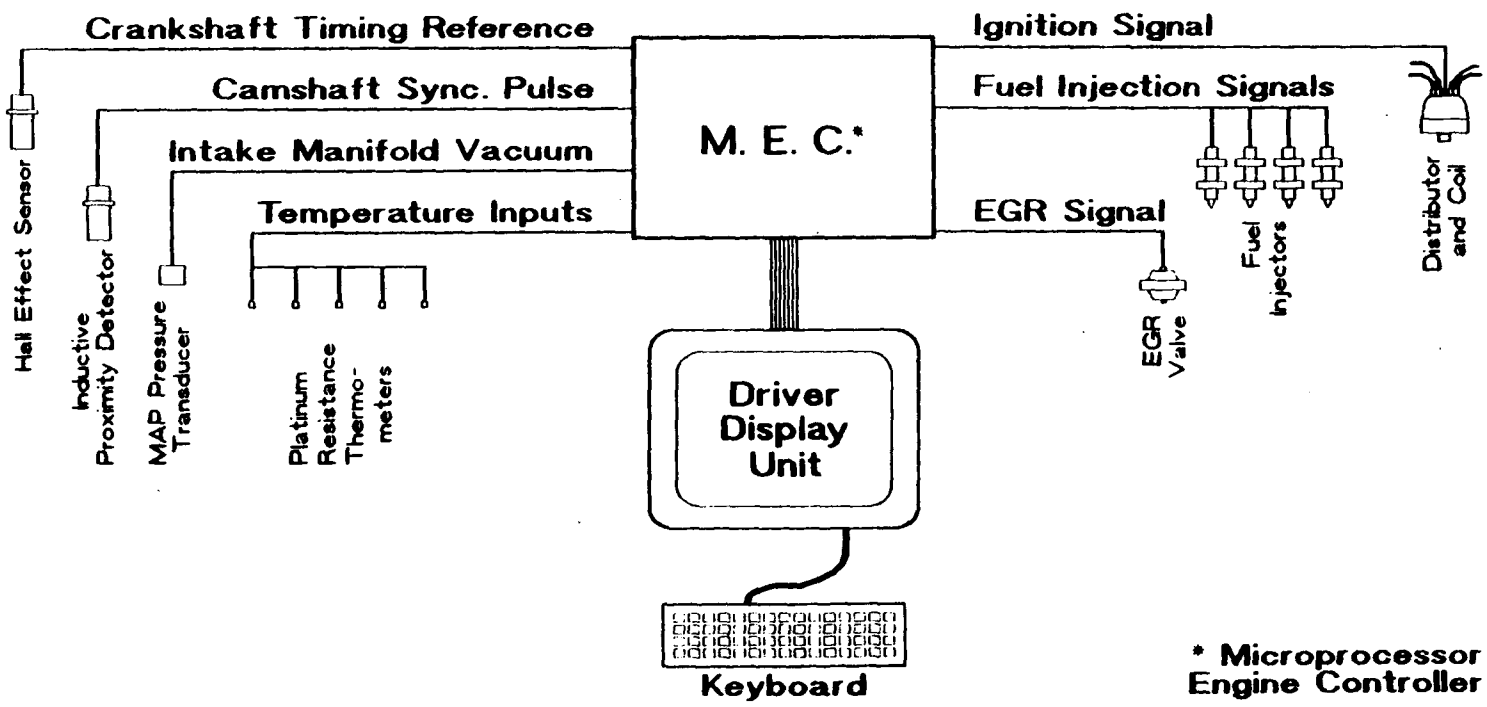
EGR SYSTEM



	PIERBURG PART Nos.:-
EGR VALVE	T4KR 7.114
ELECTRO-PNEUMATIC TRANSMITTER	7.21.031.00
CONTROL UNIT	PV 12.300

Figure 4

Input and Output of Microprocessor Engine Controller



A MEC calibration operates by defining the ignition advance and fuel injector pulse length for a given engine speed (rev/s) and manifold absolute pressure (mbar). The temperature inputs (ambient, inlet manifold, and coolant) are used to modify certain derived variables in the engine control strategy during warmup periods. The control strategy structure is fixed, but is tunable by ten maps (of 10 by 10 elements). The elements of these maps may be individually edited. Permanent or temporary offsets may also be added to every element of a specified map. The state of MEC can be constantly displayed on a Lear Siegler ADM 11 terminal. A trace of input and output variables may also be stored in volatile memory, and subsequently retrieved for display. The required changes to maps are also made via the terminal. The ten derived variables and their associated maps are described further in Table 5.

The 10 by 10 elements are accessed by using the two input values as indices (after normalization), such that a block of four map values are identified as "surrounding" the true map operating point. The map output is then computed by linear interpolation within this block. The temperature compensation coefficients (X map variables) are also linearly interpolated between adjacent defined values.

On power-up, the MEC writes a heading at the top of the screen and then writes several lines of variable names together with their current values. These values are only updated when the engine is running, consequently at power-up, the values have no significance. The final line of the display field prompts for a character to be entered. A drawing of a typical MEC VDU engine panel display is shown in Figure 5.

If the "character" is one corresponding to a map (as in Table 5), then the corresponding map will be displayed together with a prompt for map modification. While the display is being continuously updated, other characters can be entered which perform map storage and recall functions with the non-volatile memory. Up to six sets of ten 10 by 10 maps, i.e., six "proms" can be stored simultaneously in non-volatile memory.

A trace facility is also provided for diagnostic purposes. Traces can be started, aborted and displayed.[19] Up to ten variables from a pre-defined set may be stored every occasion control of the engine is invoked. Memory capacity allows up to 800 cycles to be retained. Up to four of the variables may be output on analog channels, with a facility to determine the gain of individual channels. These traces helped immeasurably in the fine tuning of MEC maps to achieve lean operation of methanol in the Audi on the chassis dynamometer with acceptable driveability.

Table 5

Microprocessor Engine Controller Maps

Map Name	Select Character	Horizontal Axis para,units,range	Vertical Axis para,units,range	Map Output para,units
Steady-State Fuel	F	rev/s,-, 20-100	MAP, mbar 100-1000	Fuel Inj. Fuel/100 arbitrary unit
Idle Fuel	G	rev/s,-, 2-20	MAP, mbar 100-1000	Fuel/Inj. Fuel/100 arbitrary unit
Exp. Impulse Time Constant	H	rev/s,-, 20-100	Fuel/Inj. 5-50	Trans. height, constant, mS
Throttle Angle Derivative arbitrary	K	rev/s,-, 10-100	MAP, mbar 100-1000	Derivative coef, unit
Advance Table	I	rev/s,-, 20-100	MAP, mbar 100-1000	Ign. advance deg BTDC/100
Idle Ignition Map	J	rev/s,-, 2-20	MAP, mbar 100-1000	Ign. advance, deg BTDC/100
EGR valve	E	rev/s,-, 20-100	MAP, mbar 100-1000	0-1000 EGR, arbitrary unit
Temperature* Compensation	X	Temp.°K,100-1000	TTC, MCT, THC, SSF, CT, EGR	0-100 percent, °K

* The X map contains "percent" of steady-state fueling, transient constant, transient height coefficient, and EGR to be applied in a specified manifold charge or coolant temperature range.

TTC = Transient time constant.
MCT = Manifold charge temperature.
THC = Transient height coefficient.
SSF = Steady-state fueling.
CT = Coolant temperature.
EGR = Exhaust gas recirculation.

Figure 5

Typical Continuously Updated MEC Engine Panel Video Display

```
RICARDO MEC (V2.8.3)
ENG SPEED (RPS) = 15.00  MAP (mB) = 365  EGR = 0  EGRPOS = -122
IGN (deg BTDC) = 12.36       E.O.I. (deg ATDC) = 330
FUEL: -  TOT = 12.19  WW = .0  TI = .0  FBL = 12.14  (TMPC = .0)
TRN HEIGHT (%) = 160, (TMPC = 0), TRN.T.C. (mS) = 178, (TMPC = 20)
TEMPS (°K): - WTR = 359, AMB = 300, MC = 343 EX = 431, CJ = 307

MAPS BEING USED ARE THOSE IN PROM 6, "BEST ECONOMY"

      This screen space available for map or trace
          modification, formatting and display
```

RPS	= Revolutions per second
mB	= Millibars pressure
MAP	= Manifold absolute pressure
EGR	= Exhaust gas recirculation
EGRPOS	= EGR valve position (arbitrary units)
IGN	= Ignition timing (degrees before top dead center)
EOI	= End of injection (degrees after top dead center)
TOT	= Total fuel output (=FBL + TRN + TMPC)
WW	= Wall wetting compensation
TI	= Throttle impulse
FBL	= Fuel baseline (interpolated from "F" and "G" maps
TRN	= Transient fuel compensation
TRNTC	= Transient time constant (milliseconds)
TMPC	= Temperature fuel compensation
WTR	= Coolant temperature (°K)
AMB	= Ambient temperature (°K)
MC	= Manifold charge temperature (°K)
EX	= Exhaust gas temperature (°K)
CJ	= Cold junction temperature (°K)

IV. Vehicle Testing for Best Economy

Once the MEC, EGR, fuel injection and all other necessary engine control systems were functioning accurately, baseline FTP tests were run to observe vehicle driveability at various speed and load combinations and during engine transients. A series of stripchart recordings were made to observe engine functions of manifold vacuum, CO emissions (percent), road speed (MPH), engine speed (rpm), and air/fuel ratio (lambda) while the vehicle operated under steady-state and cyclic conditions.

These traces and the FTP test results showed a vehicle with minimally acceptable driveability and sporadically rich operation with extremely high levels of HC and CO emissions. Specific segments of the vehicle trace were examined in more detail to see if minor adjustments might improve vehicle operation.

Examination of manifold vacuum and air/fuel ratio during transients revealed that the engine was too sensitive to small changes in throttle angle. The Ricardo MEC fueling strategy algorithm was investigated to see if changes to the algorithm could be made to smooth out the noise in the air/fuel ratio trace. This fueling strategy is included in Appendix C. As shown in this diagram, the throttle angle derivative (K) map is an independent additive function to the total fuel output, and therefore does not directly effect other map functions. The elements in the K map were zeroed out to determine whether the MEC was "smart" enough to control the engine without fueling compensation for changes in throttle position with time.

The result was a dramatic improvement in vehicle driveability and significantly leaner operation under all engine conditions. Various increments of throttle angle derivative were tested with the engine controlled in the "best economy" calibration. This testing began in early April 1987. The best economy tests were all performed with zero throttle angle derivative.

Ricardo engine dynamometer test results from mixture range tests at key point conditions indicated that the highest brake thermal efficiency was achieved at an equivalence ratio of 0.7. It was considered, from Ricardo vehicle experience of applying lean control strategies to HRCC methanol engines, that a control strategy with 0.7 equivalence ratio could be developed in a vehicle for satisfactory driveability given sophisticated transient fueling compensation. Ignition timing was kept optimum since Ricardo believed that retard from MBT would degrade engine response to an unacceptable level.

The best economy strategy was based on engine runs over the load range at 20, 40, 60 and 80 rev/s to determine MBT ignition timings with 0.7 equivalence ratio up to 900 mbar absolute inlet manifold pressure. Above this, the mixture was progressively enriched for full load conditions. The fueling level and ignition timing required for each load and speed was centered in a set of MEC maps. Following this, the engine was run with the fueling level and ignition timing automatically controlled by the MEC to obtain performance and emissions readings from which a set of specific performance maps, e.g., BSFC, BTE, equivalence ratio, BSNOx and BSHC versus speed and load, was derived.

This precise calibration resulted in efficient engine operation and a maximum brake thermal efficiency of over 33 percent. Ricardo reported improvements of up to 10 percent under low load conditions compared to the carbureted HRCC engine.

Ricardo also found high levels of HC emissions under low load conditions when operating under "best economy" calibration conditions with lean mixtures and MBT ignition timings. NOx emissions during lean operating conditions (below 6 bar) were low and half that achieved with the carbureted version of the engine.

EPA run FTP test results for best economy calibration evaluations are listed in Table 6. All of these tests were run with zero throttle angle derivative and "engine-out" exhaust emissions averaged 0.45, 6.97, and 1.38 g/mile for HC, CO and NOx emissions, respectively. These levels are acceptable given that no catalyst was installed on the vehicle and the results varied by only five to six percent. Engine-out methanol emissions, as predicted by CTAB's MXX methanol emissions calculation program, were quite high, over 10 g/mile, as expected from a methanol vehicle which does not employ a sophisticated cold-start engine control strategy.

Fuel economy program objectives were met and exceeded with the results of the best economy vehicle tests. Methanol fuel economy averaged 14.13 MPG which translates into a gasoline equivalent (energy based fuel economy) of 28.0 mpg, or 3 percent higher urban MPG than the Audi 5000 Diesel baseline.[20] Fuel economy test results varied by only ± 2 percent, such that the improvement over the Diesel engine fuel economy varied from 1 to 5 percent. Details of these and other exhaust emissions and fuel economy data are included in Appendix D.

Table 6

Best Economy Calibration FTP
Emission and Fuel Economy Results, Audi/HRCC (g/mi)

Date	HC	CO	NOx	CH3OH	HCHO	OMHCE	MPG City
04/10/87	0.47	6.7	N/R	10.90	N/T	5.19	27.8
04/14/87	0.46	7.1	1.5	10.69	.483	5.09	27.9
04/15/87	0.42	6.6	1.3	9.76	.398	4.65	28.3
Average							28.0
Average (@ constant performance)							29.7
Diesel comparison							27.0

MPG city means 1975 FTP gasoline equivalent MPG.
N/R means not reported. Stable NOx readings were not possible.
N/T means not tested for.
First test: one stall, six false starts in Bag 1.
Second test: 8 stalls, 1 false start, Bag 1.
Third test: 5 stalls, 1 false start, Bag 1.

Table 7

Performance Results, Audi/HRCC

0-50 Accel. (seconds)	30-50 Accel. (seconds)	Vehicle
13.0	7.1	Audi/HRCC
16.6	9.1	Audi/Diesel

Testing conducted on a chassis dynamometer.
For 0-50 times, gears selected for best performance.
For 30-50 times, maneuver started at 30 cruise, run in third gear.

V. Vehicle Testing for Performance

In order to compare the Audi/HRCC MPG to the Audi/Diesel MPG at equal performance, a series of acceleration tests were performed on the Audi/HRCC to compare to the values in Table 2. Several sequences of 0 to 50 and 30 to 50 MPH accelerations were run. Zero to 50 MPH times averaged 13.0 seconds and 30 to 50 MPH times averaged 7.1 seconds (see Table 7). Both sets of measurements varied by roughly ± 6.0 percent. Both EPA (measured) and Ricardo (predicted) Diesel performance values are roughly 22 percent higher (slower) than the corresponding M100 values with the Audi/HRCC as shown in Table 8.

The decision to run 0 to 50 MPH acceleration tests initially on the Audi/Diesel as a baseline was made by the previous project engineer on this program. Subsequent 0 to 50 MPH tests were run, by Ricardo simulation and by EPA on the Audi/HRCC, for direct comparison to the baseline. Zero to 60 MPH tests, as is generally the standard practice in the automotive industry, would have allowed "measured" values to be compared to on-road acceleration data by the following equation which has been derived using on-road acceleration data:[21]

$$t_{0-60}\ (\text{sec}) = 0.82\ (HP/IW)^{-0.82}$$

Using this expression, "calculated" values for 0 to 60 MPH performance of the Audi/HRCC and the Audi/Diesel vehicles (both 3,250 lbs. IW) are 17.3 and 19.8 seconds, respectively. This means that the predicted 3,250 lb. Audi performance is improved by 13 percent by using the sequentially fuel-injected methanol HRCC engine instead of the original 2.0-liter Diesel engine. This translates into a 6 percent loss in fuel economy due to the higher performance of the HRCC engine (change in performance = 0.454 change in MPG). Therefore, to compare the methanol-fueled Audi to the diesel-fueled Audi at equal performance, all fuel economy measurements generated in this test program need to be multiplied by 1.06. Multiplication of the Audi/HRCC average FTP MPG (28.0) by 1.06 yields 29.7 MPG, or a 10 percent improvement over the Audi/Diesel at constant performance.

Table 8

EPA/Ricardo Comparison MPG and Performance
Ricardo: Computer Simulation - EPA: Measured

Measure	Ricardo			EPA		
	Diesel	M100	Percent	Diesel	M100	Percent
MPG	32.9	33.7	+2%	27.2	28.0	+3%
0-50	22.9	18.0	+21%	16.6	13.0	+22%
30-50	14.4	11.0	+24%	9.1	7.1	+22%

VI. Vehicle Testing for Reduced NOx Emissions

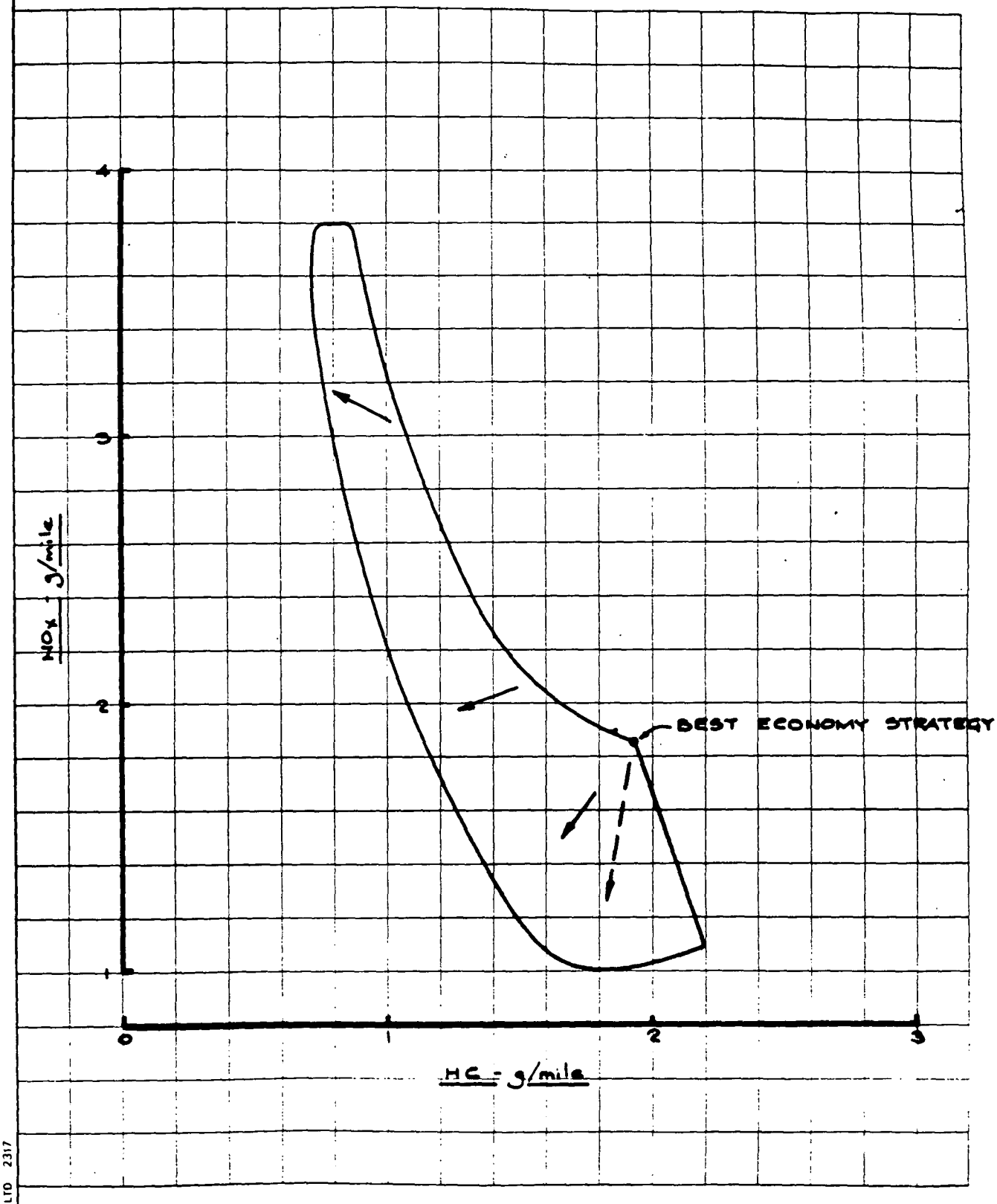
The second calibration which Ricardo developed for our evaluation was the reduced NOx strategy which employs a sophisticatd EGR control scheme and slightly richer operation (0.8 equivalence ratio) than the best economy calibration in order to achieve the project goals of 0.7 g/mi NOx exhaust emissions.

In order to determine an effective strategy for reduced NOx using exhaust gas recirculation, a Ricardo computer program "CONTROL" was used to analyze the test results from several EGR keypoint tests. The objective was to devise an alternative control strategy that would result in a maximum reduction in NOx emissions with minimum penalties of HC emissions and fuel consumption. Exploration over the range of mixture strengths and EGR rates established the operating envelope shown in Figure 6. From this data, it is clear that the best economy strategy represents a strategy towards the lower range of NOx emissions possible with MBT ignition timing. Furthermore, there is a strong link between reducing HC and increasing NOx emissions indicating that a simultaneous reduction of both is difficult to achieve, and the direction for minimum NOx is similar to that for a fuel consumption penalty. This indicates that reduced NOx will result in increased fuel consumption. This simple keypoint model also indicated that the limits presented by the test data resulted in a minimum NOx level of about 1 g/mi for the Federal Test Procedure if MBT timing were used. From this trade-off data, it was decided to pursue a strategy which would result in a minimum NOx strategy without a significant HC emission penalty, i.e., the dashed line in Figure 6.

The "CONTROL" program enabled the equivalence ratio and EGR rate for the reduced NOx strategy to be identified for the keypoint loads and speeds. This indicated that relatively rich mixtures of 0.8 and 0.9 equivalence ratio should be used with high rates of EGR to obtain NOx reduction without penalizing HC emissions. This strategy, using MBT ignition timings, resulted in a CYSIM NOx level prediction of 1.07 g/mi with a level of HC emissions similar to the best economy strategy. It was evident that a control strategy with MBT ignition timing would not enable the project goal of 0.7 g/mi to be achieved. The primary reason for the difficulty in achieving 0.7 g/mi NOx compliance was considered by Ricardo to be EPA's choice of vehicle which resulted in a poor power/weight ratio and subsequent high engine duty cycle. It was therefore necessary to apply 7°-10° ignition retard in the mid-upper load range from 20-60 rev/s in order to achieve the required level of 0.7 g/mi NOx. The final strategy resulted in a reasonable compromise between NOx reduction, HC emissions and fuel consumption. However, Ricardo believed that when operating at, or close to, the dilution tolerance limit of an engine, the use of ignition retard would result in a significant deterioration of driveability.

VW HRCC METHANOL 1·457l [79·5mm x 73·4mm]

HC - NO_x TRADE OFF



Following calibration of the control strategy, the engine was then run with auto fueling/auto ingition/auto EGR to obtain performance and emission readings from which the specific reduced NOx strategy performance maps were derived.

As a result, up to 15 percent EGR is used under medium load conditions and part load equivalence ratios are in the range of 0.8 to 0.9. Brake thermal efficiency was slightly reduced with the maximum reduced by 2 percent to 31 percent. Comparison of the reduced NOx maps with the best economy maps shows that at low load conditions, significant reductions have been achieved but increased HC emissions are evident at higher loads. Conversely, NOx emissions are somewhat increased at low load conditions, although they remain at a low absolute level but are significantly reduced in the medium to high load range; the peak NOx level of 12 g/kW h is reduced to 2 g/Kw h over the range of engine speed used during the FTP drive cycle.

When we began testing the Audi/HRCC with the MEC set on the reduced NOx strategy, it was difficult to achieve accurate NOx emissions, because NOx response failed to return to zero stripchart deflections after pre-sample bag analyzer span checks. The error was determined to be less than 5 percent by the amount of deflection from the zero point and this deflection remained stable throughout most tests. However, the cause of interference by methanol exhaust has not been determined as of this writing. Preliminary analysis determined that the deflection from zero was proportional to methanol emissions and did not occur at low methanol emission rates or with other methanol vehicles and other NOx measuring instruments.[23] This problem is still being investigated within the Test and Evaluation Branch.

A catalyst, with a loading of 9:1 Pt:Rh, was installed on the Audi/HRCC vehicle to see if the level of catalyst-out emissions was significantly lower than engine-out emissions enough to not interfere with accurate operation of the NOx analyzer. Although emission levels were significantly reduced, particularly the reported HC and NOx emissions, problems with the NOx analyzer persisted. It was then decided to complete testing of the reduced NOx (zero throttle angle) calibration without the catalyst and merely note that NOx emissions are in error by the amount of the response deflection from zero. The results of this testing are shown in Table 9.

These test results show that the NOx emission target of 0.7 g/mi was easily achieved with the HRCC engine in the Audi with acceptable driveability. Unfortunately, though NOx averaged 0.44 g/mi (37 percent below the emission target), other exhaust emissions were substantially high, particularly formaldehyde and methanol emissions.

Table 9

Reduced NOx Calibration FTP
Emission and Fuel Economy Results, Audi/HRCC (g/mi)

Date	HC	CO	NOx	CH3OH	HCHO	OMHCE	MPG City
07/09/87	0.44	13.5	0.54	10.20	.348	4.86	26.8
08/27/87	0.46	13.8	0.40	10.56	.395	5.03	26.8
08/28/87	0.50	10.3	0.39	11.43	.405	5.44	26.5
Average	0.47	14.5	0.44	10.73	.383	5.11	26.7

MPG city means 1975 gaosline equivalent mpg.
Test one: 5 stalls, 1 false start in Bag 1.
Test two: No stalls, false starts reported.
Test three: 4 stalls in Bag 1.

It was recognized that more than enough NOx control had been achieved at the expense of other emissions and fuel consumption, though driveability was much better than Ricardo predicted. Ricardo was then asked to submit the ignition timing maps from the original reduced NOx strategy that (Ricardo reported) achieved 1.07 g/mi NOx in the cycle simulations. The idea was to give up a little NOx control to make the overall emissions performance in the reduced NOx calibration more acceptable. The results showed not only higher NOx emissions, though still within project goals, but also higher HC, CO, and methanol emissions. Methanol emissions were calculated for all emissions tests in this test program using the CTAB MXX emission factor program and are included in Appendix D.

Some weaknesses of the Ricardo CYSIM predictive capabilities were identified in MVEL Audi/HRCC vehicle testing. Although all project goals were achieved and the engine showed an unlimited ability for alternate engine control flexibility, it was believed that the completely optimized lean operation of methanol, particularly during cold starts, has yet to be realized with this engine, vehicle, and control system combination. Driveability is indeed a parameter that the predictive capabilities of the model are not sophisticated enough to determine. Transient operation of the vehicle was, all in all, quite acceptable though the times predicted for accelerations were considerably higher than the measured performance times.

VII. Conclusions

1. The application of sequential fuel injection to the HRCC methanol engine was performed successfully with an 11 percent increase in rated power over the carbureted version. The installation of this engine in the Audi 5000 (Diesel) vehicle and subsequent chassis dynamometer evaluation was also accomplished successfully.

2. On a "gasoline" equivalent basis, the Audi/HRCC (28 MPG city) demonstrated a 3 percent improvement in fuel economy over the certification Audi/Diesel value. On a constant performance basis, obtained by comparison to on-road data, the Audi/HRCC showed an improvement of 10 percent in fuel economy compared to the Audi/Diesel.

3. Measured and predicted Audi/HRCC performance is improved by 22 percent over Audi/Diesel performance. The Audi/HRCC averaged 13.0 seconds on ten 0-50 MPH acceleration tests and 7.1 seconds on ten 30-50 MPH runs. Ricardo's predicted values were 1.4 to 1.6 times higher (slower) than EPA's measured values, but the percent improvement (22 to 24 percent) was the same.

4. Reduced NOx emissions, 0.44 g/mi $\pm$ 0.07 g/mi, are capable of being achieved with the sophisticated engine management system provided by the Ricardo microprocessor engine controller. An optimum combination of EGR rate, HC emissions, ignition timing and transient control were obtained to achieve this objective.

5. Transient operation of the Audi/HRCC was obtained with acceptable driveability for both best economy and reduced NOx control strategies when the MEC was calibrated with zero throttle angle derivative. This result indicates that there are already enough transient fueling controls built in to the Ricardo MEC fueling strategy, such that minute changes in fuel output with small changes in throttle angle are not necessary, and actually degrade engine performance and driveability.

6. Engine cold start control needs to be improved and is the source of unacceptably high methanol emissions. A follow-up program which will modify the cylinder head for use of pencil injectors with open-valve variable start of injection through MEC control may address this shortcoming of the current state of Audi/HRCC development.

7. Had the HRCC engine been placed in a vehicle with a more appropriate vehicle weight and engine compartment configuration, i.e., a VW Rabbit, the engine vehicle combination would have a 30 percent improvement in power/weight ratio and a Ricardo estimated additional 3.3 percent improvment in fuel economy as well as an additional 12 percent reduction in NOx emissions. However, these simulated emissions and fuel economy values were obtained without reoptimization of the engine control strategy to account for the different control required at given engine speeds and loads with the 2500 lb inertia weight.

8. It is hoped that the application of a cylinder head configuration more closely resembling "direct injection," with the pencil injectors and variable start of injection, will further improve fuel economy and engine exhaust emissions. With fuel injected past open intake valves, it is believed that heat losses will be minimal, A/F ratio can be higher, more residuals will be burned (more combustion near TDC), and the engine should theoretically start quicker.

9. The microprocessor engine controller and the air/fuel ratio meter were invaluable engine management and diagnostic tools in the application of the sequentially fuel-injected HRCC engine in the Audi 5000 vehicle. Program objectives would have been quite difficult to obtain without them.

VIII. Future Engine Modifications and Vehicle Evaluation

At the completion of the second Ricardo contract, additional contract funds still remained and Ricardo agreed to use them for the further development of the HRCC engine concept. It was decided, as an attempt to improve cold startability and warm-up emissions, that the HRCC engine would be modified to employ low-cost high-speed "direct-injection" methanol combustion.

An additional VW Rabbit cylinder head was machined with the same compression ratio and squish as the original HRCC design to incorporate pencil (stream-type) fuel injectors as opposed to the previous spray-cone injectors.[24] MEC software is being modified to change the end of injection such that the start of injection will vary with fuel quantity during engine transients. The injection phasing will remain the same at 70° CA.

This work will soon be completed by Ricardo such that EPA evaluation of this HRCC modification can be performed. The theory behind this system is that enough of the spray will ignite before impingement so that the delay period will be normal, while the bulk of the spray will have to evaporate from the cavity walls prior to combustion. Thus, the second stage of the combustion process is slowed down, avoiding excessive rates of pressure rise. With fuel injected past open intake valves, it is theorized that heat losses will be minimal as more combustion occurs at TDC, more residuals are burned, leaner combustion is possible, and engine startability and warm-up emissions should be measurably improved.

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APPENDIX A

A-1

W. Clemmens

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ANN ARBOR, MICHIGAN 48105

OFFICE OF
AIR, NOISE AND RADIATION

OCT 19 1983

MEMORANDUM:

SUBJECT: Results of Initial Ricardo VW Testing

FROM: Bruce Michael
Technical Support Staff

TO: Charles Gray, Director
Emission Control Technology Division

THRU: William Clemmens, Project Manager
Phil Lorang, Chief
Technical Support Staff

EPA funded a contract for Ricardo to develop an optimum chamber shape for a High Ratio Compact (combustion) Chamber (HRCC) engine. The contract specified delivery of that engine to EPA in Ann Arbor. Prior to continuing with EPA plans to install the engine into a vehicle, the engine was tested on the engine dynamometer to ensure that the engine was operating properly after shipment, and to check correlation of testing equipment.

This memo presents the initial EPA dynamometer tests of this HRCC engine, and compares them with the results Ricardo obtained at their lab. These initial results will also be used as baseline data with which to compare our further development of the engine.

To briefly summarize, the EPA results were in close agreement to the Ricardo results in thermal efficiency, power, fuel consumption, and emisions. The volumetric efficiency reported by Ricardo was higher than that tested at EPA.

Results

From the beginning, we experienced problems with trying to test the engine in its as-received condition. We replaced the valves prior to running our first tests (see the "Engine History" section), so technically we do not have an exact comparison to the Ricardo tests. However, because stock replacement parts were used and all settings were the same as at Ricardo, I believe that we can compare the data as if the engine were in the as-received condition. Figures 1-3 graphically show thermal efficiency, power, and fuel consumption for both the initial EPA tests* and the Ricardo tests. Ricardo test data was used to generate results on our own computer for these comparisons. However, because of the manner in which Ricardo ran their tests, Ricardo data from a range of "percent powers" had to be used in our program as if they were a single "percent power". As can be seen, even with this data conversion, the EPA results are generally in very close agreement with the Ricardo results.

The Ricardo reported results were usually better than the results we obtained using their input data, however. For example, the Ricardo report shows a maximum horsepower of 70.6 and thermal efficiency of 32% at full load whereas the EPA generated results using their data shows only 68.2 hp and 30% efficiency. The different values apparently are due to different horsepower correction factors (DIN vs. SAE).

The Ricardo data could not be used to calculate volumetric efficiency on our computer, therefore the Ricardo reported results were hand drawn on the graph showing the initial EPA results (Figure 4). Their results showed about 10% better efficiency than our tests. Again, the difference in calculating results is probably the cause of this. Our many tests both before and after the engine rebuild gave very consistent results (see Figures 5 and 6), so I do not believe we had a problem with our initial testing.

Idle fuel consumption and emission measurements at EPA were all performed after the engine rebuild of 6/01/83. Idle fuel consumption is shown in Figure 7. Ricardo reported lower fuel consumption for all ignition timing settings than we did. Ricardo performed idle tests at 750 rpm whereas ours were at 875 rpm, a difference of 17%. This probably accounts

*EPA test No. 1173, which was prior to the engine rebuild.

for most of our larger idle fuel consumption, which ranges from about 5-20% greater than theirs. Another factor is that Ricardo measured fuel mass during their tests and converted it to volume using an assumed specific gravity about 3% higher than we do which resulted in Ricardo reporting a lower fuel volume and therefore lower fuel consumption values.** One interesting note is that Ricardo ran seven idle tests at 19°BTDC and used only the last test for use in their graph. Two of the six earlier tests showed higher fuel consumption than did our test at 20°BTDC. Apparently Ricardo did not use the earlier tests because the test cell and fuel temperatures were not yet stabilized.

Emission maps for our HC, CO and NOx results are shown in Figures 8-10. The emission maps were drawn using coarse map data obtained after the 6/1/83 engine rebuild. For comparison, many Ricardo points are shown on the maps, in circles with the letter "R". There is reasonable agreement for all three emissions; the agreement for NOx seems to be the best.

**When I input the Ricardo data into our computer, I converted their measured fuel mass values to volume. This was performed by using textbook specific gravities for the reported fuel temperatures. The specific gravities I used were generally about .796 whereas they used .818 for all cases. Measured data on our fuel indicates a specific gravity of .7955.

Engine History at EPA (Summary test results are shown in the Appendix)

4/22/83 First dynamometer runs (warmups and engine check-out) at EPA in as-received condition. Best torque measured was 75-77 ft-lbs.

4/27/83 In attempting to find TDC for accurate timing measurements, the small rubber stop fell into cylinder No. 1. The head was removed to retrieve it. When the head was put back on, the camshaft cover was not replaced. This was felt to be alright, since it had been done on an engine with a similar timing belt set-up (Daihatsu). However, in doing an engine warm-up the camshaft belt came off and the valves were bent.

5/4/83 Installed new intake and exhaust valves.

5/17/83 First fine maps, without emissions, run. (Test 1173.) Peak torque was 81.0 ft.-lbs.

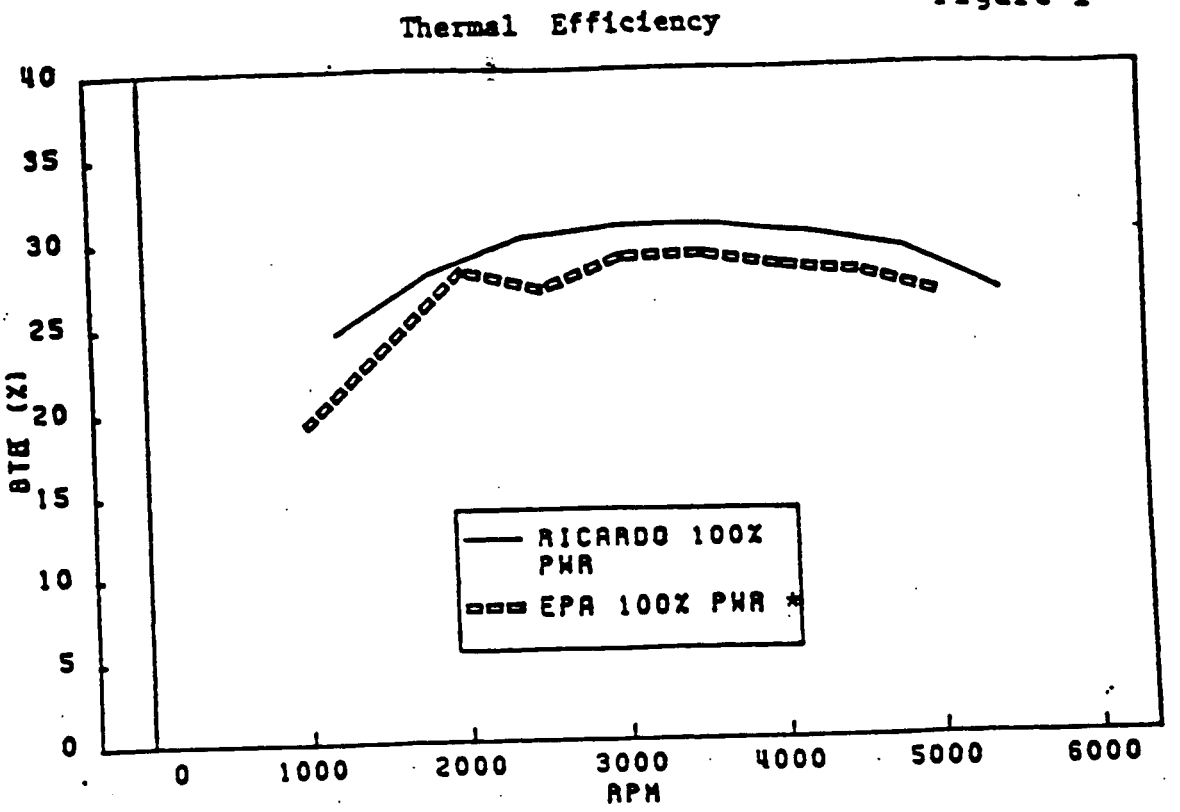
5/18/83 Engine failure. The apparent reason was that some of the material Ricardo used in reforming the intake channels flaked off and got into the combustion chamber. This seems likely, because a lot of material is missing from the No. 3 intake channel, and the No. 3 cylinder wall was greatly damaged.

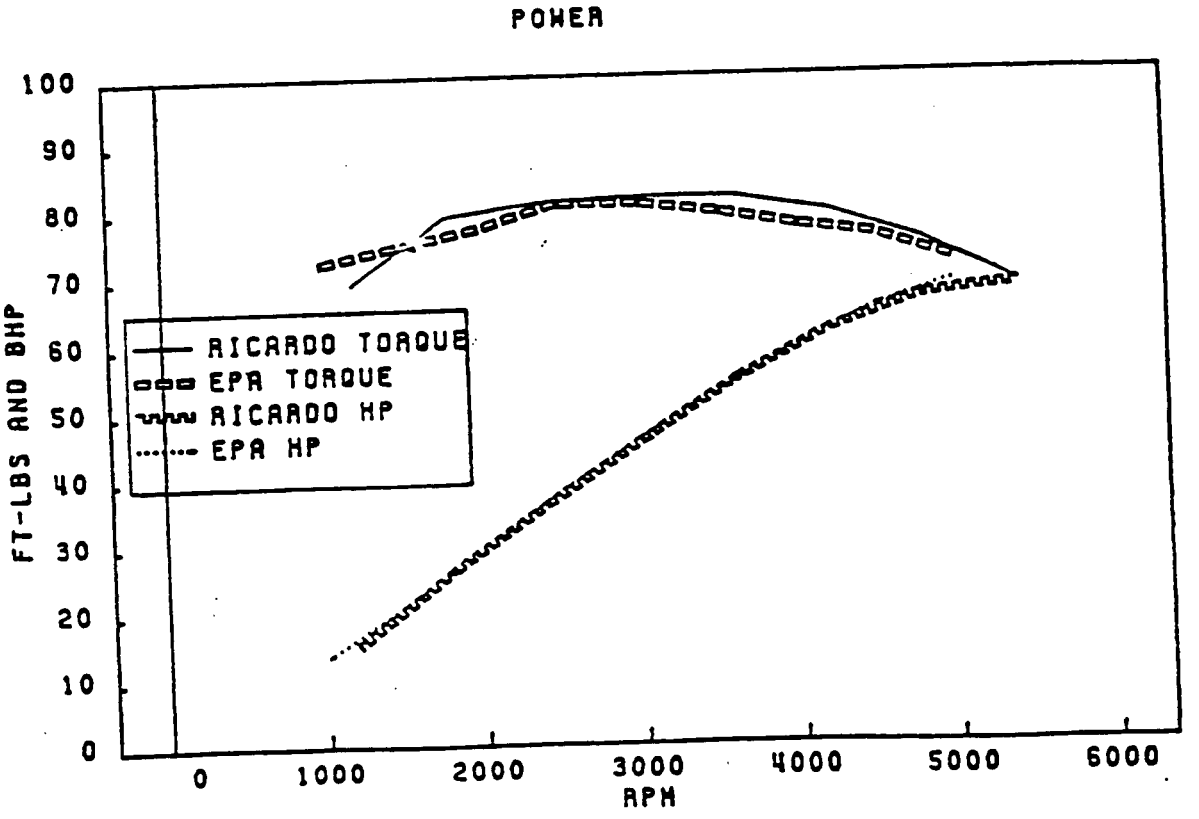
6/1/83 Reassembled engine with new block, new head (without the material in the intake channels), new pistons and valves, and the original crank and rods. Coarse maps and emissions tests run shortly after. (Tests 1175-1178.) Peak torque was 81.5 ft.-lbs.

6/28/83 Carburetor cleaned due to engine not idling well. Idle tests and fine maps run after this. (Tests 1334 and 1287.)

cc: w/attachments
J. Alson
W. Clemmens
W. Smuda
R. Wagner
L. Landman

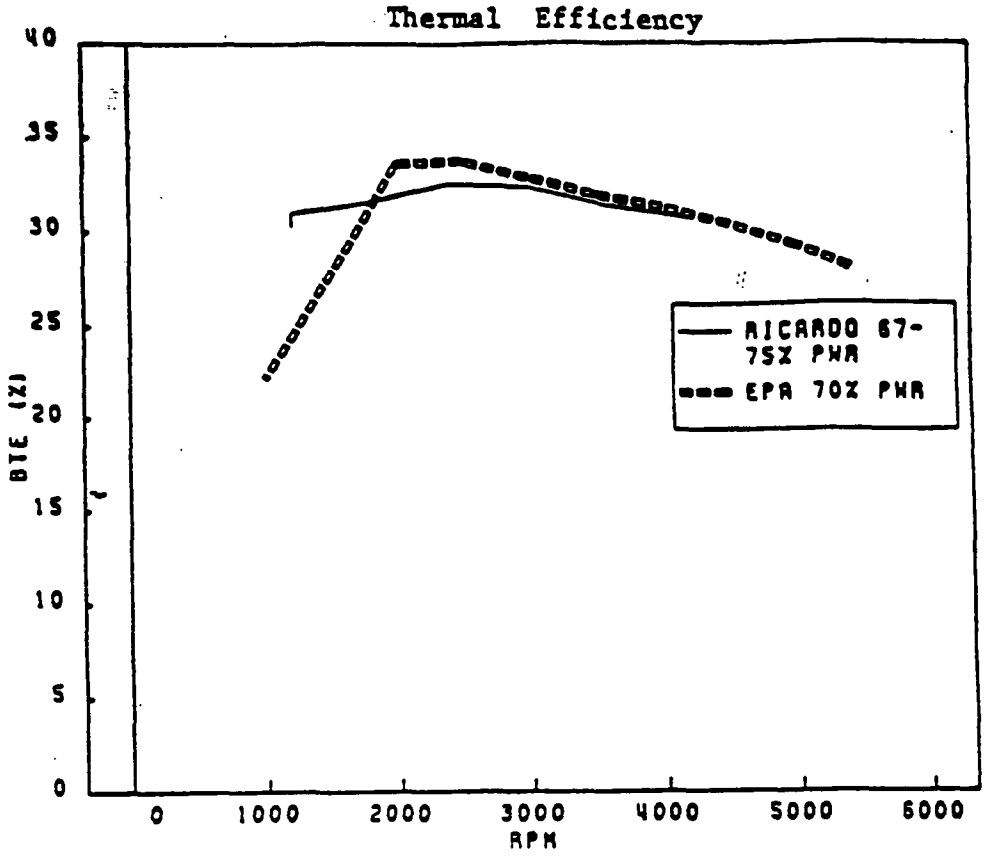
Figure 1





* EPA results from test 1173, Ricardo results on test 1361.

Figure 2


Thermal Efficiency
BTE (%)
RPM
RICARDO 67-75% PWR
EPA 70% PWR
0
5
10
15
20
25
30
35
40
0
1000
2000
3000
4000
5000
6000

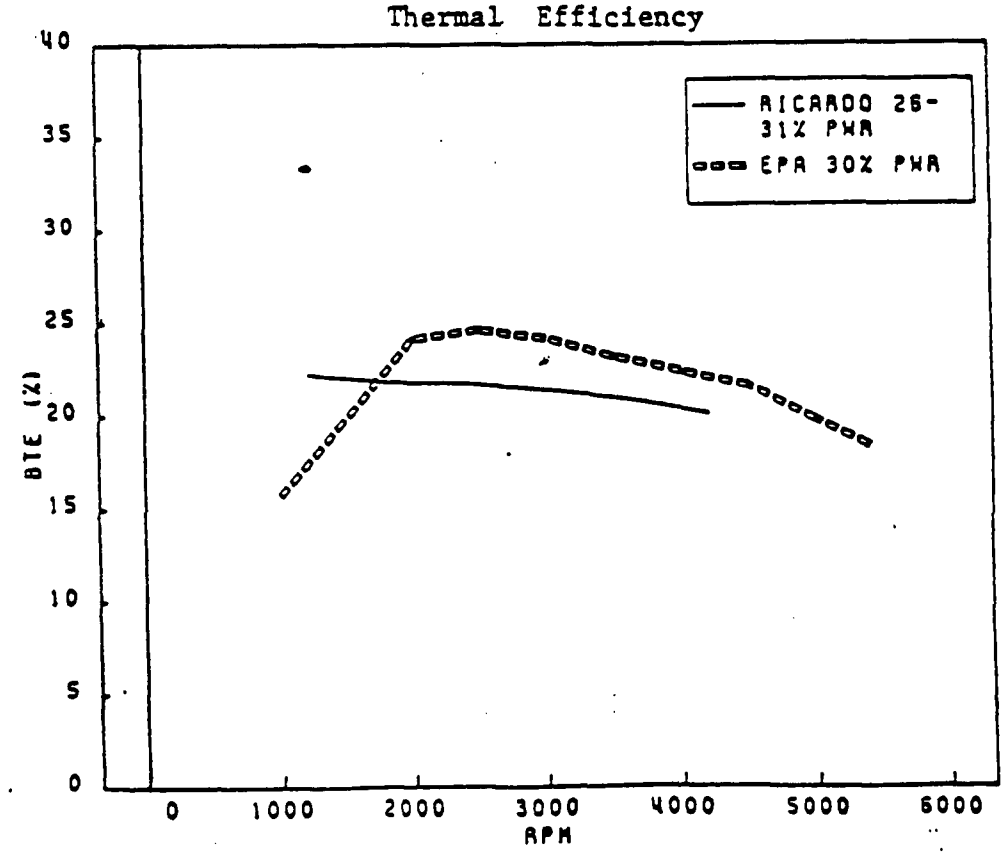
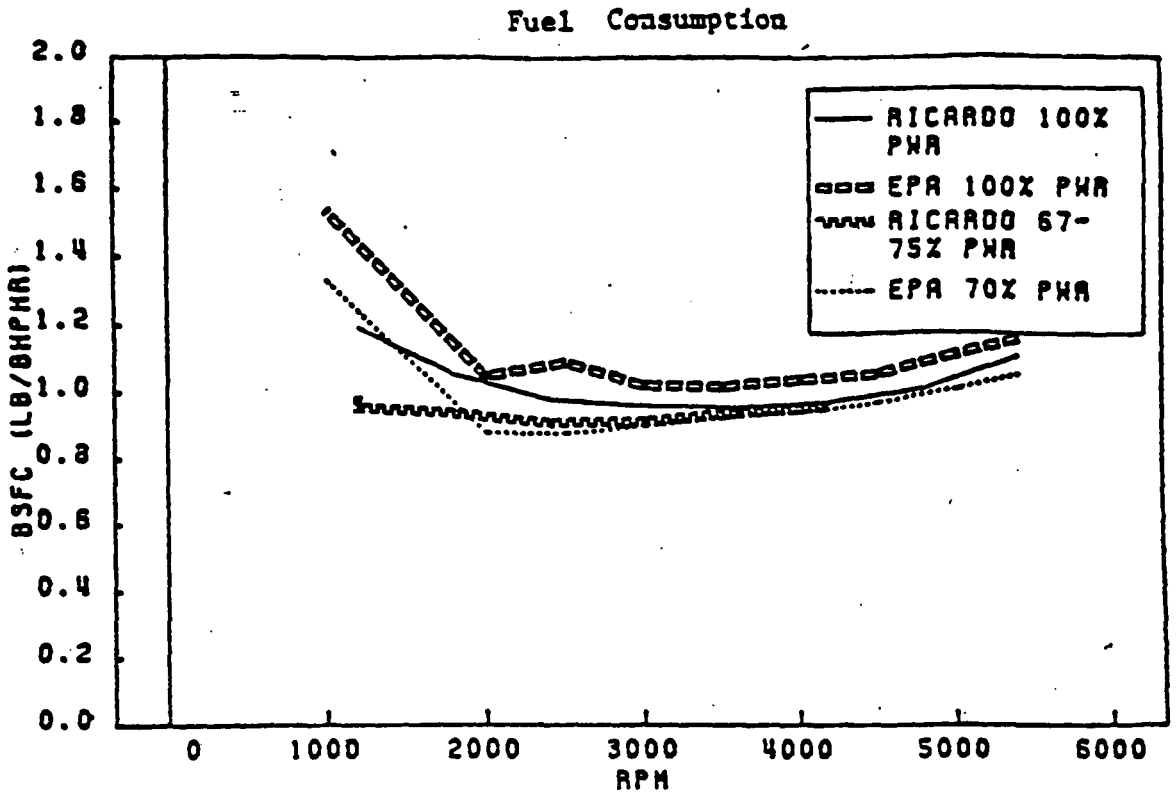

Thermal Efficiency
BTE (%)
RPM
RICARDO 26-31% PWR
EPA 30% PWR
0
5
10
15
20
25
30
35
40
0
1000
2000
3000
4000
5000
6000

Figure 3


Fuel Consumption
BSFC (LB/BHPHR)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
6000
RPM
RICARDO 100% PWR
EPA 100% PWR
RICARDO 67-75% PWR
EPA 70% PWR

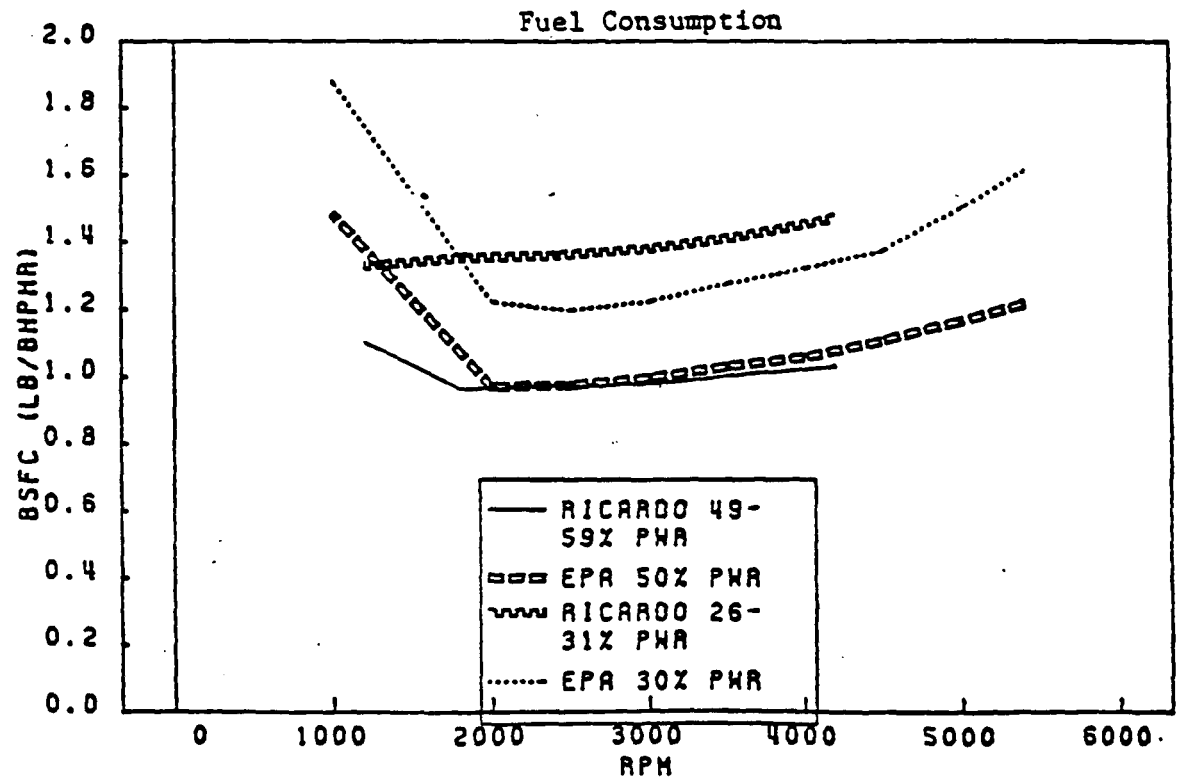

Fuel Consumption
BSFC (LB/BHPHR)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
6000
RPM
RICARDO 49-59% PWR
EPA 50% PWR
RICARDO 26-31% PWR
EPA 30% PWR

Figure 4

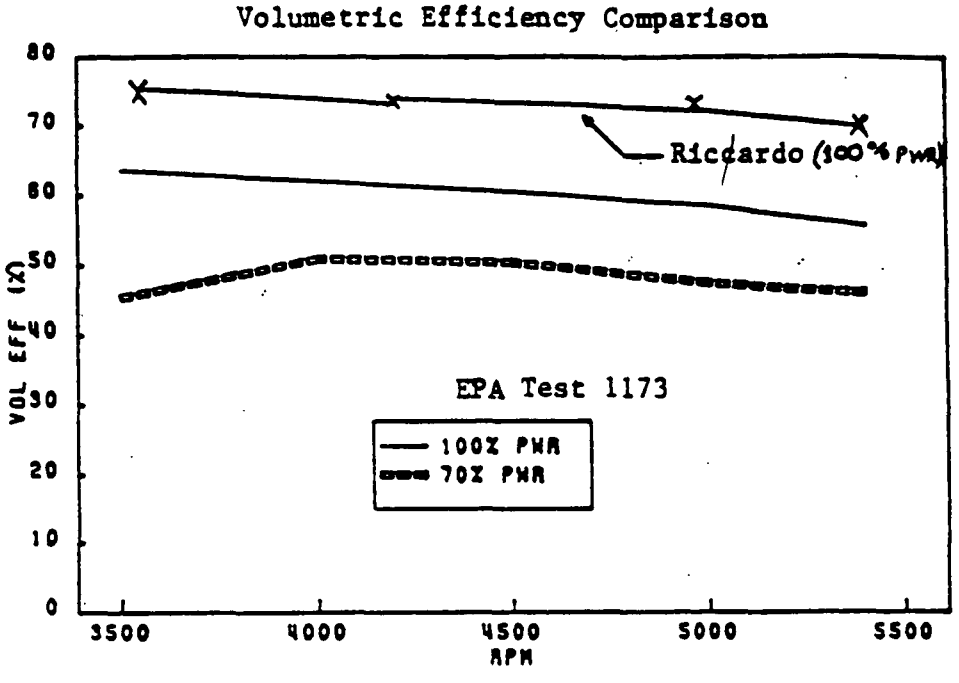
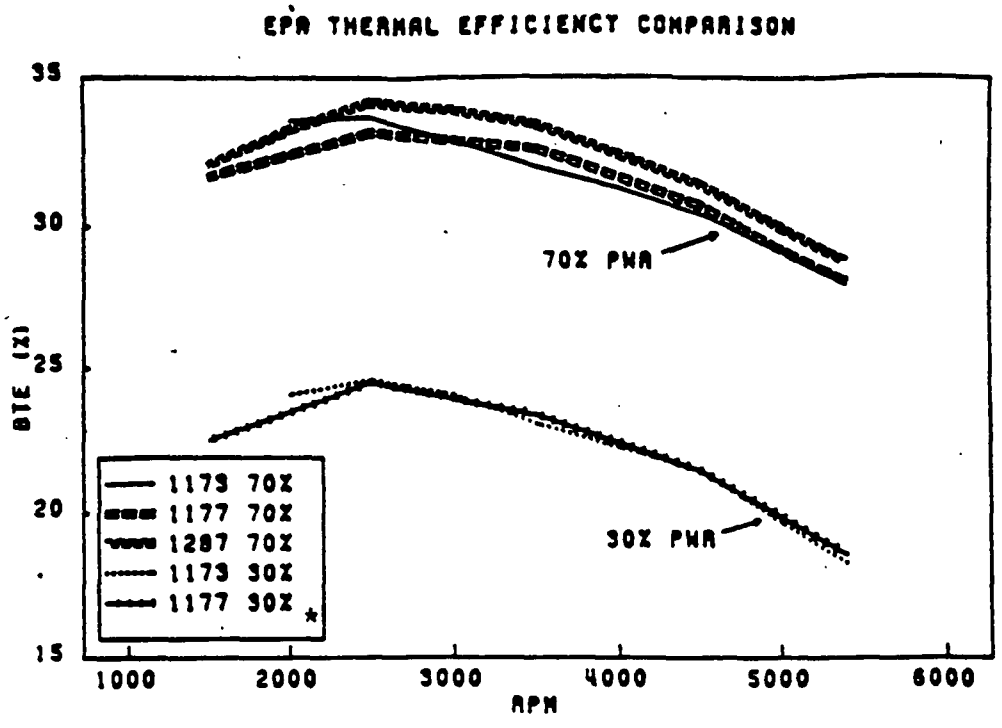

Volumetric Efficiency Comparison
80
70
60
50
40
30
20
10
0
VOL EFF (%)
3500
4000
4500
5000
5500
RPM
Riccardo (100% PWR)
EPA Test 1173
100% PWR
70% PWR

Figure 5



* Test 1287 at 30% pwr could not be graphed due to the graphics program only allowing 5 lines.

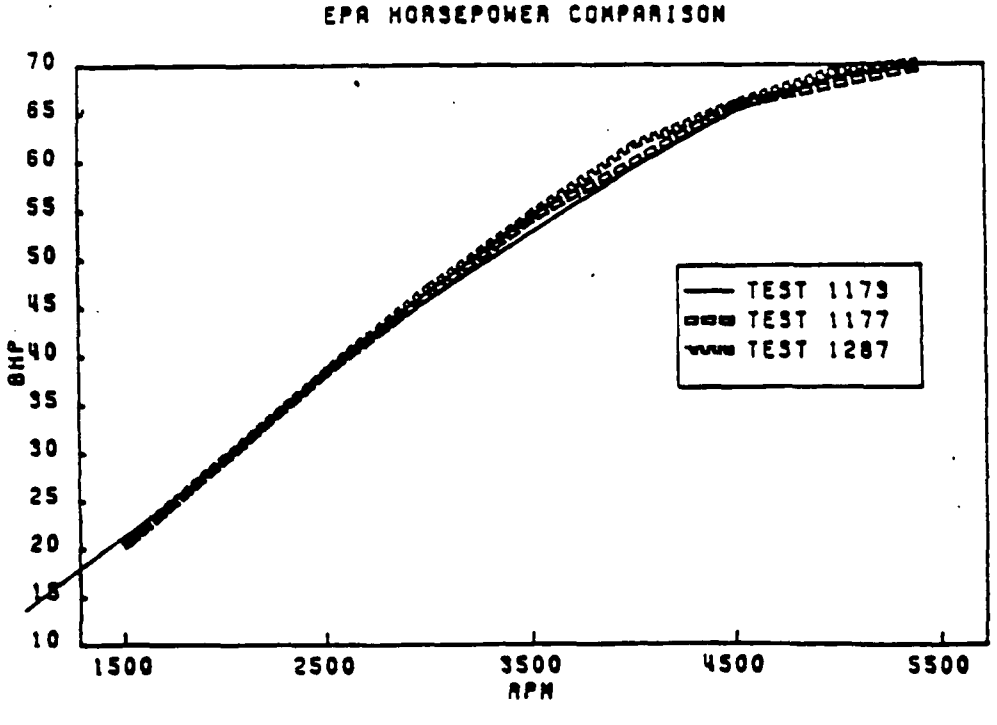


Figure 6

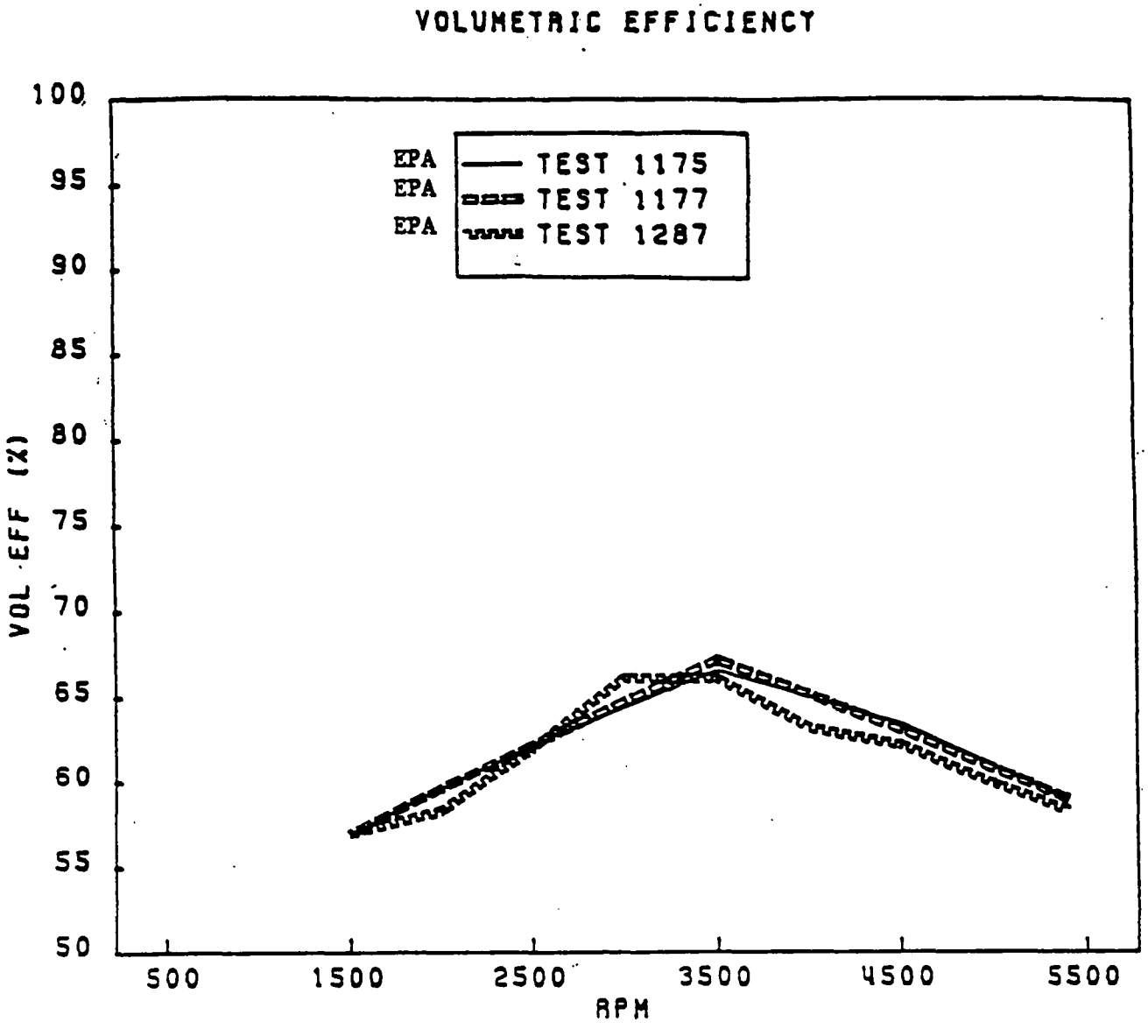

VOLUMETRIC EFFICIENCY
EPA TEST 1175
EPA TEST 1177
EPA TEST 1287
VOL EFF (%)
100
95
90
85
80
75
70
65
60
55
50
500
1500
2500
3500
4500
5500
RPM

Figure 7

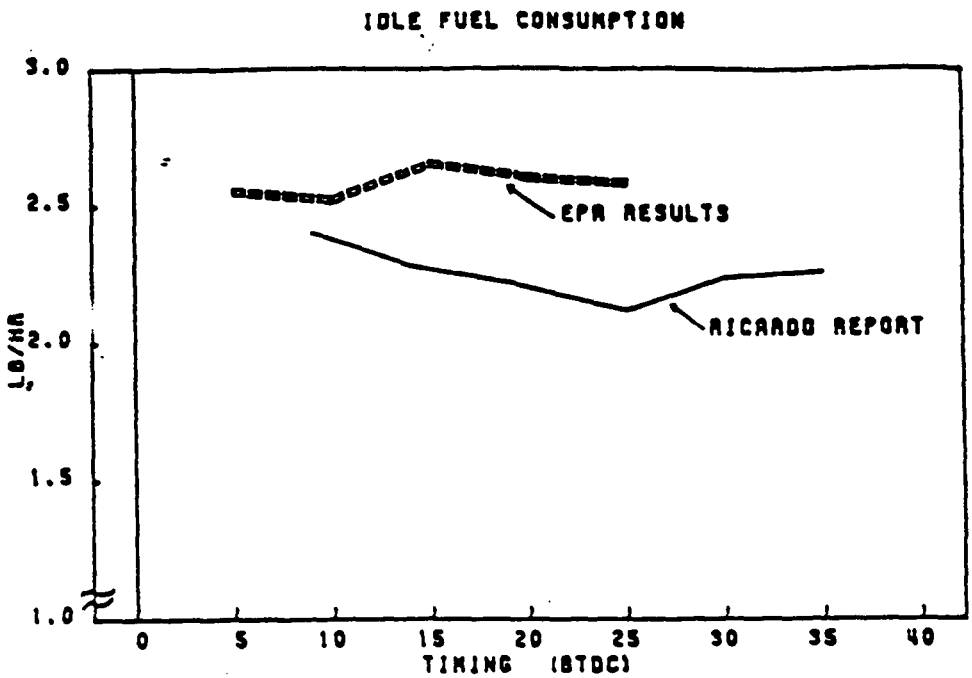

IDLE FUEL CONSUMPTION
3.0
2.5
2.0
1.5
1.0
LB/HR
EPA RESULTS
RICARDO REPORT
0
5
10
15
20
25
30
35
40
TIMING (BTDC)

Figure 8

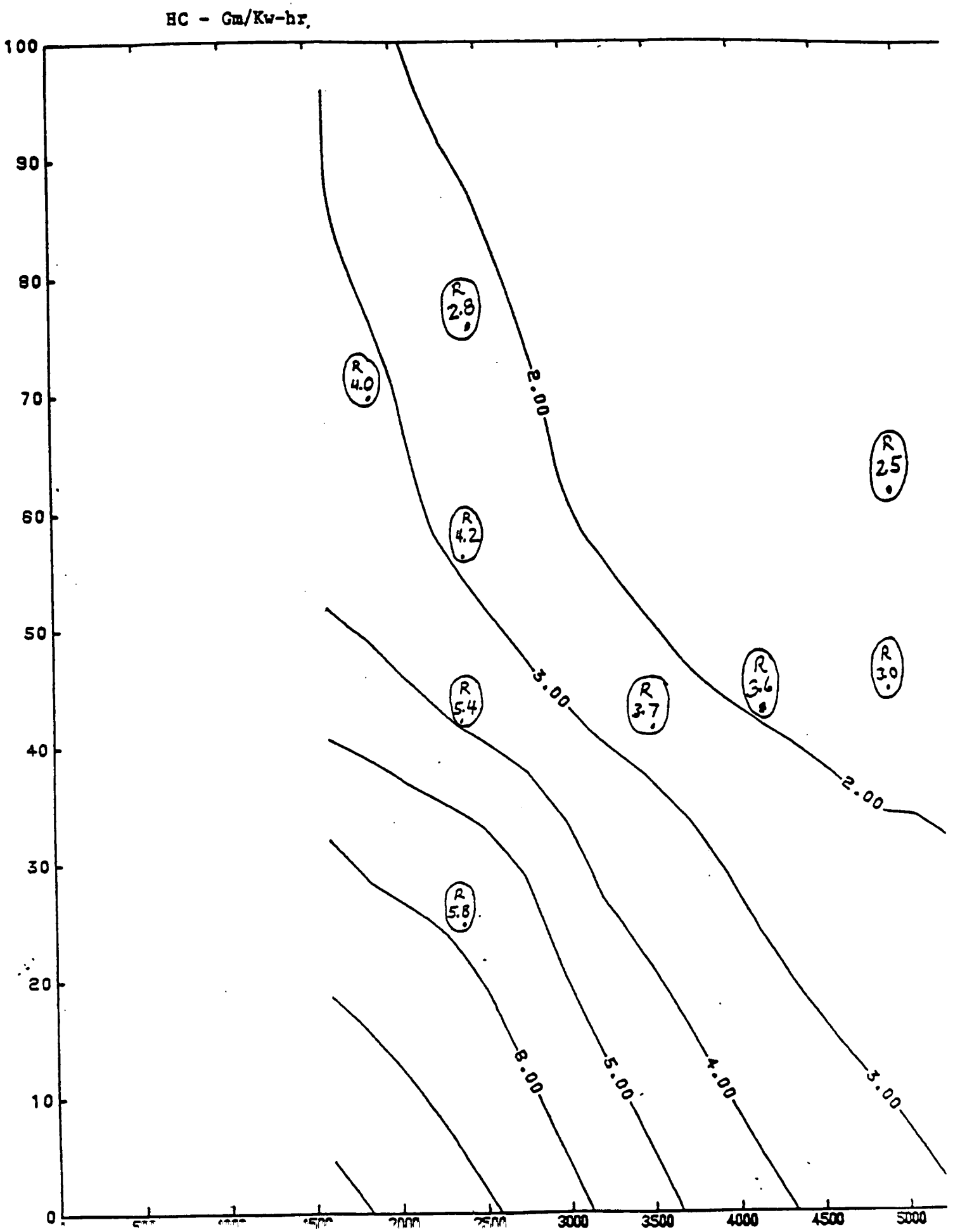

HC - Gm/Kw-hr.
100
90
80
70
60
50
40
30
20
10
0
2000
2500
3000
3500
4000
4500
5000
R 2.8
R 4.0
R 4.2
R 5.4
R 5.8
R 2.5
R 3.0
R 3.6
R 3.7
2.00
3.00
2.00
8.00
5.00
4.00
3.00

Figure 9

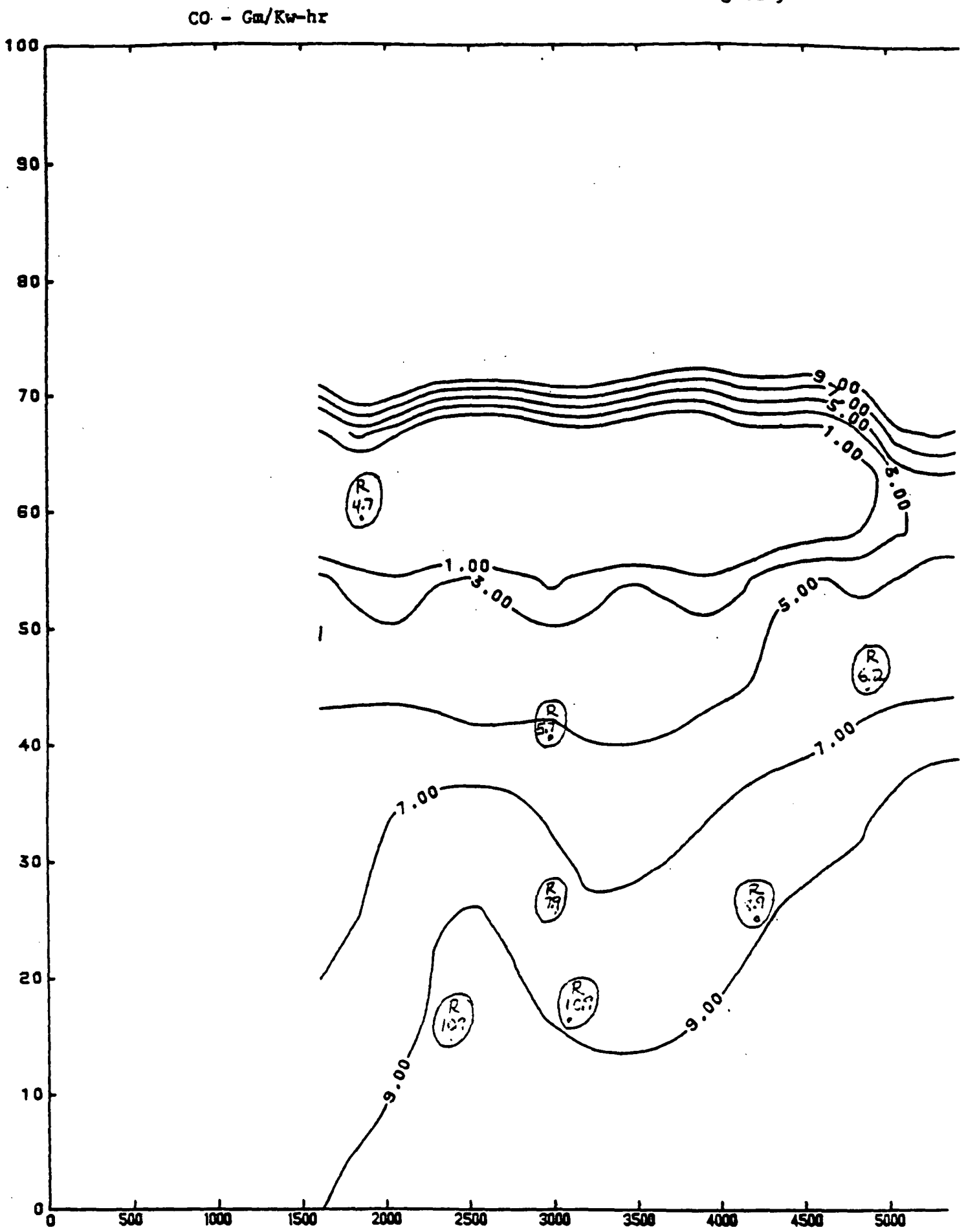
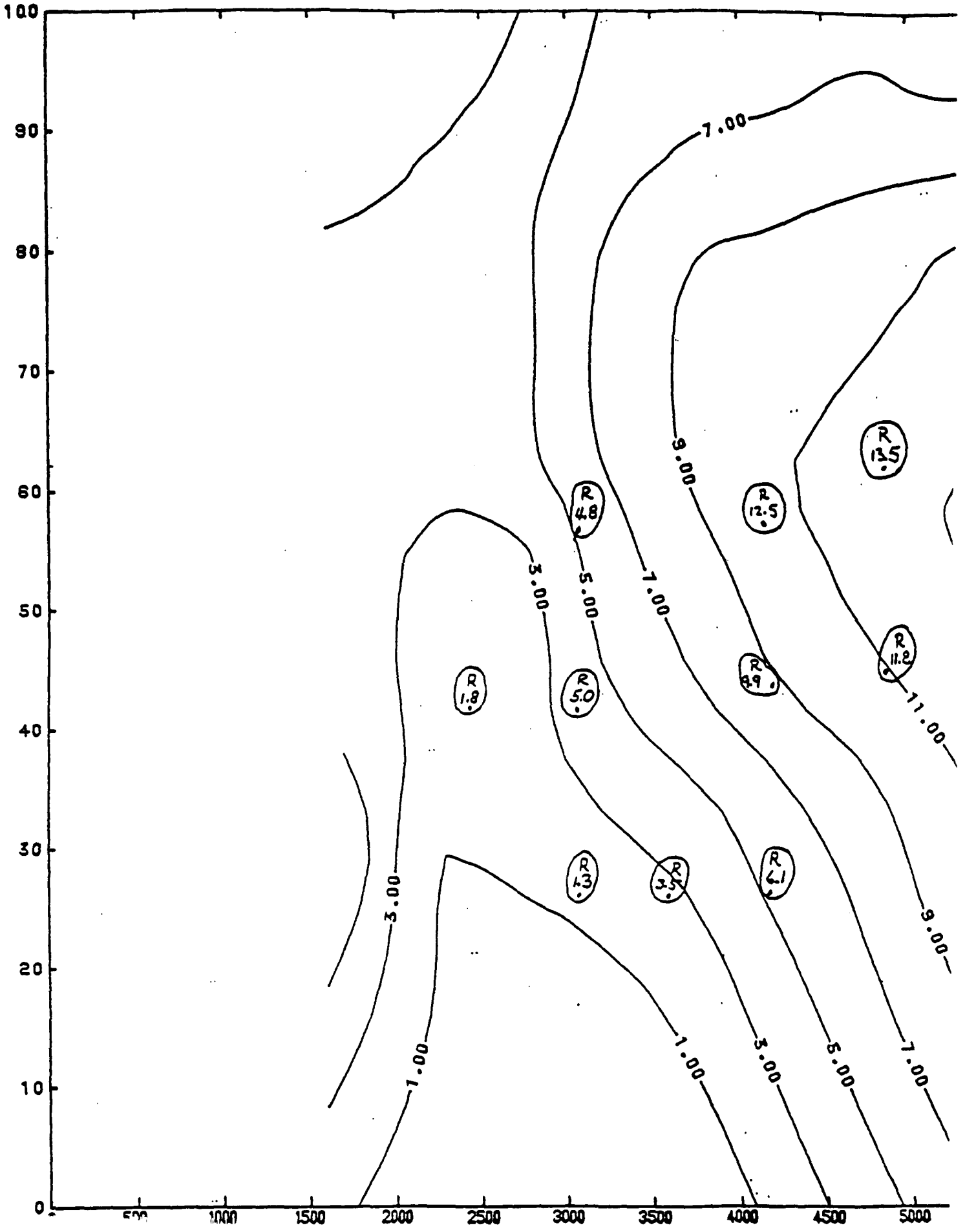

CO - Gm/Kw-hr
100
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
9.00
5.00
1.00
3.00
7.00
R 4.7
R 6.2
R 5.7

Figure 10

NOx - Gm/Kw-hr



TEST NO.: HD-811175 ENGINE: 590 VW-8 0 TEST D/T: 6- 8-83 9: 0 REPORT D/T: 09-19-83 09:40 P062581

SUMMARY REPORT (First test with rebuilt engine)

RPM	TORQ. FT-LB	% MAX TQ.	THR POSN	IGN. TIMG.	INJ. TIMG.	CORR. BHP	MEAS. A/F	PHI EQUIV RATIO	AIR LB/HR	FUEL LB/HR	BSFC LB/ BHPHR	BSFC GAS EQUIV LB/ BHPHR	ENERGY EFFICIENCY %	1000* MBTU/ BHPHR	BRAKE SPECIFIC EMISSIONS (G/BHPHR) BSHC	BSCO	BSCO2	BSNOX	BSALDYH	BSPART
5400	67.7	100	32	25.08	0.	70.40	4.65	1.39	368.5	79.30	1.126	0.529	26.2	9.74	0.0	0.0	0.0	0.0		0.0
5400	46.9	70	70	24.08	0.	48.52	5.43	1.19	274.1	50.47	1.040	0.489	28.3	8.99	0.0	0.0	0.0	0.0		0.0
5400	33.7	50	112	26.08	0.	34.88	3.08	2.10	129.0	41.88	1.201	0.564	24.5	10.38	0.0	0.0	0.0	0.0		0.0
5400	20.0	30	145	25.08	0.	20.68	2.48	2.61	80.9	32.63	1.578	0.741	18.7	13.64	0.0	0.0	0.0	0.0		0.0
4500	76.9	100	24	15.08	0.	66.26	4.85	4.34	330.3	68.15	1.029	0.483	28.6	8.89	0.0	0.0	0.0	0.0		0.0
4500	53.3	70	60	22.08	0.	45.92	6.32	1.02	274.1	43.40	0.945	0.444	31.2	8.17	0.0	0.0	0.0	0.0		0.0
4500	39.0	50	102	25.08	0.	33.57	3.11	2.08	110.1	35.42	1.055	0.496	27.9	9.12	0.0	0.0	0.0	0.0		0.0
4500	23.4	30	137	30.08	0.	20.14	2.71	2.38	71.9	26.50	1.315	0.618	22.4	11.37	0.0	0.0	0.0	0.0		0.0
3500	81.5	100	14	18.08	0.	54.57	5.04	1.28	269.6	53.45	0.980	0.460	30.1	8.47	0.0	0.0	0.0	0.0		0.0
3500	57.0	70	50	20.08	0.	38.16	6.46	1.00	220.2	34.10	0.894	0.420	33.0	7.72	0.0	0.0	0.0	0.0		0.0
3500	40.0	50	92	25.08	0.	26.80	3.14	2.06	84.5	26.86	1.002	0.471	29.4	8.66	0.0	0.0	0.0	0.0		0.0
3500	24.5	30	129	30.08	0.	16.40	2.78	2.33	56.2	20.22	1.233	0.579	23.9	10.66	0.0	0.0	0.0	0.0		0.0
2500	80.5	100	10	16.08	0.	38.50	4.41	1.47	179.7	40.79	1.060	0.498	27.8	9.16	0.0	0.0	0.0	0.0		0.0
2500	56.7	70	32	15.08	0.	27.13	7.22	0.90	170.7	23.64	0.871	0.409	33.8	7.53	0.0	0.0	0.0	0.0		0.0
2500	40.4	50	76	21.08	0.	19.34	6.63	0.98	121.3	18.30	0.946	0.444	31.1	8.18	0.0	0.0	0.0	0.0		0.0
2500	24.6	30	115	28.08	0.	11.79	3.50	1.85	48.1	13.74	1.165	0.548	25.3	10.07	0.0	0.0	0.0	0.0		0.0
1500	70.0	100	20	6.08	0.	20.11	4.63	1.40	98.9	21.35	1.062	0.499	27.7	9.18	0.0	0.0	0.0	0.0		0.0
1500	48.6	70	33	6.08	0.	13.95	7.87	0.82	98.9	12.56	0.900	0.423	32.7	7.78	0.0	0.0	0.0	0.0		0.0
1500	35.7	50	90	16.08	0.	10.25	3.99	1.62	40.4	10.14	0.989	0.465	29.8	8.55	0.0	0.0	0.0	0.0		0.0
1500	21.0	30	145	20.08	0.	6.03	3.81	1.70	29.2	7.66	1.270	0.597	23.2	10.98	0.0	0.0	0.0	0.0		0.0

TEST NO.: HD-811173 ENGINE: 590 VW 1 TEST D/T: 5-17-83 10: 0 REPORT D/T: 08-22-83 16:37 PO62581

SUMMARY REPORT (First EPA test)

RPM	TORQ. FT-LB	% MAX TQ.	THR POSN	IGN. TIMG.	INJ. TIMG.	CORR. BHP	MEAS. A/F	PHI EQUIV RATIO	AIR LB/HR	FUEL LB/HR	BSFC LB/ BHPHR	BSFC GAS EQUIV LB/ BHPHR	ENERGY EFFICIENCY %	ENERGY EFFICIENCY 1000* MBTU/ BHPHR	BRAKE SPECIFIC EMISSIONS (G/BHPHR) BSHC	BSCO	BSCO2	BSNOX	BSALDYH	BSPART
5400	68.0	100	33	23.08	0.	69.80	4.64	1.39	375.6	80.96	1.160	0.545	25.4	10.03	0.0	0.0	0.0	0.0		0.0
5400	61.0	90	37	23.08	0.	62.65	6.08	1.06	372.9	61.34	0.979	0.460	30.1	8.46	0.0	0.0	0.0	0.0		0.0
5400	54.5	80	52	25.08	0.	56.04	6.08	1.06	343.3	56.47	1.008	0.473	29.2	8.71	0.0	0.0	0.0	0.0		0.0
5400	47.6	70	70	30.08	0.	48.98	6.01	1.08	310.0	51.57	1.053	0.495	28.0	9.10	0.0	0.0	0.0	0.0		0.0
5400	40.8	60	92	30.08	0.	42.01	3.31	1.96	156.4	47.25	1.125	0.528	26.2	9.72	0.0	0.0	0.0	0.0		0.0
5400	34.1	50	110	32.08	0.	35.12	3.14	2.06	133.9	42.65	1.214	0.570	24.3	10.50	0.0	0.0	0.0	0.0		0.0
5400	27.4	40	1270	30.08	0.	28.20	2.82	2.29	107.8	38.20	1.355	0.636	21.7	11.71	0.0	0.0	0.0	0.0		0.0
5400	20.1	30	1470	30.08	0.	20.67	2.59	2.50	86.3	33.34	1.613	0.758	18.3	13.94	0.0	0.0	0.0	0.0		0.0
5400	13.7	20	161	30.08	0.	14.09	2.66	2.44	73.7	27.75	1.970	0.925	15.0	17.03	0.0	0.0	0.0	0.0		0.0
5400	6.8	10	1780	30.08	0.	6.99	2.84	2.28	66.5	23.44	3.353	1.575	8.8	28.98	0.0	0.0	0.0	0.0		0.0
5000	72.2	100	29	25.08	0.	68.70	4.79	1.35	365.8	76.42	1.112	0.523	26.5	9.62	0.0	0.0	0.0	0.0		0.0
5000	64.2	90	360	25.08	0.	61.08	6.21	1.04	356.8	57.49	0.941	0.442	31.3	8.14	0.0	0.0	0.0	0.0		0.0
5000	58.0	80	490	25.08	0.	55.23	6.17	1.05	328.0	53.19	0.963	0.452	30.6	8.32	0.0	0.0	0.0	0.0		0.0
5000	50.2	70	670	30.08	0.	47.86	6.14	1.05	296.6	48.30	1.009	0.474	29.2	8.72	0.0	0.0	0.0	0.0		0.0
5000	43.0	60	90	30.08	0.	41.00	3.30	1.96	146.0	44.22	1.079	0.507	27.3	9.32	0.0	0.0	0.0	0.0		0.0
5000	36.0	50	1090	30.08	0.	34.34	3.02	2.14	120.4	39.87	1.161	0.545	25.4	10.03	0.0	0.0	0.0	0.0		0.0
5000	28.9	40	1270	30.08	0.	27.56	2.77	2.34	98.0	35.42	1.285	0.604	22.9	11.11	0.0	0.0	0.0	0.0		0.0
5000	21.6	30	1450	30.08	0.	20.60	2.55	2.54	78.6	30.83	1.497	0.703	19.7	12.94	0.0	0.0	0.0	0.0		0.0
5000	14.1	20	1620	30.08	0.	13.44	2.61	2.47	67.4	25.78	1.918	0.901	15.4	16.58	0.0	0.0	0.0	0.0		0.0
5000	7.5	10	1800	30.08	0.	7.15	2.87	2.26	62.5	21.78	3.048	1.432	9.7	26.34	0.0	0.0	0.0	0.0		0.0
4500	76.0	100	250	23.08	0.	65.14	4.96	1.30	340.6	68.66	1.054	0.495	27.9	9.11	0.0	0.0	0.0	0.0		0.0
4500	68.0	90	280	23.08	0.	58.34	6.46	1.00	340.6	52.75	0.904	0.425	32.6	7.82	0.0	0.0	0.0	0.0		0.0
4500	60.8	80	420	25.08	0.	52.17	6.42	1.01	309.1	48.17	0.923	0.434	31.9	7.98	0.0	0.0	0.0	0.0		0.0
4500	53.0	70	590	30.08	0.	45.47	6.43	1.01	283.1	44.00	0.968	0.455	30.4	8.36	0.0	0.0	0.0	0.0		0.0
4500	45.9	60	800	30.08	0.	39.38	6.35	1.02	254.8	40.15	1.019	0.479	28.9	8.81	0.0	0.0	0.0	0.0		0.0
4500	38.0	50	1020	30.08	0.	32.61	3.10	2.09	111.4	35.94	1.102	0.518	26.7	9.53	0.0	0.0	0.0	0.0		0.0
4500	30.6	40	1200	30.08	0.	26.26	2.87	2.26	90.8	31.68	1.206	0.567	24.4	10.43	0.0	0.0	0.0	0.0		0.0
4500	23.1	30	1360	30.08	0.	19.83	2.78	2.33	75.5	27.16	1.370	0.644	21.5	11.84	0.0	0.0	0.0	0.0		0.0
4500	15.0	20	1560	30.08	0.	12.87	2.75	2.35	62.9	22.84	1.775	0.834	16.6	15.34	0.0	0.0	0.0	0.0		0.0
4500	7.8	10	1760	30.08	0.	8.34	3.16	2.05	58.4	18.49	2.216	1.041	13.3	19.16	0.0	0.0	0.0	0.0		0.0
4000	77.5	100	20	25.08	0.	59.36	5.04	1.28	310.0	61.57	1.037	0.487	28.4	8.97	0.0	0.0	0.0	0.0		0.0
4000	69.8	90	240	25.08	0.	53.48	6.56	0.99	309.1	47.10	0.881	0.414	33.4	7.61	0.0	0.0	0.0	0.0		0.0
4000	62.2	80	380	26.08	0.	47.70	6.54	0.99	282.2	43.15	0.904	0.425	32.6	7.82	0.0	0.0	0.0	0.0		0.0
4000	54.3	70	540	30.08	0.	41.64	6.50	1.00	254.3	39.14	0.940	0.442	31.3	8.13	0.0	0.0	0.0	0.0		0.0
4000	46.3	60	750	32.08	0.	35.52	5.89	1.10	206.7	35.11	0.988	0.464	29.8	8.54	0.0	0.0	0.0	0.0		0.0
4000	38.6	50	950	30.08	0.	29.61	3.24	2.00	101.1	31.25	1.055	0.496	27.9	9.12	0.0	0.0	0.0	0.0		0.0
4000	31.0	40	1120	30.08	0.	23.77	3.01	2.15	82.2	27.36	1.151	0.541	25.6	9.85	0.0	0.0	0.0	0.0		0.0
4000	23.2	30	1310	30.08	0.	17.77	1.53	4.23	35.9	23.48	1.321	0.621	22.3	11.42	0.0	0.0	0.0	0.0		0.0
4000	15.5	20	1520	30.08	0.	11.88	0.91	7.11	18.0	19.75	1.663	0.781	17.7	14.37	0.0	0.0	0.0	0.0		0.0
4000	7.7	10	1720	30.08	0.	5.90	0.17	37.15	2.7	15.48	2.625	1.233	11.2	22.69	0.0	0.0	0.0	0.0		0.0

TEST NO.: HD-811173 ENGINE: 590 VW 1 TEST D/T: 5-17-83 10: 0 REPORT D/T: 08-22-83 16:37 P062581

SUMMARY REPORT

RPM	TORQ. FT-LB	% MAX TQ.	THR POSN	IGN. TIMG.	INJ. TIMG.	CORR. BHP	MEAS. A/F	PHI EQUIV RATIO	AIR LB/HR	FUEL LB/HR	BSFC LB/ BHPHR	BSFC GAS EQUIV LB/ BHPHR	ENERGY EFFICIENCY %	1000* MBTU/ BHPHR	BRAKE SPECIFIC EMISSIONS (G/BHPHR) BSHC	BSCO	BSCO2	BSNOX	BSALDYH	BSPART
3500	79.5	100	140	22.08	0.	52.80	5.18	1.25	277.7	53.61	1.015	0.477	29.0	8.78	0.0	0.0	0.0	0.0		0.0
3500	71.0	90	190	23.08	0.	46.92	6.32	1.02	260.6	41.23	0.879	0.413	33.5	7.60	0.0	0.0	0.0	0.0		0.0
3500	63.5	80	350	25.08	0.	41.95	5.34	1.21	202.2	37.86	0.903	0.424	32.6	7.80	0.0	0.0	0.0	0.0		0.0
3500	55.9	70	470	25.08	0.	36.91	5.83	1.11	197.7	33.94	0.919	0.432	32.0	7.95	0.0	0.0	0.0	0.0		0.0
3500	47.4	60	680	30.08	0.	31.29	5.95	1.09	179.7	30.23	0.966	0.454	30.5	8.35	0.0	0.0	0.0	0.0		0.0
3500	39.4	50	850	30.08	0.	26.01	6.05	1.07	161.8	26.75	1.028	0.483	28.6	8.89	0.0	0.0	0.0	0.0		0.0
3500	31.8	40	1070	30.08	0.	20.98	4.03	1.61	95.3	23.64	1.126	0.529	26.2	9.74	0.0	0.0	0.0	0.0		0.0
3500	23.9	30	1300	30.08	0.	15.78	2.99	2.16	60.2	20.12	1.275	0.599	23.1	11.02	0.0	0.0	0.0	0.0		0.0
3500	16.1	20	1470	30.08	0.	10.63	3.51	1.84	58.4	16.64	1.566	0.736	18.8	13.54	0.0	0.0	0.0	0.0		0.0
3500	8.1	10	1840	30.08	0.	5.35	3.68	1.76	49.4	13.44	2.512	1.180	11.7	21.72	0.0	0.0	0.0	0.0		0.0
3000	80.9	100	110	22.08	0.	45.82	0.0	0.0	0.0	46.65	1.018	0.478	28.9	8.80	0.0	0.0	0.0	0.0		0.0
3000	73.4	90	130	23.08	0.	41.55	6.94	0.93	248.5	35.83	0.862	0.405	34.2	7.45	0.0	0.0	0.0	0.0		0.0
3000	64.5	80	300	23.08	0.	36.49	7.02	0.92	224.7	31.99	0.877	0.412	33.6	7.58	0.0	0.0	0.0	0.0		0.0
3000	57.2	70	400	25.08	0.	32.37	6.98	0.93	202.2	28.96	0.895	0.420	32.9	7.73	0.0	0.0	0.0	0.0		0.0
3000	49.0	60	550	25.08	0.	27.74	7.04	0.92	182.0	25.84	0.931	0.438	31.6	8.05	0.0	0.0	0.0	0.0		0.0
3000	41.0	50	790	30.08	0.	23.21	7.01	0.92	161.8	23.08	0.995	0.467	29.6	8.60	0.0	0.0	0.0	0.0		0.0
3000	32.4	40	1030	30.08	0.	18.33	4.40	1.47	88.1	20.02	1.092	0.513	27.0	[illegible]44	0.0	0.0	0.0	0.0		0.0
3000	24.2	30	1250	30.08	0.	13.70	2.41	2.68	40.4	16.75	1.223	0.574	24.1	10.57	0.0	0.0	0.0	0.0		0.0
3000	16.1	20	1500	30.08	0.	9.11	2.45	2.64	33.7	13.75	1.509	0.709	19.5	13.04	0.0	0.0	0.0	0.0		0.0
3000	8.1	10	1900	30.08	0.	4.58	3.26	1.99	35.9	11.04	2.407	1.131	12.2	20.81	0.0	0.0	0.0	0.0		0.0
2500	81.0	100	10	22.08	0.	38.25	4.41	1.47	183.3	41.54	1.086	0.510	27.1	9.39	0.0	0.0	0.0	0.0		0.0
2500	72.8	90	130	22.08	0.	34.38	0.0	0.0	0.0	28.91	0.841	0.395	35.0	7.27	0.0	0.0	0.0	0.0		0.0
2500	64.2	80	220	20.08	0.	30.30	7.11	0.91	184.2	25.91	0.855	0.402	34.4	7.39	0.0	0.0	0.0	0.0		0.0
2500	56.8	70	330	22.08	0.	26.80	0.0	0.0	0.0	23.41	0.873	0.410	33.7	7.55	0.0	0.0	0.0	0.0		0.0
2500	48.2	60	560	25.08	0.	22.75	4.72	1.37	98.9	20.96	0.921	0.433	32.0	7.96	0.0	0.0	0.0	0.0		0.0
2500	40.4	50	790	30.08	0.	19.07	0.0	0.0	0.0	18.56	0.974	0.457	30.3	8.42	0.0	0.0	0.0	0.0		0.0
2500	32.1	40	1010	32.08	0.	15.15	1.97	3.28	31.5	15.95	1.053	0.495	28.0	9.10	0.0	0.0	0.0	0.0		0.0
2500	24.1	30	1260	30.08	0.	11.37	0.0	0.0	0.0	13.61	1.197	0.562	24.6	10.34	0.0	0.0	0.0	0.0		0.0
2500	16.5	20	1660	30.08	0.	7.79	0.0	0.0	0.0	11.59	1.488	0.699	19.8	12.86	0.0	0.0	0.0	0.0		0.0
2500	10.2	10	1940	30.08	0.	4.82	1.96	3.30	18.0	9.16	1.903	0.894	15.5	16.45	0.0	0.0	0.0	0.0		0.0
2000	77.4	100	60	20.08	0.	29.26	0.0	0.0	0.0	30.53	1.044	0.490	28.2	9.02	0.0	0.0	0.0	0.0		0.0
2000	70.2	90	070	20.08	0.	26.53	0.0	0.0	0.0	22.26	0.839	0.394	35.1	7.25	0.0	0.0	0.0	0.0		0.0
2000	62.4	80	130	20.08	0.	23.57	0.0	0.0	0.0	20.17	0.856	0.402	34.4	7.40	0.0	0.0	0.0	0.0		0.0
2000	54.1	70	360	22.08	0.	20.43	0.0	0.0	0.0	17.91	0.876	0.412	33.6	7.58	0.0	0.0	0.0	0.0		0.0
2000	46.5	60	55	22.08	0.	17.56	0.0	0.0	0.0	15.98	0.910	0.427	32.4	7.86	0.0	0.0	0.0	0.0		0.0
2000	38.7	50	740	25.08	0.	14.62	7.30	0.89	103.3	14.16	0.969	0.455	30.4	8.37	0.0	0.0	0.0	0.0		0.0
2000	31.2	40	100	30.08	0.	11.79	0.0	0.0	0.0	12.35	1.048	0.492	28.1	9.06	0.0	0.0	0.0	0.0		0.0
2000	23.0	30	1450	32.08	0.	8.69	0.0	0.0	0.0	10.61	1.222	0.574	24.1	10.56	0.0	0.0	0.0	0.0		0.0
2000	15.5	20	1730	30.08	0.	5.85	0.0	0.0	0.0	8.99	1.535	0.721	19.2	13.27	0.0	0.0	0.0	0.0		0.0
2000	7.2	10	1960	30.08	0.	2.72	0.0	0.0	0.0	6.66	2.445	1.149	12.0	21.14	0.0	0.0	0.0	0.0		0.0

TEST NO.: HD-811177 ENGINE: 590 VW-8 0 TEST D/T: 6- 9-83 9: 0 REPORT D/T: 08-22-83 16:37 PO62581

SUMMARY REPORT (Test with rebuilt engine)

RPM	TORQ. FT-LB	% MAX TQ.	THR POSN	IGN. TIMG.	INJ. TIMG.	CORR. BHP	MEAS. A/F	PHI EQUIV RATIO	AIR LB/HR	FUEL LB/HR	BSFC LB/ BHPHR	BSFC GAS EQUIV LB/ BHPHR	ENERGY EFFICIENCY %	1000* MBTU/ BHPHR	BRAKE SPECIFIC EMISSIONS (G/BHPHR) BSHC	BSCO	BSCO2	BSNOX	BSALDYH	BSPART
5400	67.4	100	32	25.08	0.	69.64	4.65	1.39	368.5	79.22	1.138	0.534	25.9	9.83	0.971	62.546	531.78	4.120		0.0
5400	47.0	70	68	20.08	0.	48.54	6.01	1.08	305.5	50.87	1.048	0.492	28.1	9.06	0.829	5.329	679.81	9.157		0.0
5400	33.4	50	110	25.08	0.	34.50	2.98	2.17	124.9	41.95	1.216	0.571	24.2	10.51	0.838	4.575	773.37	9.589		0.0
5400	20.0	30	1450	30.08	0.	20.64	2.47	2.62	80.9	32.70	1.584	0.744	18.6	13.69	1.509	9.347	962.93	7.878		0.0
4500	76.5	100	24	15.08	0.	65.75	4.86	1.33	328.0	67.53	1.027	0.482	28.7	8.88	0.914	69.673	512.19	4.583		0.0
4500	53.4	70	56	22.08	0.	45.91	6.33	1.02	278.6	44.00	0.958	0.450	30.7	8.28	0.985	4.379	582.07	7.891		0.0
4500	38.0	50	99	25.08	0.	32.68	3.05	2.12	107.8	35.34	1.082	0.508	27.2	9.35	1.104	3.550	666.22	7.780		0.0
4500	23.0	30	1340	30.08	0.	19.77	2.62	2.47	71.0	27.07	1.369	0.643	21.5	11.84	1.806	6.464	810.05	5.100		0.0
3500	81.0	100	140	15.08	0.	54.12	5.10	1.27	271.8	53.35	0.986	0.463	29.9	8.52	0.891	87.384	469.61	4.135		0.0
3500	56.5	70	450	20.08	0.	37.73	6.46	1.00	220.2	34.09	0.904	0.425	32.6	7.81	1.174	3.488	548.07	6.328		0.0
3500	40.5	50	860	23.08	0.	27.02	3.13	2.06	85.4	27.24	1.008	0.474	29.2	8.72	1.542	2.965	610.92	4.973		0.0
3500	24.3	30	1250	30.08	0.	16.32	2.69	2.40	55.3	20.54	1.259	0.591	23.4	10.88	2.607	3.791	742.83	2.280		0.0
2500	79.9	100	10	12.08	0.	38.28	4.40	1.47	179.7	40.87	1.068	0.502	27.6	9.23	1.111	128.755	409.44	1.682		0.0
2500	56.0	70	320	23.08	0.	26.83	7.18	0.90	170.7	23.80	0.887	0.417	33.2	7.67	1.833	3.637	501.90	2.982		0.0
2500	40.0	50	720	20.08	0.	19.16	7.02	0.92	130.3	18.56	0.968	0.455	30.4	8.37	2.362	3.165	566.70	1.426		0.0
2500	24.5	30	110	25.08	0.	11.73	3.51	1.84	49.4	14.09	1.201	0.564	24.5	10.38	3.963	6.825	709.66	0.866		0.0
1500	70.9	100	30	15.08	0.	20.38	4.70	1.38	98.9	21.05	1.033	0.485	28.5	8.93	2.299	99.609	444.40	1.676		0.0
1500	50.0	70	31	15.08	0.	14.38	7.40	0.87	98.9	13.36	0.930	0.437	31.7	8.04	2.795	3.519	537.26	2.769		0.0
1500	35.4	50	92	20.08	0.	10.18	3.89	1.66	40.4	10.40	1.022	0.480	28.8	8.84	3.135	3.198	582.83	3.638		0.0
1500	21.3	30	1420	20.08	0.	6.12	3.81	1.70	30.6	8.01	1.309	0.615	22.5	11.32	4.699	4.884	721.78	5.126		0.0

TEST NO.: HD-811287 ENGINE: 590 VW-8 O TEST D/T: 6-13-83 8:30 REPORT D/T: 08-22-83 16:38 P062581

SUMMARY REPORT (Rebuilt engine and carb cleaned)

RPM	TORQ. FT-LB	% MAX TQ.	THR POSN	IGN. TIMG.	INJ. TIMG.	CORR. BHP	MEAS. A/F	PHI EQUIV RATIO	AIR LB/HR	FUEL LB/HR	BSFC LB/ BHPHR	BSFC GAS EQUIV LB/ BHPHR	ENERGY EFFICIENCY %	1000* MBTU/ BHPHR	----- BRAKE SPECIFIC EMISSIONS (G/BHPHR) ---- BSHC	BSCO	BSCO2	BSNOX	BSALDYH	BSPART
5400	68.0	100	330	12.08	0.	70.13	4.79	1.35	364.0	75.93	1.083	0.509	27.2	9.36	0.0	0.0	0.0	0.0		0.0
5400	61.0	90	340	14.08	0.	62.94	6.14	1.05	368.5	59.98	0.953	0.448	30.9	8.24	0.0	0.0	0.0	0.0		0.0
5400	55.0	80	480	16.08	0.	56.71	6.05	1.07	337.0	55.74	0.983	0.462	30.0	8.50	0.0	0.0	0.0	0.0		0.0
5400	47.7	70	690	18.08	0.	49.14	5.99	1.08	301.1	50.28	1.023	0.481	28.8	8.85	0.0	0.0	0.0	0.0		0.0
5400	40.9	60	890	21.08	0.	42.13	5.64	1.15	256.1	45.44	1.079	0.507	27.3	9.32	0.0	0.0	0.0	0.0		0.0
5400	34.3	50	1110	22.08	0.	35.32	3.14	2.06	130.3	41.45	1.174	0.551	25.1	10.14	0.0	0.0	0.0	0.0		0.0
5400	27.0	40	1300	24.08	0.	27.81	3.22	2.01	103.3	32.05	1.153	0.542	25.6	9.96	0.0	0.0	0.0	0.0		0.0
5400	20.5	30	1480	24.08	0.	21.10	2.73	2.37	85.4	31.30	1.484	0.697	19.9	12.83	0.0	0.0	0.0	0.0		0.0
5400	13.0	20	1620	26.08	0.	13.37	2.58	2.51	69.6	26.99	2.019	0.948	14.6	17.45	0.0	0.0	0.0	0.0		0.0
5400	6.5	10	1790	26.08	0.	6.69	2.56	2.52	57.5	22.44	3.353	1.575	8.8	28.98	0.0	0.0	0.0	0.0		0.0
5000	72.8	100	300	12.08	0.	69.38	4.70	1.38	346.0	73.60	1.061	0.498	27.8	9.17	0.0	0.0	0.0	0.0		0.0
5000	65.0	90	310	14.08	0.	62.00	6.20	1.04	355.0	57.22	0.923	0.434	31.9	7.98	0.0	0.0	0.0	0.0		0.0
5000	58.4	80	450	16.08	0.	55.69	6.16	1.05	323.1	52.44	0.942	0.442	31.3	8.14	0.0	0.0	0.0	0.0		0.0
5000	51.2	70	610	18.08	0.	48.82	6.18	1.05	296.6	47.98	0.983	0.462	30.0	8.50	0.0	0.0	0.0	0.0		0.0
5000	43.8	60	830	21.08	0.	41.75	6.14	1.05	265.1	43.19	1.034	0.486	28.5	8.94	0.0	0.0	0.0	0.0		0.0
5000	36.5	50	1060	24.08	0.	34.79	3.12	2.07	121.3	38.86	1.117	0.525	26.4	9.65	0.0	0.0	0.0	0.0		0.0
5000	29.0	40	1250	25.08	0.	27.64	2.92	2.22	98.9	33.88	1.226	0.576	24.0	10.60	0.0	0.0	0.0	0.0		0.0
5000	21.9	30	1470	27.08	0.	20.86	2.58	2.51	75.9	29.47	1.412	0.664	20.9	12.21	0.0	0.0	0.0	0.0		0.0
5000	14.6	20	1640	28.08	0.	13.90	2.46	2.63	61.6	24.98	1.797	0.844	16.4	15.53	0.0	0.0	0.0	0.0		0.0
5000	7.5	10	1790	28.08	0.	7.14	2.61	2.48	53.9	20.64	2.889	1.357	10.2	24.98	0.0	0.0	0.0	0.0		0.0
4500	77.0	100	250	12.08	0.	65.99	4.81	1.35	323.5	67.29	1.020	0.479	28.9	8.81	0.0	0.0	0.0	0.0		0.0
4500	69.0	90	260	14.08	0.	59.24	6.30	1.03	328.0	52.07	0.879	0.413	33.5	7.60	0.0	0.0	0.0	0.0		0.0
4500	62.3	80	380	16.08	0.	53.46	6.22	1.04	301.1	48.38	0.905	0.425	32.5	7.82	0.0	0.0	0.0	0.0		0.0
4500	54.6	70	550	18.08	0.	46.84	6.32	1.02	278.1	43.98	0.939	0.441	31.4	8.12	0.0	0.0	0.0	0.0		0.0
4500	46.6	60	760	21.08	0.	39.96	6.39	1.01	251.6	39.39	0.986	0.463	29.9	8.52	0.0	0.0	0.0	0.0		0.0
4500	38.5	50	1020	24.08	0.	33.00	3.08	2.10	107.8	35.06	1.062	0.499	27.7	9.18	0.0	0.0	0.0	0.0		0.0
4500	31.0	40	1210	26.08	0.	26.57	2.91	2.22	89.4	30.71	1.156	0.543	25.5	9.99	0.0	0.0	0.0	0.0		0.0
4500	23.5	30	1400	27.08	0.	20.14	2.70	2.40	71.4	26.48	1.315	0.618	22.4	11.36	0.0	0.0	0.0	0.0		0.0
4500	15.5	20	1610	28.08	0.	13.28	2.50	2.58	56.2	22.44	1.689	0.793	17.4	14.60	0.0	0.0	0.0	0.0		0.0
4500	7.9	10	1810	28.08	0.	6.77	2.69	2.41	49.4	18.39	2.717	1.276	10.8	23.48	0.0	0.0	0.0	0.0		0.0
4000	80.9	100	200	14.08	0.	61.62	4.83	1.34	292.1	60.48	0.982	0.461	30.0	8.48	0.0	0.0	0.0	0.0		0.0
4000	72.4	90	210	14.08	0.	55.22	6.36	1.02	301.1	47.31	0.857	0.402	34.4	7.41	0.0	0.0	0.0	0.0		0.0
4000	64.5	80	340	16.08	0.	49.19	6.35	1.02	274.1	43.17	0.878	0.412	33.6	7.59	0.0	0.0	0.0	0.0		0.0
4000	56.5	70	500	18.08	0.	43.08	6.43	1.01	251.6	39.13	0.908	0.427	32.4	7.85	0.0	0.0	0.0	0.0		0.0
4000	48.0	60	720	21.08	0.	36.60	6.45	1.00	224.7	34.82	0.951	0.447	31.0	8.22	0.0	0.0	0.0	0.0		0.0
4000	39.7	50	980	24.08	0.	30.27	3.05	2.12	94.4	30.93	1.022	0.480	28.8	8.83	0.0	0.0	0.0	0.0		0.0
4000	32.0	40	1150	26.08	0.	24.39	2.95	2.20	80.0	27.14	1.113	0.523	26.5	9.62	0.0	0.0	0.0	0.0		0.0
4000	24.4	30	1360	28.08	0.	18.60	2.69	2.41	62.9	23.40	1.258	0.591	23.4	10.88	0.0	0.0	0.0	0.0		0.0
4000	17.0	20	1540	28.08	0.	12.96	2.73	2.37	53.9	19.72	1.522	0.715	19.4	13.15	0.0	0.0	0.0	0.0		0.0
4000	8.0	10	1730	30.08	0.	6.10	3.16	2.05	49.4	15.64	2.566	1.205	11.5	22.18	0.0	0.0	0.0	0.0		0.0

TEST NO.: HD-811361 ENGINE: 590 VW-B 0 TEST D/T: 1-13-83 13: 0 REPORT D/T: 08-22-83 16:38 P062581

SUMMARY REPORT (Ricardo test data)

RPM	TORQ. FT-LB	% MAX TQ.	THR POSN	IGN. TIMG.	INJ. TIMG.	CORR. BHP	MEAS. A/F	PHI EQUIV RATIO	AIR LB/HR	FUEL LB/HR	BSFC LB/ BHPHR	BSFC GAS EQUIV LB/ BHPHR	ENERGY EFFICIENCY %	1000* MBTU/ BHPHR	BRAKE SPECIFIC EMISSIONS (G/BHPHR) BSHC	BSCO	BSCO2	BSNOX	BSALDYH	BSPART
5400	68.6	100		22.08	0.	68.21	0.0	0.0	0.0	75.49	1.107	0.520	26.6	9.57	0.0	0.0	0.0	0.0		0.0
4800	75.3	100		22.08	0.	66.56	0.0	0.0	0.0	67.24	1.010	0.475	29.2	8.73	0.0	0.0	0.0	0.0		0.0
4800	59.6	79		24.08	0.	51.98	0.0	0.0	0.0	51.09	0.983	0.462	30.0	8.50	0.0	0.0	0.0	0.0		0.0
4800	46.6	62		30.08	0.	40.64	0.0	0.0	0.0	43.84	1.079	0.507	27.3	9.32	0.0	0.0	0.0	0.0		0.0
4800	34.1	45		34.08	0.	29.74	0.0	0.0	0.0	36.14	1.215	0.571	24.2	10.50	0.0	0.0	0.0	0.0		0.0
4200	79.7	100		22.08	0.	61.64	0.0	0.0	0.0	59.89	0.972	0.456	30.3	8.40	0.0	0.0	0.0	0.0		0.0
4200	59.6	75		24.08	0.	45.88	0.0	0.0	0.0	43.95	0.958	0.450	30.7	8.28	0.0	0.0	0.0	0.0		0.0
4200	46.6	58		29.08	0.	35.87	0.0	0.0	0.0	36.85	1.027	0.483	28.7	8.88	0.0	0.0	0.0	0.0		0.0
4200	34.1	43		33.08	0.	26.25	0.0	0.0	0.0	30.40	1.158	0.544	25.4	10.01	0.0	0.0	0.0	0.0		0.0
4200	21.2	27		35.08	0.	16.32	0.0	0.0	0.0	24.00	1.471	0.691	20.0	12.71	0.0	0.0	0.0	0.0		0.0
3600	81.9	100		21.08	0.	54.29	0.0	0.0	0.0	51.84	0.955	0.449	30.8	8.25	0.0	0.0	0.0	0.0		0.0
3600	59.6	73		22.08	0.	38.99	0.0	0.0	0.0	36.61	0.939	0.441	31.4	8.12	0.0	0.0	0.0	0.0		0.0
3600	46.6	57		28.08	0.	30.48	0.0	0.0	0.0	30.66	1.006	0.473	29.3	8.69	0.0	0.0	0.0	0.0		0.0
3600	34.1	42		31.08	0.	22.31	0.0	0.0	0.0	25.25	1.132	0.532	26.0	9.78	0.0	0.0	0.0	0.0		0.0
3600	21.2	26		33.08	0.	13.87	0.0	0.0	0.0	19.65	1.417	0.666	20.8	12.25	0.0	0.0	0.0	0.0		0.0
3000	82.0	100		18.08	0.	45.30	0.0	0.0	0.0	43.29	0.956	0.449	30.8	8.26	0.0	0.0	0.0	0.0		0.0
3000	59.6	73		19.08	0.	32.77	0.0	0.0	0.0	29.84	0.910	0.428	32.4	7.87	0.0	0.0	0.0	0.0		0.0
3000	46.6	57		23.08	0.	25.62	0.0	0.0	0.0	24.99	0.975	0.458	30.2	8.43	0.0	0.0	0.0	0.0		0.0
3000	34.1	42		28.08	0.	18.59	0.0	0.0	0.0	20.44	1.100	0.517	26.8	9.51	0.0	0.0	0.0	0.0		0.0
3000	21.2	26		30.08	0.	11.56	0.0	0.0	0.0	15.95	1.380	0.648	21.3	11.93	0.0	0.0	0.0	0.0		0.0
3000	14.0	17		31.08	0.	7.63	0.0	0.0	0.0	13.25	1.736	0.816	17.0	15.01	0.0	0.0	0.0	0.0		0.0
2400	81.3	100		16.08	0.	35.93	0.0	0.0	0.0	35.03	0.975	0.458	30.2	8.43	0.0	0.0	0.0	0.0		0.0
2400	59.6	73		15.08	0.	25.99	0.0	0.0	0.0	23.52	0.905	0.425	32.5	7.82	0.0	0.0	0.0	0.0		0.0
2400	46.6	57		19.08	0.	20.32	0.0	0.0	0.0	19.78	0.973	0.457	30.3	8.41	0.0	0.0	0.0	0.0		0.0
2400	34.1	42		24.08	0.	14.87	0.0	0.0	0.0	16.35	1.099	0.516	26.8	9.50	0.0	0.0	0.0	0.0		0.0
2400	21.2	26		27.08	0.	9.25	0.0	0.0	0.0	12.58	1.360	0.639	21.7	11.76	0.0	0.0	0.0	0.0		0.0
2400	12.7	16		27.08	0.	5.54	0.0	0.0	0.0	9.74	1.759	0.826	16.7	15.21	0.0	0.0	0.0	0.0		0.0
1800	79.3	100		12.08	0.	26.28	0.0	0.0	0.0	27.59	1.050	0.493	28.1	8.07	0.0	0.0	0.0	0.0		0.0
1800	55.7	70		12.08	0.	18.38	0.0	0.0	0.0	17.13	0.932	0.438	31.6	8.06	0.0	0.0	0.0	0.0		0.0
1800	46.6	59		14.08	0.	15.37	0.0	0.0	0.0	14.80	0.963	0.452	30.6	8.32	0.0	0.0	0.0	0.0		0.0
1800	34.1	43		21.08	0.	11.25	0.0	0.0	0.0	11.87	1.055	0.496	27.9	9.12	0.0	0.0	0.0	0.0		0.0
1800	21.2	27		23.08	0.	6.99	0.0	0.0	0.0	9.45	1.352	0.635	21.8	11.69	0.0	0.0	0.0	0.0		0.0
1800	12.7	16		23.08	0.	4.19	0.0	0.0	0.0	7.31	1.745	0.820	16.9	15.09	0.0	0.0	0.0	0.0		0.0
1200	69.4	100		10.08	0.	15.34	0.0	0.0	0.0	18.25	1.190	0.559	24.7	10.29	0.0	0.0	0.0	0.0		0.0
1200	51.8	75		9.08	0.	11.39	0.0	0.0	0.0	10.82	0.950	0.446	31.0	8.21	0.0	0.0	0.0	0.0		0.0
1200	46.6	67		11.08	0.	10.25	0.0	0.0	0.0	9.97	0.973	0.457	30.3	8.41	0.0	0.0	0.0	0.0		0.0
1200	34.1	49		19.08	0.	7.50	0.0	0.0	0.0	8.26	1.101	0.517	26.7	9.52	0.0	0.0	0.0	0.0		0.0
1200	21.2	31		23.08	0.	4.66	0.0	0.0	0.0	6.19	1.329	0.624	22.2	11.48	0.0	0.0	0.0	0.0		0.0
1200	12.7	18		22.08	0.	2.79	0.0	0.0	0.0	4.82	1.725	0.811	17.1	14.92	0.0	0.0	0.0	0.0		0.0

TEST NO.: HD-811173 ENGINE: 590 VW 1 TEST D/T: 5-17-83 10: 0 REPORT D/T: 08-22-83 16:37 P062581

SUMMARY REPORT

RPM	TORQ. FT-LB	% MAX TQ.	THR POSN	IGN. TIMG.	INJ. TIMG.	CORR. BHP	MEAS. A/F	PHI EQUIV RATIO	AIR LB/HR	FUEL LB/HR	BSFC LB/ BHPHR	BSFC GAS EQUIV LB/ BHPHR	ENERGY EFFICIENCY %	1000* MBTU/ BHPHR	----- BRAKE SPECIFIC EMISSIONS (G/BHPHR) ---- BSHC	BSCO	BSCO2	BSNOX	BSALDYH	BSPART
1000	72.4	100	30	18.0B	0.	13.68	0.0	0.0	0.0	21.02	1.536	0.722	19.2	13.28	0.0	0.0	0.0	0.0		0.0
1000	64.0	90	40	18.0B	0.	12.10	0.0	0.0	0.0	15.58	1.288	0.605	22.9	11.14	0.0	0.0	0.0	0.0		0.0
1000	58.3	80	150	20.0B	0.	11.02	0.0	0.0	0.0	14.23	1.291	0.607	22.8	11.16	0.0	0.0	0.0	0.0		0.0
1000	51.0	70	380	20.0B	0.	9.64	0.0	0.0	0.0	12.82	1.330	0.625	22.1	11.50	0.0	0.0	0.0	0.0		0.0
1000	43.4	60	520	22.0B	0.	8.20	0.0	0.0	0.0	11.28	1.376	0.646	21.4	11.89	0.0	0.0	0.0	0.0		0.0
1000	38.0	50	870	30.0B	0.	7.18	0.0	0.0	0.0	10.65	1.483	0.697	19.9	12.82	0.0	0.0	0.0	0.0		0.0
1000	29.4	40	1210	30.0B	0.	5.56	0.0	0.0	0.0	9.19	1.653	0.777	17.8	14.29	0.0	0.0	0.0	0.0		0.0
1000	22.2	30	1430	30.0B	0.	4.20	0.0	0.0	0.0	7.89	1.880	0.883	15.7	16.25	0.0	0.0	0.0	0.0		0.0
1000	14.4	20	1660	30.0B	0.	2.72	0.0	0.0	0.0	6.30	2.316	1.088	12.7	20.02	0.0	0.0	0.0	0.0		0.0
1000	7.3	10	1920	30.0B	0.	1.38	0.0	0.0	0.0	4.93	3.574	1.679	8.2	30.80	0.0	0.0	0.0	0.0		0.0

TEST NO.: HD-811287 ENGINE: 590 VW-B 0 TEST D/T: 6-13-83 8:30 REPORT D/T: 08-22-83 16:38 P062581

SUMMARY REPORT

RPM	TORQ. FT-LB	% MAX TQ.	THR POSN	IGN. TIMG.	INJ. TIMG.	CORR. BHP	MEAS. A/F	PHI EQUIV RATIO	AIR LB/HR	FUEL LB/HR	BSFC LB/BHPHR	BSFC GAS EQUIV LB/BHPHR	ENERGY EFFICIENCY %	1000* MBTU/BHPHR	BRAKE SPECIFIC EMISSIONS (G/BHPHR) BSHC	BSCO	BSCO2	BSNOX	BSALDYH	BSPART
3500	82.0	100	140	12.08	0.	54.66	5.01	1.29	267.4	53.32	0.976	0.458	30.2	8.43	0.0	0.0	0.0	0.0		0.0
3500	73.5	90	160	14.08	0.	49.06	6.63	0.98	274.1	41.33	0.842	0.396	35.0	7.28	0.0	0.0	0.0	0.0		0.0
3500	69.8	80	300	16.08	0.	46.59	6.55	0.99	247.1	37.71	0.809	0.380	36.4	7.00	0.0	0.0	0.0	0.0		0.0
3500	57.0	70	460	18.08	0.	38.04	6.43	1.01	215.7	33.54	0.882	0.414	33.4	7.62	0.0	0.0	0.0	0.0		0.0
3500	49.5	60	680	21.08	0.	33.02	6.34	1.02	193.2	30.48	0.923	0.434	31.9	7.98	0.0	0.0	0.0	0.0		0.0
3500	41.5	50	890	22.08	0.	28.83	6.30	1.03	170.7	27.10	0.940	0.441	31.3	8.12	0.0	0.0	0.0	0.0		0.0
3500	32.5	40	1080	24.08	0.	21.67	3.06	2.11	71.0	23.18	1.070	0.503	27.5	9.25	0.0	0.0	0.0	0.0		0.0
3500	24.0	30	1320	28.08	0.	16.00	2.72	2.38	53.9	19.79	1.237	0.581	23.8	10.69	0.0	0.0	0.0	0.0		0.0
3500	17.0	20	1480	28.08	0.	11.34	2.91	2.22	49.4	16.97	1.497	0.703	19.7	12.94	0.0	0.0	0.0	0.0		0.0
3500	8.5	10	1680	28.08	0.	5.66	3.30	1.96	44.9	13.61	2.403	1.129	12.3	20.77	0.0	0.0	0.0	0.0		0.0
3000	82.3	100	110	12.08	0.	47.00	4.96	1.30	229.2	46.20	0.983	0.462	30.0	8.50	0.0	0.0	0.0	0.0		0.0
3000	74.5	90	120	12.08	0.	42.60	6.71	0.96	238.1	35.48	0.833	0.391	35.4	7.20	0.0	0.0	0.0	0.0		0.0
3000	66.6	80	180	14.08	0.	38.10	6.54	0.99	211.2	32.30	0.848	0.398	34.7	7.33	0.0	0.0	0.0	0.0		0.0
3000	57.7	70	380	14.08	0.	33.01	6.59	0.98	188.7	28.65	0.868	0.408	33.9	7.50	0.0	0.0	0.0	0.0		0.0
3000	49.5	60	570	18.08	0.	28.32	6.69	0.97	170.7	25.54	0.902	0.424	32.7	7.80	0.0	0.0	0.0	0.0		0.0
3000	41.5	50	750	20.08	0.	23.73	6.95	0.93	157.3	22.62	0.953	0.448	30.9	8.24	0.0	0.0	0.0	0.0		0.0
3000	33.0	40	1030	24.08	0.	18.87	2.96	2.19	58.0	19.61	1.039	0.488	28.4	8.98	0.0	0.0	0.0	0.0		0.0
3000	24.5	30	1230	22.08	0.	14.01	2.99	2.17	49.4	16.56	1.182	0.555	24.9	10.22	0.0	0.0	0.0	0.0		0.0
3000	16.5	20	1430	25.08	0.	9.43	3.38	1.91	47.2	13.96	1.480	0.695	19.9	12.79	0.0	0.0	0.0	0.0		0.0
3000	8.2	10	1890	26.08	0.	4.69	3.71	1.74	40.4	10.90	2.326	1.093	12.7	20.11	0.0	0.0	0.0	0.0		0.0
2500	81.0	100	100	12.08	0.	38.57	4.42	1.47	179.3	40.59	1.052	0.494	28.0	9.10	0.0	0.0	0.0	0.0		0.0
2500	73.4	90	110	12.08	0.	35.01	6.32	1.02	184.2	29.13	0.832	0.391	35.4	7.19	0.0	0.0	0.0	0.0		0.0
2500	65.0	80	200	12.08	0.	31.01	7.06	0.92	184.2	26.10	0.842	0.395	35.0	7.28	0.0	0.0	0.0	0.0		0.0
2500	56.5	70	330	14.08	0.	26.95	7.25	0.89	168.5	23.24	0.862	0.405	34.2	7.45	0.0	0.0	0.0	0.0		0.0
2500	49.0	60	470	15.08	0.	23.37	7.25	0.89	152.3	21.02	0.900	0.423	32.7	7.78	0.0	0.0	0.0	0.0		0.0
2500	40.6	50	770	18.08	0.	19.34	6.84	0.95	125.8	18.40	0.951	0.447	31.0	8.22	0.0	0.0	0.0	0.0		0.0
2500	33.0	40	970	20.08	0.	15.71	3.78	1.71	60.7	16.05	1.022	0.480	28.8	8.83	0.0	0.0	0.0	0.0		0.0
2500	24.3	30	1190	22.08	0.	11.56	3.48	1.86	47.2	13.54	1.172	0.550	25.1	10.13	0.0	0.0	0.0	0.0		0.0
2500	16.4	20	1660	24.08	0.	7.79	3.61	1.79	40.4	11.22	1.439	0.676	20.5	12.44	0.0	0.0	0.0	0.0		0.0
2500	8.4	10	1940	25.08	0.	3.99	3.74	1.73	33.7	9.01	2.259	1.061	13.0	19.53	0.0	0.0	0.0	0.0		0.0
2000	77.9	100	060	8.08	0.	29.62	4.44	1.46	134.8	30.35	1.025	0.481	28.7	8.86	0.0	0.0	0.0	0.0		0.0
2000	70.5	90	070	10.08	0.	26.82	6.38	1.01	143.3	22.46	0.837	0.393	35.2	7.24	0.0	0.0	0.0	0.0		0.0
2000	63.0	80	100	10.08	0.	23.96	7.51	0.86	152.3	20.29	0.847	0.398	34.8	7.32	0.0	0.0	0.0	0.0		0.0
2000	54.0	70	320	12.08	0.	20.53	7.43	0.87	134.8	18.15	0.884	0.415	33.3	7.64	0.0	0.0	0.0	0.0		0.0
2000	46.5	60	490	15.08	0.	17.68	6.98	0.93	112.3	16.10	0.910	0.428	32.4	7.87	0.0	0.0	0.0	0.0		0.0
2000	39.0	50	690	18.08	0.	14.82	7.10	0.91	101.1	14.23	0.960	0.451	30.7	8.30	0.0	0.0	0.0	0.0		0.0
2000	31.5	40	850	18.08	0.	11.97	6.59	0.98	83.1	12.61	1.053	0.495	28.0	9.10	0.0	0.0	0.0	0.0		0.0
2000	23.4	30	1420	20.08	0.	8.89	3.62	1.79	38.2	10.56	1.188	0.558	24.8	10.27	0.0	0.0	0.0	0.0		0.0
2000	15.5	20	1720	21.08	0.	5.89	3.61	1.79	31.5	8.72	1.481	0.696	19.9	12.80	0.0	0.0	0.0	0.0		0.0
2000	7.8	10	1930	22.08	0.	2.96	3.84	1.69	26.5	6.90	2.329	1.094	12.6	20.13	0.0	0.0	0.0	0.0		0.0

TEST NO.: HD-811287 ENGINE: 590 VW-B 0 TEST D/T: 6-13-83 8:30 REPORT D/T: 08-22-83 16:38 P062581

SUMMARY REPORT

RPM	TORQ. FT-LB	% MAX TQ.	THR POSN	IGN. TIMG.	INJ. TIMG.	CORR. BHP	MEAS. A/F	PHI EQUIV RATIO	AIR LB/HR	FUEL LB/HR	BSFC LB/ BHPHR	BSFC GAS EQUIV LB/ BHPHR	ENERGY EFFICIENCY %	ENERGY EFFICIENCY 1000* MBTU/ BHPHR	BRAKE SPECIFIC EMISSIONS (G/BHPHR) BSHC	BSCO	BSCO2	BSNOX	BSALDYH	BSPART
1500	72.8	100	030	8.08	0.	20.75	4.67	1.39	98.9	21.18	1.021	0.480	28.9	8.82	0.0	0.0	0.0	0.0		0.0
1500	63.0	90	030	8.08	0.	17.98	6.57	0.99	101.1	15.39	0.856	0.402	34.4	7.40	0.0	0.0	0.0	0.0		0.0
1500	58.0	80	070	8.08	0.	16.55	7.17	0.90	105.6	14.74	0.891	0.418	33.1	7.70	0.0	0.0	0.0	0.0		0.0
1500	49.5	70	340	8.08	0.	14.12	7.45	0.87	96.6	12.97	0.918	0.431	32.1	7.94	0.0	0.0	0.0	0.0		0.0
1500	43.7	60	400	10.08	0.	12.46	7.47	0.87	89.9	12.03	0.965	0.453	30.5	8.34	0.0	0.0	0.0	0.0		0.0
1500	37.0	50	620	14.08	0.	10.55	7.64	0.85	80.9	10.59	1.004	0.472	29.3	8.68	0.0	0.0	0.0	0.0		0.0
1500	28.5	40	1240	20.08	0.	8.13	3.55	1.83	31.5	8.87	1.091	0.513	27.0	9.43	0.0	0.0	0.0	0.0		0.0
1500	22.0	30	1460	20.08	0.	6.27	3.77	1.72	29.2	7.75	1.236	0.581	23.8	10.68	0.0	0.0	0.0	0.0		0.0
1500	15.0	20	1640	20.08	0.	4.28	4.04	1.60	26.1	6.45	1.509	0.709	19.5	13.04	0.0	0.0	0.0	0.0		0.0
1500	7.9	10	1800	20.08	0.	2.25	5.21	1.24	27.0	5.17	2.297	1.079	12.8	19.86	0.0	0.0	0.0	0.0		0.0

A-20

APPENDIX B

SUBCOMPACT CARS (Continued)

Manufacturer	Fuel Economy		Vehicle Description				
Manufacturer Car Line	Estimated MPG	Average Annual Fuel Costs	Engine Description CID/Cyl Type		Transmission	Fuel System	Body Type Interior Space Passenger Trunk or Cargo (Cu. Ft.)
MERCEDES-BENZ							
450SLC	16	$844	275(4.5L)/8	(CAL)(FFS)	A3	FI	2DR-80/8
OLDSMOBILE							
STARFIRE	22	$614	151(2.5L)/4		M4	2	HBK-78/10
	24	$563	151(2.5L)/4		A3	2	
	15	$900	231(3.8L)/6	(GM-BUICK)	M4	2	
	19	$710	231(3.8L)/6	(GM-BUICK)	A3	2	
PLYMOUTH							
CHAMP	37	$364	86/4		M4	2	HBK-77/11
	35	$386	86/4		M4X2	2	
	33	$409	98/4		M4X2	2	
	30	$450	98/4		A3	2	
HORIZON/	23	$587	105/4		M4	2	HBK-81/17
TURISMO	24	$563	105/4		A3	2	
SAPPORO	21	$643	156/4		M5	2	2DR-78/8
	22	$614	156/4		A3	2	
PONTIAC							
FIREBIRD	20	$675	231(3.8L)/6	(GM-BUICK)	A3	2	2DR-85/7
	16	$844	301(4.9L)/8		A3	4	
	14	$964	301(4.9L)/8	(TURBO)	A3	4	
SUNBIRD	22	$614	151(2.5L)/4		M4	2	2DR-79/7
	24	$563	151(2.5L)/4		A3	2	HBK-78/10
	15	$900	231(3.8L)/6	(GM-BUICK)	M4	2	
	20	$675	231(3.8L)/6	(GM-BUICK)	A3	2	
SUBARU							
SUBARU	25	$540	97/4	(NO CAT)	M4	2	2DR-77/12
	32	$421	97/4	(CAT)	M4	2	4DR-78/12
	25	$540	97/4	(NO CAT)	M5	2	HBK-78/12
	32	$421	97/4	(CAT)	M5	2	
	21	$643	109/4		A3	2	
SUBARU 4WD	23	$587	97/4	(NO CAT)	M4	2	HBK-78/12
TOYOTA							
CELICA	23	$587	134/4		M4	2	2DR-75/9
	21	$643	134/4		M5	2	HBK-75/14
	20	$675	134/4		A3	2	
CELICA SUPRA	19	$710	156/6	(CAL)(FFS)	M5	FI	HBK-75/13
	21	$643	156/6	(CAL)(FFS)	A4	FI	
COROLLA	28	$482	108/4		M4	2	2DR-79/11
	27	$500	108/4		M5	2	4DR-79/11
	26	$520	108/4		A3	2	HBK-75/14
COROLLA	33	$409	89/4		M4	2	2DR-80/9
TERCEL	31	$436	89/4		M5	2	HBK-80/13
	29	$466	89/4		A3	2	
CORONA	23	$587	134/4		M4	2	4DR-80/11
	21	$643	134/4		M5	2	HBK-77/18
	20	$675	134/4		A3	2	
CRESSIDA	21	$643	156/6	(CAL)(FFS)	A4	FI	4DR-80/11
VOLKSWAGEN							
DASHER	36	$334	90/4	(DIESEL)	M4	FI	HBK-76/15
(Cont.)	23	$587	97/4		M4	FI	

SUBCOMPACT CARS (Continued)

Manufacturer	Fuel Economy		Vehicle Description				
Manufacturer Car Line	Estimated MPG	Average Annual Fuel Costs	Engine Description CID/Cyl Type		Transmission	Fuel System	Body Type Interior Space Passenger Trunk or Cargo (Cu. Ft.)
VOLKSWAGEN (Cont.)							
DASHER (Cont.)	22	$614	97/4		A3	FI	
JETTA	25	$540	97/4		M5	FI	2DR-78/13
	22	$614	97/4		A3	FI	4DR-77/13
RABBIT	27	$500	89/4		M4	1	2DR-77/8
	40	$300	90/4	(DIESEL)	M4	FI	HBK-77/14
	42	$286	90/4	(DIESEL)	M5	FI	
	24	$563	97/4		M4	FI	
	25	$540	97/4		M5	FI	
	23	$587	97/4		A3	FI	
SCIROCCO	24	$563	97/4		M4	FI	HBK-72/14
	25	$540	97/4		M5	FI	
	23	$587	97/4		A3	FI	

COMPACT CARS

Manufacturer	Fuel Economy		Vehicle Description				
Manufacturer Car Line	Estimated MPG	Average Annual Fuel Costs	Engine Description CID/Cyl Type		Transmission	Fuel System	Body Type Interior Space Passenger Trunk or Cargo (Cu. Ft.)
AMC							
CONCORD	22	$614	151/4		M4	2	2DR-90/11
	20	$675	151/4		A3	2	4DR-90/11
	17	$794	258/6	(FFS)	M4	2	
	18	$751	258/6	(FFS)	A3	2	
PACER	17	$794	258/6	(FFS)	M4	2	HBK-91/11
	18	$751	258/6	(FFS)	A3	2	
AUDI							
5000	27	$444	121/5	(DIESEL)	M5	FI	4DR-90/15
	17	$794	131/5		M5	FI	
	17	$794	131/5		A3	FI	
BMW							
733 I	16	$844	196(3.2L)/6	(CAL)(FFS)	M4	FI	4DR-94/13
	16	$844	196(3.2L)/6	(CAL)(FFS)	A3	FI	
BUICK							
SKYLARK	24	$563	151(2.5L)/4		M4	2	2DR-94/14
	22	$614	151(2.5L)/4		A3	2	4DR-95/14
	20	$675	173(2.8L)/6		M4	2	
	20	$675	173(2.8L)/6		A3	2	
FIAT							
STRADA	25	$540	91(1500CC)/4		M5	2	HBK-85/15
	24	$563	91(1500CC)/4		A3	2	
FORD							
GRANADA	19	$710	250(4.1L)/6		M4	1	2DR-89/15
	17	$794	250(4.1L)/6		A3	1	4DR-93/15
	17	$794	302(5.0L)/8		A3	2	
LINCOLN-MERCURY							
MONARCH (Cont.)	19	$710	250(4.1L)/6		M4	1	2DR-89/16

1980 FUEL ECONOMY PROGRAM

49 STATE TEST CAR LIST - PASSENGER CARS (GAS MILEAGE GUIDE)

MFR.	VEHICLE ID.	A/C SIM	ACT. DYNO HP	CITY EMISSIONS (GRAMS/MILE) HC	CO	CO2	NOX	CITY MPG	HIGHWAY EMISSIONS (GRAMS/MILE) HC	CO	CO2	NOX	HIGHWAY MPG	COMBINED MPG
AUDI	384	YES	7.9	0.107	1.00	396.	1.23	22	0.029	0.04	258.	2.87	34	26
AUDI														
AUDI	490-669	NO	7.0	0.405	1.33	371.	1.71	27	0.170	0.44	236.	1.10	43	33
									0.156	0.48	235.	1.05	43	
AUDI														
AUDI	637-80	YES	7.0	0.160	1.20	531.	1.47	17	0.030	0.0	352.	1.09	25	20
AUDI	125-80	YES	7.0	0.250	2.50	529.	1.53	17	0.020	0.0	296.	1.32	30	21
AUDI														
AUDI	027-80	YES	6.5	0.178	4.11	437.	0.35	20	0.056	0.47	319.	0.01	28	23
FUJI														
FUJI	* 80FE-12	NO	9.4	0.256	3.61	351.	1.20	25	0.005	0.43	248.	1.65	36	29
FUJI	* 80FE-12	NO	9.4	0.240	3.37	356.	1.27	24	0.004	0.76	261.	1.77	34	28
FUJI	* 80FE-12	NO	9.4	0.288	3.65	351.	1.21	25	0.006	0.61	222.	1.69	40	30
FUJI	80FE-12	NO	9.4	0.251	3.91	361.	1.29	24	0.005	0.73	228.	1.50	39	29
FUJI														
FUJI	* 80FE-10	NO	9.4	0.288	1.52	274.	1.27	32	0.047	0.02	217.	1.59	41	35
FUJI	* 80FE-10	NO	9.4	0.254	1.14	271.	1.19	32	0.052	0.13	194.	1.42	46	37
									0.052	0.03	194.	1.47	46	
FUJI														
FUJI	* 80FE-1	NO	9.2	0.187	4.24	379.	1.07	23	0.003	0.78	262.	1.21	34	27
FUJI	* 80FE-11	NO	9.4	0.336	3.15	387.	1.08	23	0.002	0.32	266.	1.52	33	26
				0.267	3.70	395.	1.17	22	0.008	0.52	275.	1.56	32	
FUJI														
FUJI	80FE-16	NO	9.4	0.167	4.90	390.	1.02	22	0.002	0.49	287.	1.16	31	25
FUJI	80FE-15	NO	9.4	0.301	6.14	395.	1.38	22	0.002	0.23	295.	1.24	30	25
FUJI	80FE-14	NO	9.4	0.276	6.14	421.	1.52	21	0.008	1.58	308.	1.86	29	24

V.I. REPORT APR 10, 1980 01:57:45
1980 FUEL ECONOMY PROGRAM
49 STATE TEST CAR LIST - PASSENGER CARS (GAS MILEAGE GUIDE)

MFR	CARLINE NAME	VEHICLE ID	DISP /CID	CARB VENT /FI	COMP. RATIO	HP	CONTROL SYSTEM	TRNS-O/D	E.T.W. LBS.	AXLE RATIO	N/V RATIO
AUDI	4000	384	97	FI	8.1	76	FI /EGR/OXD/ / /CAN	M4-2	2500	4.11	56.6
AUDI			BASIC ENGINE DESCRIPTOR: (DIESEL)								
AUDI	5000	490-669	121	FI	23.0	67	FI / / / / /NON	M5-2	3250	4.78	46.1
AUDI			BASIC ENGINE DESCRIPTOR: NONE								
AUDI	5000	637-80	131	FI	8.1	103	FI /EGR/OXD/ / /CAN	A3-1	3000	3.90	56.4
AUDI	5000	125-80	131	FI	8.1	103	FI /EGR/OXD/ / /CAN	M5-2	3000	4.11	46.0
AUDI			BASIC ENGINE DESCRIPTOR: (CAL)(FFS)								
AUDI	4000	027-80	131	FI	8.2	100	FI /3WY/CLS/ / /CAN	A3-1	2875	3.45	53.9
FUJI			BASIC ENGINE DESCRIPTOR: (NO CAT)								
FUJI	SUBARU WAGON	'80FE-12	97	2	8.5	67	EGR/PLS/OTR/ / /CAN	M4-2	2375	3.89	57.0
FUJI	SUBARU WAGON	'80FE-12	97	2	8.5	67	EGR/PLS/OTR/ / /CAN	M4-2	2500	3.89	57.0
FUJI	SUBARU	'80FE-12	97	2	8.5	67	EGR/PLS/OTR/ / /CAN	M5-2	2375	3.89	44.0
FUJI	SUBARU WAGON	80FE-12	97	2	8.5	67	EGR/PLS/OTR/ / /CAN	M5-2	2500	3.89	44.0
FUJI			BASIC ENGINE DESCRIPTOR: (CAT)								
FUJI	SUBARU	'80FE-10	97	2	9.0	68	EGR/PLS/OXD/ / /CAN	M4-2	2375	3.70	54.0
FUJI	SUBARU	'80FE-10	97	2	9.0	68	EGR/PLS/OXD/ / /CAN	M5-2	2375	3.70	42.0
FUJI			BASIC ENGINE DESCRIPTOR: (NO CAT)								
FUJI	BRAT 4WD	'80FE-1	97	2	8.5	67	EGR/PLS/OTR/ / /CAN	M4-2	2500	3.89	59.0
FUJI	SUBARU WAGON 4WD	'80FE-11	97	2	8.5	67	EGR/PLS/OTR/ / /CAN	M4-2	2625	3.89	59.0
FUJI			BASIC ENGINE DESCRIPTOR: NONE								
FUJI	SUBARU	80FE-16	109	2	8.7	72	EGR/PLS/OTR/ / /CAN	A3-1	2375	3.59	56.0
FUJI	SUBARU	80FE-15	109	2	8.7	72	EGR/PLS/OTR/ / /CAN	A3-1	2500	3.59	56.0
FUJI	SUBARU WAGON	80FE-14	109	2	8.7	72	EGR/PLS/OTR/ / /CAN	A3-1	2625	3.80	59.0

CERT
1980 TEST CAR
LIST

COMPACT CARS

MANUFACTURER / CAR LINE	EST. MPG	AVERAGE ANNUAL FUEL COST	COMB MPG	HWY MPG	ENGINE DESCRIPTION CID/CYL (TYPE)		TRANS-MISSION	FUEL SYS	BODY TYPE INTERIOR SPACE PASSENGER/ TRUNK OR CARGO(CU.FT.)
AMC									
CONCORD	22	$ 614	25	30	151/ 4		M4	2	2DR- 90/11
	20	$ 675	22	25	151/ 4		A3	2	4DR- 90/11
	17	$ 794	21	26	258/ 6	(FFS)	M4	2	
	18	$ 751	20	25	258/ 6	(FFS)	A3	2	
PACER	17	$ 794	21	26	258/ 6	(FFS)	M4	2	HBK- 91/11
	18	$ 751	20	25	258/ 6	(FFS)	A3	2	
AUDI									
5000	27	$ 444	33	43	121/ 5	(DIESEL)	M5	FI	4DR- 90/15
	17	$ 794	21	30	131/ 5		M5	FI	
	18	$ 751	20	25	131/ 5	(CAL)(FFS) (TURBO)	A3	FI	
	17	$ 794	20	25	131/ 5		A3	FI	
BMW									
733 I	16	$ 844	19	23	196(3.2L) / 6	(CAL)(FFS)	M4	FI	4DR- 94/13
	16	$ 844	19	23	196(3.2L) / 6	(CAL)(FFS)	A3	FI	
BUICK									
SKYLARK	24	$ 563	29	38	151(2.5L) / 4		M4	2	2DR- 94/14
	22	$ 614	26	34	151(2.5L) / 4		A3	2	4DR- 95/14
	20	$ 675	24	33	173(2.8L) / 6		M4	2	
	20	$ 675	23	30	173(2.8L) / 6		A3	2	
FIAT									
STRADA	25	$ 540	29	35	91(1500CC)/ 4		M5	2	HBK- 85/16
	24	$ 563	26	30	91(1500CC)/ 4		A3	2	
	28	$ 482	31	38	91(1500CC)/ 4	(CALIF)	M5	FI	
	26	$ 520	29	32	91(1500CC)/ 4	(CALIF)	A3	FI	
FORD									
GRANADA	19	$ 710	22	28	250(4.1L) / 6		M4	1	2DR- 89/15
	17	$ 794	19	23	250(4.1L) / 6		A3	1	4DR- 93/15
	17	$ 794	20	25	302(5.0L) / 8		A3	2	
JAGUAR									
XJ	15	$ 900	17	22	258(4.2L) / 6	(CAL)(FFS)	A3	FI	4DR- 91/10

1980 MODEL YEAR LIGHT-DUTY TRUCKS

MANUFACTURER / EMISSION FAMILY / (CUBIC INCH DISPLACEMENT) / CARLINES COVERED	VEHICLE CARLINE REPRESENTED	EMISSION CONTROL SYSTEM	ENGINE DISP.& CARB VENTURIS	TRANS	EQUIV TEST WEIGHT (LBS)	AXLE RATIO	CERTIFICATION LEVELS: EXHAUST EMISSIONS (GRAMS/MILE) HYDRO-CARBONS	CARBON MONOXIDE	OXIDES OF NITROGEN	EVAPOR. EMISSIONS (GRAMS) HYDRO-CARBONS
VOLKSWAGEN - FAMILY COMBINATIONS CERTIFIED:										
ENGINE FAMILY TEST VEHICLES										
37 PC / 37 P (CONT.)										
(EXHAUST DETERIORATION FACTORS FOR -		FI /EGR/OXD/ / /	FAMILY 37 PC				1.000	1.000	1.000	N/A)
(EVAPOR. DETERIORATION FACTORS FOR -		/ / / / /CAN	FAMILY 37 PC				N/A	N/A	N/A	0.159)
37 PF / 37 P (97)										
P/U 2WD	C P/U 2WD	FI /EGR/ / / /CAN	97-FI	4-3	2500	3.76	1.3	7.8	1.5	N/A
	C P/U 2WD	FI /EGR/ / / /CAN	97-FI	4-4	2375	3.90	1.2	7.4	1.4	1.5
	C P/U 2WD	FI /EGR/ / / /CAN	97-FI	4-5	2375	3.90	1.4	7.9	1.8	N/A
(EXHAUST DETERIORATION FACTORS FOR -		FI /EGR/ / / /	FAMILY 37 PF				1.000	1.221	1.000	N/A)
(EVAPOR. DETERIORATION FACTORS FOR -		/ / / / /CAN	FAMILY 37 PF				N/A	N/A	N/A	0.159)
VOLKSWAGEN - EVAP-EMISSION FAMILIES:										
EVAPORATIVE-EMISSION FAMILY TEST VEHICLES										
N	VANAGON 2WD	FI /3WY/CLS/ / /CAN	120-FI	4-3	3875	4.09	0.28	7.6	1.1	0.77
	C VANAGON 2WD	FI /EGR/OXD/ / /CAN	120-FI	4-4	3500	4.57	1.0	13.	2.6	0.69
37 P	C P/U 2WD	FI /EGR/OXD/ / /CAN	97-FI	4-3	2500	3.76	0.10	2.0	1.4	1.2
	P/U 2WD	FI /EGR/ / / /CAN	97-FI	4-4	2375	3.90	1.2	7.4	1.8	1.5

1980 MODEL YEAR LIGHT-DUTY DIESEL VEHICLES

MANUFACTURER / EXHAUST EMISSION FAMILIES / (CUBIC INCH DISPLACEMENT) / CARLINES COVERED	VEHICLE CARLINE REPRESENTED	EMISSION CONTROL SYSTEM	ENGINE DISP.& CARB VENTURIS	TRANS	EQUIV TEST WEIGHT (LBS)	AXLE RATIO	CERTIFICATION LEVELS: EXHAUST EMISSION (GRAMS/MILE) HYDRO-CARBONS	CARBON MONOXIDE	OXIDES OF NITROGEN	EVAPOR. EMISSIONS (GRAMS) HYDRO-CARBONS
AUDI - FAMILIES CERTIFIED:										
ENGINE FAMILY TEST VEHICLES										
DA (121)										
5000	5000	FI / / / / /NON	121-FI	4-5	3250	4.78	0.40	1.3	1.7	N/A
(EXHAUST DETERIORATION FACTORS FOR -		FI / / / / /	FAMILY DA				1.000	1.000	1.000	N/A)
GENERAL MOTORS - FAMILIES CERTIFIED:										
ENGINE FAMILY TEST VEHICLES										
03J9ZG (348)										
CUTLASS WAGON	SEVILLE	FI /EGR/ / / /NON	348-FI	4-3	4500	2.41	0.20	1.3	1.8	N/A
CUTLASS	CATALINA/BONNE WGN	FI /EGR/ / / /NON	348-FI	4-3	4750	2.73	0.32	1.3	1.4	N/A
CUTLASS SUPREME	NINETY EIGHT	FI /EGR/ / / /NON	348-FI	L-3	4500	2.41	0.35	1.3	1.5	N/A
IMPALA/CAPRICE WGN	CUTLASS	FI /EGR/ / / /NON	348-FI	L-3	4000	2.29	0.39	1.3	1.4	N/A
CATALINA/BONNE WGN										
CATALINA/BONNE.										
CUSTOM CRUISER WG										
DELTA 88										
LESABRE										
ESTATE WAGON										
NINETY EIGHT										
ELECTRA										
DEVILLE/BROUGHAM										
TORONADO										
RIVIERA										
ELDORADO										
SEVILLE										
(EXHAUST DETERIORATION FACTORS FOR -		FI /EGR/ / / /	FAMILY 03J9ZG				1.149	1.114	1.036	N/A)
MERCEDES BENZ - FAMILIES CERTIFIED:										
ENGINE FAMILY TEST VEHICLES										
80.20.34.24 (146)										
C 2400/280E/300D	C 2400/280E/300D	FI / / / / /NON	146-FI	4-4	3500	3.69	0.31	0.93	1.4	N/A
2400/280E/300D	C 2400/280E/300D	FI / / / / /NON	146-FI	4-4	3500	3.69	0.38	1.1	1.1	N/A

Listing of -F at 15:21:28 on JUL 16, 1986 for CCAd=SN80

	MFR CODE	IW	FRONT DRIVE	4 WD	DIESEL	SEDAN	RATED HP	ENGFAM INDEX	N/V	CID	TRANS	OD	BBLS	NO. CYLS.	PERF. INDEX	VEH SIZE CLASS CODE	MY	VEH CLASS	SALES VOL.	SALES BASE	CARLINE CODE	INJ	NO TURBO	MPG			MODEL NAME
																						FWD					
1	591	3000	FMDS				67	59021	56	121.0	M52	0	5	18.41		4	80	FLDD	9809	9809	5015	21.00		27.20	43.00	32.59	5000
2	591	3000	FAMS				103	59026	44	131.0	A31	0	5	13.46		4	80	CLDV	4790	4790	5015	21.40		16.70	24.60	19.52	5000
3	591	3000	FMMS				103	59026	44	131.0	M52	0	5	13.19		4	80	CLDV	663	663	5015	21.40		14.90	30.40	19.34	5000
4	591	3500	FAMS				107	59028	44	131.0	A31	0	5	14.78		4	80	FLDV	3987	3987	5015	21.40		17.50	24.90	20.20	5000
5	591	3000	FAMS				107	59027	44	131.0	A31	0	5	13.06		4	80	FLDV	10840	10840	5015	21.10		16.20	24.30	19.06	5000
6	591	3000	FMMS				107	59027	44	131.0	M52	0	5	12.81		4	80	FLDV	1809	1809	5015	21.10		16.10	29.50	20.24	5000

Chassis dyno

Audi 5000 Diesel
Accl. Test
6-30-83

0 - 50 mph	30 - 50 mph
1. 15.75 sec	1. 8.0 sec
2. 18.75 sec	2. 8.5 sec
3. 15.0 sec	3. 9.5 sec
4. 15.75 sec	4. 9.5 sec
5. 17.50 sec	5. 9.0 sec
AVG. 16.55 sec (16.3125)	AVG. 9.10 sec
S DEV 1.5350 (1.6630)	S DEV .4183

1980 AUDI 5000 S DIESEL

VIN = 43A013[illegible]

TECHNICAL DATA

Engine
Diesel engine
See page 105

Four stroke, five cylinders in line, in front of front axle tilted to right, crankshaft with six main bearings, spur-belt overhead camshaft.

Water cooling, thermostatically-controlled, with electric fan, thermostatically operated.

Pressure oil feed with gear-type pump and full flow filter.

Electric fuel pump. CIS fuel injection system.

Paper element air cleaner with temperature sensitive intake air pre-heating.

Exhaust emission control system. Activated charcoal filter (carbon canister) in the fuel system.

– Maximum output SAE net	103 hp at 5300 rpm. 110 hp at 5300 rpm*
– Maximum torque SAE net	112.4 ft. lbs. at 4000 rpm 163 Nm at 4000 rpm 115.9 ft. lb. at 4000 rpm* 168 Nm at 4000 rpm*
– Displacement	130.8 cu. in/2144 cm^3
– Stroke	3.40 in/86.4 mm
– Bore	3.13 in/79.5 mm
– Compression ratio	8.0:1
Cooling system	Electric fan with thermo switch. Water pump spur-belt driven.
Fuel	Canada models: **"Regular"**, incl. low-lead or unleaded fuels **"Unleaded fuel only"** for cars with catalytic converter.

* Canada models only.

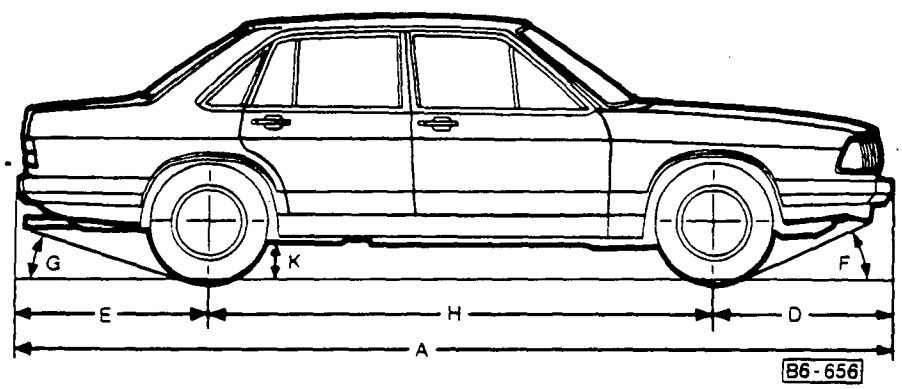
Transmissions:	**Automatic Transmission** Automatic transmission with separate final drive. The transmission consists of a hydrodynami torque converter and planetary gearing with three forward gears and one reverse. Front wheel drive with two constant velocity joints per drive shaft. **Manual Transmission** Single plate, dry clutch. Hydraulic clutch system. Baulk synchronized five-speed transmission and bevel gear differential in one housing. Front wheel drive with two constant velocity joints per drive shaft.	
Body/Chassis:	All steel unitized body/chassis, passenger compartment designed as safety cell, front anc rear ends designed to absorb impact energy.	
Steering:	Rack and pinion steering (power assisted) with maintenance-free tie rods.	
Front wheel suspension:	Independent **front wheel** suspension: coil spring/shock absorber struts with negative stee ring roll radius, stabilizer bar.	
Rear wheel suspension:	**Rear wheel** suspension: torsion crank axle with Panhard rod for lateral stability, progressiv coil springs, telescopic shock absorbers.	
Service (foot) brakes:	Foot brakes:	Power assisted, dual diagonal hydraulic system, disc brakes witl brake wear indicators at front, self-adjusting drum brakes at rear brake pressure regulator for the rear wheels.
Parking brakes:	Parking brake:	Mechanical, effective on rear wheels.
Tires:	Steel belted radial tires 185/70 SR (HR) 14. Steel rims 5½ J × 14 or light alloy rim: 6J × 14 (Always go by information listed on label inside of fuel tank flap).	
Tire size and pressure:	Tire pressures:	See sticker on inside of the fuel filler flap.

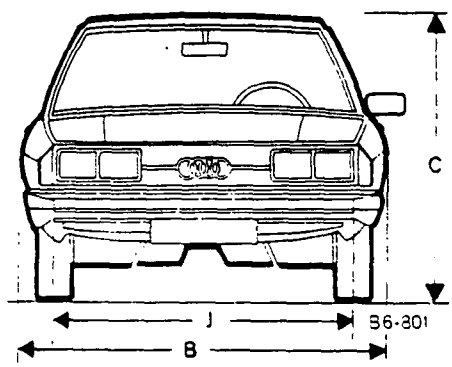
Electrical system

See page 106 for **Diesel engine.**

Voltage	12 Volts
Battery	63 Ampere hours
Starter	1.5 hp/1.1 kW
Radiator fan	250 watts
Alternator	1050 watts 14 volts/75 amp.
Size of V-belts:	
for alternator	9.5 x 800
for air conditioner	12.5 x 915
for power assisted steering	12.5 x 1003 LA
Ignition distributor	with combined vacuum and centrifugal spark advance
Ignition system	Transistorized (breakerless)
Firing order	1 – 2 – 4 – 5 – 3
Spark plugs	Bosch W 175 T30 Beru 175/14/3A Champion N8 Y
for California models	Bosch WR 7 DS Beru RS 35 Champion N 8 GY
Plug thread	14 mm
Electrode gap	0.027 in/0.7 mm

90





Dimensions

A – 189.0 in/4798 mm
B – 69.6 in/1768 mm
C – 54.7 in/1390 mm (unladen)
D – 40.3 in/1023 mm
E – 42.9 in/1087 mm
F – 24°
G – 19° (unladen)
H – 105.9 in/2688 mm (unladen)
J – 57.9 in/1470 mm
K – 4.4 in/ 112 mm (laden)

Turning circle, curb to curb 33.8 ft/10.3 m.

Weights

Vehicle capacity weight	see sticker on the inside of the fuel filler flap.
Curb weight with Manual Transmission	2703 lb/1225 kg
Curb weight with Automatic Transmission	2736 lb/1240 kg
Gross vehicle weight	see Safety Compliance Sticker on the left door jamb.
Gross axle weight, front	
Gross axle weight, rear	
Permissible roof weight*	165 lb/75 kg

* Applies only to roof rack mounted to rain gutters. Distribute load evenly!

Lubricants

Engine oil

Always use quality oil labeled "For Service API/SE" for the engine of your Audi. Engine oils are graded according to their viscosity. The proper grade to be used in your engine depends on existing climatic or seasonal conditions.
The table on the right contains the grading for oils to be used in your Audi engine. As temperature ranges of the different oil grades overlap, **brief** variations in outside temperatures are no cause for alarm. It is also permissible to mix oil of different viscosities if you find it necessary to add oil.

Transmission oil

Hypoid oil*	Single-grade	Multi-grade	Specifications	Additive basis
Manual Transmission	SAE 80 W	SAE 80 W/90	Mil-L-2105 API/GL 4	sulphur phosphorus
Final drive of the Automatic Transmission	SAE 90	—	Mil-L-2105 B API/GL 5	

* Does not have to be changed

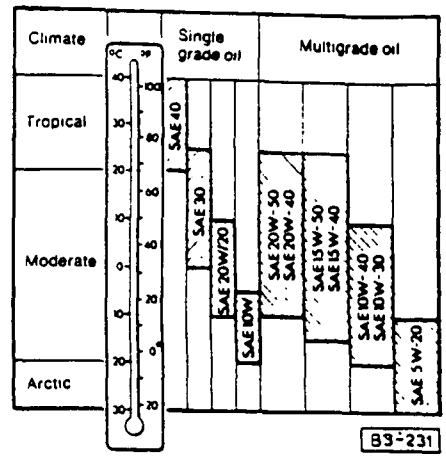
Automatic Transmission and torque converter require **ATF** all year round. All **ATFs labeled Dexron** can be used.

Lubricant additives

If your Audi is properly maintained, it is uneconomical to mix any type of additive with fuel, or lubricating oils and transmission fluids.

Battery

Silicone **spray or petroleum jelly** should be used for the battery terminals and posts.



When using single grade SAE 10 W or multi grade SAE 5 W-20 engine oil avoid high speed long distance driving if the outside temperature rises above the indicated limit.

DIESEL ENGINE

This portion of the Owner's Manual contains information that applies to Audi 5000 vehicles with **Diesel Engine.**
As this Owner's Manual is based on the gasoline engine equipped car, there are certain data that do not apply to your Audi 5000 Diesel, such as Catalytic Converter, Exhaust Gas Recirculation, Emission Control System, Fuel Octane Rating, Engine Oil Grades, Spark Plugs.
Please read the following pages before you drive your Audi 5000 Diesel, especially the explanations on

- **Starting with pre-glow**
- **Diesel Fuel No. 2**
- **Engine oil grade: API/CC or CD**

All other information and operating instructions for your Audi as described in this Owner's Manual apply. For warranty and service information consult your **Warranty & Maintenance** booklet.

Technical data

Engine

Four stroke, five cylinders in line, crankshaft with six main bearings, spur-belt overhead camshaft.

Water cooling, thermostatically-controlled, with electric fan, thermostatically operated.

Pressure oil feed with gear-type pump and full flow filter. Mechanical fuel injection pump, fuel injectors.

Paper element air cleaner.

Maximum output SAE net	67 hp at 4800 rpm
Maximum torque SAE net	90 ft. lb at 3000 rpm 125 Nm at 3000 rpm
Displacement	121 cu. in./1986 ccm
Stroke	3.402 in/86.4 mm
Bore	3.012 in/76.5 mm
Compression ratio	23:1
Cooling system	Electric fan with thermo switch. Water pump spur-belt driven.
Fuel	Diesel Fuel No. 2

Transmission

5-speed Manual Transmission.

Diesel 1(

Cooling system

Capacity	9.9 U.S. quarts/9.4 liters

Electrical system

Battery	88 Ah
Starter	2.0 hp
Radiator fan	250 watts
Alternator	75 Amp/1050 watts
V-belt for alternator	9 × 813 LA
for air conditioner	12.5 x 915
for power assisted steering	12.5 x 1050

Weights

Curb weight with Manual Transmission	2736 lb/1240 kg

ENGINE	
Horsepower SAE net	103 hp at 5300 rpm
Canada models only	110 hp at 5300 rpm
Diesel engine	67 hp at 4800 rpm
No. of cylinders	5
Displacement	130.8 cu. in/2144 cm³
Diesel engine	121 cu. in/1986 cm³
Type	in line, front mount
Cooling	water-cooled
Fuel/air supply	CIS fuel injection
Diesel engine	mech. fuel injection
Fuel tank capacity	19.8 U.S. gal./ 75 liters
Engine oil capacity with filter change	4.8 U.S. qt/ 4.5 liters
without filter change	4.5 U.S. qt/ 4.0 liters

VEHICLE LENGTH	189.0 in/4798 mm
WIDTH	69.6 in/1768 mm
HEIGHT	54.7 in/1390 mm
(unladen)	

BRAKES	dual diagonal circuits, power-assisted, discs front, drums rear
SUSPENSION	front wheels: independent rear wheels: torsion crank axle with Panhard rod
STEERING	rack-and-pinion, power-assisted

DRIVE TRAIN	
Type	front wheel drive
Gears (Manual)	5 forward, 1 reverse
Speeds (Automatic)	3 forward, 1 reverse

ELECTRICAL	
SYSTEM	12 Volt
Battery	63 Ampere hours
Diesel engine	88 Ampere hours
Alternator	1050 watts (14 volts/75 amp.)

Capacities

See page 106 for **Diesel engine.**

	U.S.	Metric
Fuel tank	19.8 gal	75.0 liters
Reserve of total capacity	2.1 gal	8.0 liters
Cooling system including heater	8.6 qt	8.1 liters
Engine oil (API/SE)		
with filter change	4.8 qt	4.5 liters
without filter change	4.3 qt	4.0 liters
Oil capacity between upper and lower marks on dipstick	1.1 qt	1.0 liter
Automatic Transmission		
at change (ATF)	3.2 qt	3.0 liters
final drive (hypoid oil – does not have to be changed)	1.1 qt	1.0 liter
Manual Transmission (hypoid oil – does not have to be changed)	2.75 qt	2.75 liters
Windshield washer container	1.8 qt	1.7 liters
Power assisted steering	0.8 qt	0.8 liter

APPENDIX C

BEST ECONOMY MAPS

RICARDO
CONSULTING ENGINEERS

EEPROM BEST ECONOMY/OPT IGN.FEB 1986

H.A.- RPS(*10), V.A.- FUEL(*5) << Exp. Impulse Time Constant(mS) - "C" >

	1	2	3	4	5	6	7	8	9	10
10	0080	0030	0035	0030	0030	0050	0050	0050	0050	0050
9	0090	0030	0030	0040	0035	0050	0050	0050	0050	0050
8	0100	0035	0035	0050	0035	0050	0050	0050	0050	0050
7	0110	0040	0040	0055	0040	0050	0050	0050	0050	0050
6	0120	0045	0045	0055	0040	0050	0050	0050	0050	0050
5	0130	0050	0050	0060	0045	0050	0050	0050	0050	0050
4	0140	0055	0055	0060	0045	0050	0050	0050	0050	0050
3	0150	0060	0060	0065	0050	0050	0050	0050	0050	0050
2	0150	0060	0060	0065	0050	0050	0050	0050	0050	0050
1	0150	0060	0060	0065	0050	0050	0050	0050	0050	0050

H.A.- RPS(*10), V.A.- MAP(mB*100) << Throttle Angle Derivative - "K" >>

	1	2	3	4	5	6	7	8	9	10
10	0000	0140	0200	0200	0200	0200	0200	0200	0200	0200
9	0000	0160	0310	0280	0150	0200	0200	0200	0200	0200
8	0000	0180	0330	0300	0170	0200	0200	0200	0200	0200
7	0000	0200	0340	0320	0210	0200	0200	0200	0200	0200
6	0000	0220	0350	0340	0240	0200	0200	0200	0200	0200
5	0000	0240	0375	0360	0260	0200	0200	0200	0200	0200
4	0000	0270	0400	0380	0280	0200	0000	0200	0200	0200
3	0000	0300	0450	0400	0300	0200	0200	0200	0200	0200
2	0000	0300	0450	0400	0300	0200	0200	0200	0200	0200
1	0000	0300	0450	0400	0300	0200	0200	0200	0200	0200

H.A.- RPS(*10), V.A.- MAP(mB*100)<< Advance Table(deg/100 BTDC) - "I" >>

	1	2	3	4	5	6	7	8	9	10
[illegible]	0500	0500	0900	1300	1400	1500	1600	1700	1700	1800
[illegible]	0500	1600	1700	1900	2000	2200	2200	2200	2200	2200
8	0500	1900	2000	2100	2200	2300	2400	2600	2600	2600
7	0600	2100	2100	2200	2300	2400	2600	2700	2700	2700
6	0000	2300	2300	2300	2300	2500	2600	2700	2700	2700
5	0600	2300	2300	2300	2300	2500	2600	2700	2700	2800
4	0600	2300	2300	2300	2400	2500	2600	2700	2700	2800
3	0600	2300	2300	2300	2400	2500	2600	2700	2700	2800
2	0600	2300	2300	2300	2400	2500	2600	2700	2700	2800
1	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000

H.A.- RPS(*2), V.A.- MAP(mB*100) < Idle Ign. Map - "J" (deg/100 BTDC) >

	1	2	3	4	5	6	7	8	9	10
10	0000	0000	0000	0000	0000	0500	0500	0500	0500	0500
9	0000	0000	0000	0000	0000	0500	0500	0800	1000	1600
8	0000	0000	0000	0000	0000	0500	0700	1000	1400	1900
7	0000	0000	0000	0000	0000	0600	0800	1200	1600	2100
6	0000	0000	0000	0400	0600	0600	0800	1200	1700	2300
5	0000	0000	0000	0400	0600	0600	0800	1400	1800	2300
4	0000	0000	0000	0400	0600	0600	0800	1600	2000	2300
3	0000	0000	0000	0400	0600	0600	0800	1600	2000	2300
2	0000	0000	0000	0400	0600	0600	0800	1300	1600	2000
1	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000

EEPROM BEST ECONOMY/OPT IGN.FEB 1986 recalled

H.A.- RPS(*10), V.A.- MAP(mB*100)<< Fuel Injection Table(Fuel/100) - "F" >>

10	0000	4100	4600	4950	5350	5450	5700	5900	6100	6300
9	0000	2380	2575	2710	2800	2815	2930	2990	3050	3100
8	0000	2130	2275	2395	2470	2480	2590	2650	2700	2750
7	0000	1850	1980	2080	2125	2165	2240	2305	2380	2450
6	0000	1580	1690	1770	1830	1840	1950	1970	2020	2100
5	0000	1350	1420	1470	1520	1530	1640	1640	1670	1700
4	0000	1100	1160	1170	1220	1220	1320	1320	1350	1400
3	0000	0900	0915	0930	0970	1010	1050	1200	OVRUN	OVRUN
2	0000	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN
1	0000	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN
	1	2	3	4	5	6	7	8	9	10

H.A.- RPS(*2), V.A.- MAP(mB*100) < Idle Fuel Map - "G" (Fuel/100) >

10	6000	6000	6000	6000	6000	6000	6000	6000	6000	4100
9	4500	4500	4500	4500	4400	4200	4000	4000	4000	2380
8	4200	4200	4200	4000	3700	3400	3200	3200	3200	2130
7	3800	3800	3800	3500	3200	3000	2600	2600	2600	1850
6	3000	3000	3000	2700	2400	2100	2000	2000	2000	1580
5	2600	2600	2400	2200	2000	1700	1700	1600	1600	1350
4	2000	1900	1800	1600	1600	1480	1370	1280	1250	1100
3	OVRUN	OVRUN	1500	1400	1300	1200	1020	0950	0900	0900
2	OVRUN	OVRUN	1800	1600	1500	1200	1200	1200	1200	1200
1	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN
	1	2	3	4	5	6	7	8	9	10

H.A.- RPS(*10), V.A.- FUEL(*5) << Exp. Impulse Height(%) - "H" >>

10	0000	0030	0030	0030	0030	0030	0030	0030	0030	0030
9	0000	0050	0040	0040	0045	0030	0030	0030	0030	0030
3	0000	0070	0045	0050	0060	0030	0030	0030	0030	0030
7	0000	0080	0050	0055	0070	0030	0030	0030	0030	0030
6	0000	0090	0060	0060	0080	0030	0030	0030	0030	0030
5	0000	0100	0070	0065	0085	0030	0030	0030	0030	0030
4	0000	0110	0080	0075	0090	0030	0030	0030	0030	0030
3	0000	0120	0090	0080	0100	0030	0030	0030	0030	0030
2	0000	0120	0090	0080	0100	0030	0030	0030	0030	0030
1	0000	0120	0090	0080	0100	0030	0030	0030	0030	0030
	1	2	3	4	5	6	7	8	9	10

H.A.- RPS(*2), V.A.- MAP(mB*100) << WW Idle Height - "W" >>

10	0000	0000	0000	0000	0000	0000	0060	0060	0060	0060
9	0000	0000	0000	0000	0000	0000	0060	0060	0060	0060
8	0000	0000	0000	0000	0000	0000	0080	0060	0060	0060
7	0000	0000	0000	0000	0000	0000	0080	0080	0060	0060
6	0000	0000	0000	0000	0000	0000	0100	0100	0060	0060
5	0000	0000	0000	0000	0000	0000	0120	0120	0120	0120
4	0000	0000	0000	0000	0000	0000	0140	0140	0120	0125
3	0000	0000	0000	0000	0000	0000	0160	0160	0120	0125
2	0000	0000	0000	0000	0000	0000	0160	0160	0120	0125
1	0000	0000	0000	0000	0000	0000	0000	0080	0060	0060
	1	2	3	4	5	6	7	8	9	10

RICARDO
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EEPROM BEST ECONOMY/OPT IGN.FEB 1986 recalled
H.A.- RPS(*10), V.A.- MAP(mB*100) < E.G.R. 0 to 1000 >

	1	2	3	4	5	6	7	8	9	10
10	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
9	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
8	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
7	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
6	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
5	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
4	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
3	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
2	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
1	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000

5 Two Line Temp. Comp. Tables (COMP./TEMP.), TEMP(KELVIN), COMP(%)

	1	2	3	4	5	6	7	8	9	10
10	0200	0200	0200	0200	0200	0180	0160	0140	0100	0100
9	0270	0280	0290	0295	0300	0305	0310	0317	0323	0328
8	0200	0200	0200	0200	0200	0180	0160	0140	0100	0100
7	0270	0280	0290	0295	0300	0305	0310	0317	0323	0328
6	0350	0250	0200	0160	0140	0125	0115	0110	0100	0100
5	0270	0280	0285	0290	0295	0305	0310	0320	0330	0340
4	0100	0100	0100	0100	0100	0100	0100	0100	0100	0100
3	0100	0100	0100	0100	0100	0100	0100	0100	0100	0100
2	0000	0000	0000	0000	0000	0000	0020	0040	0070	0100
1	0270	0280	0285	0290	0295	0305	0310	0320	0330	0340

REDUCED NOx MAPS

RICARDO
CONSULTING ENGINEERS

EEPROM REDUCED NOX STRATEGY JUNE 86

H.A.- RPS(*10), V.A.- MAP(mB*100)<< Fuel Injection Table(Fuel/100) - "F" >>

10	0000	4100	4600	4950	5350	5450	5700	5900	6100	6300
9	0000	2660	2750	2820	2930	3030	3900	5000	5400	5700
8	0000	2170	2250	2280	2340	2365	2700	2970	3000	3050
7	0000	1830	1900	1960	1980	2000	2280	2550	2620	2650
6	0000	1540	1690	1750	1800	1820	2000	2200	2240	2300
5	0000	1300	1420	1470	1500	1510	1670	1820	1850	1900
4	0000	1210	1190	1175	1250	1290	1360	1470	1490	1520
3	0000	0900	0915	0920	1000	1080	1100	1200	OVRUN	OVRUN
2	0000	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN
1	0000	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN
	1	2	3	4	5	6	7	8	9	10

H.A.- RPS(*2), V.A.- MAP(mB*100) < Idle Fuel Map - "G" (Fuel/100) >

10	6000	6000	6000	6000	6000	6000	6000	6000	6000	4100
9	4500	4500	4500	4500	4400	4200	4000	4000	4000	2600
8	4200	4200	4200	4000	3700	3400	3200	3200	3200	2170
7	3800	3800	3800	3500	3200	3000	2600	2600	2600	1830
6	3000	3000	3000	2700	2400	2100	2000	2000	2000	1540
5	2600	2600	2400	2200	2000	1700	1700	1600	1600	1300
4	2000	1900	1800	1600	1600	1480	1370	1280	1250	1210
3	OVRUN	OVRUN	1500	1400	1300	1200	1020	0950	0900	0900
2	OVRUN	OVRUN	1800	1600	1500	1200	1200	1200	1200	1200
1	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN	OVRUN
	1	2	3	4	5	6	7	8	9	10

H.A.- RPS(*10), V.A.- FUEL(*5) << Exp. Impulse Height(%) - "H" >>

10	0110	0110	0020	0040	0020	0030	0030	0030	0030	0030
9	0110	0110	0030	0040	0020	0030	0030	0030	0030	0030
8	0120	0120	0030	0045	0025	0030	0030	0030	0030	0030
7	0120	0120	0030	0045	0025	0030	0030	0030	0030	0030
6	0130	0130	0030	0050	0030	0030	0030	0030	0030	0030
5	0140	0140	0050	0050	0030	0030	0030	0030	0030	0030
4	0140	0140	0060	0055	0035	0030	0030	0030	0030	0030
3	0150	0150	0060	0055	0035	0030	0030	0030	0030	0030
2	0150	0150	0060	0060	0040	0030	0030	0030	0030	0030
1	0150	0150	0060	0060	0040	0030	0030	0030	0030	0030
	1	2	3	4	5	6	7	8	9	10

H.A.- RPS(*2), V.A.- MAP(mB*100) << WW Idle Height - "W" >>

10	0000	0000	0000	0000	0000	0000	0060	0060	0060	0060
9	0000	0000	0000	0000	0000	0000	0060	0060	0060	0060
8	0000	0000	0000	0000	0000	0000	0080	0060	0060	0060
7	0000	0000	0000	0000	0000	0000	0080	0080	0060	0060
6	0000	0000	0000	0000	0000	0000	0100	0100	0060	0060
5	0000	0000	0000	0000	0000	0000	0120	0120	0120	0120
4	0000	0000	0000	0000	0000	0000	0140	0140	0120	0125
3	0000	0000	0000	0000	0000	0000	0160	0160	0120	0130
2	0000	0000	0000	0000	0000	0000	0160	0160	0120	0130
1	0000	0000	0000	0000	0000	0000	0000	0080	0060	0060
	1	2	3	4	5	6	7	8	9	10

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EEPROM REDUCED NOX STRATEGY JUNE 86 recalled

H.A.- RPS(*10), V.A.- FUEL(*5) << Exp. Impulse Time Constant(mS) - "C" >

10	0035	0030	0085	0050	0080	0150	0150	0150	0150	0150
9	0040	0035	0090	0055	0090	0150	0150	0150	0150	0150
8	0045	0035	0095	0060	0100	0150	0150	0150	0150	0150
7	0050	0040	0100	0065	0110	0150	0150	0150	0150	0150
6	0055	0040	0105	0070	0120	0150	0150	0150	0150	0150
5	0060	0045	0110	0075	0130	0150	0150	0150	0150	0150
4	0065	0045	0115	0075	0140	0150	0150	0150	0150	0150
3	0070	0050	0120	0080	0150	0150	0150	0150	0150	0150
2	0070	0050	0120	0080	0150	0150	0150	0150	0150	0150
1	0070	0050	0120	0080	0150	0150	0150	0150	0150	0150
	1	2	3	4	5	6	7	8	9	10

H.A.- RPS(*10), V.A.- MAP(mB*100) << Throttle Angle Derivative - "K" >>

10	0000	0220	0120	0260	0320	0300	0300	0300	0300	0300
9	0330	0230	0130	0280	0330	0300	0300	0300	0300	0300
8	0340	0240	0140	0290	0340	0300	0300	0300	0300	0300
7	0350	0250	0150	0300	0350	0300	0300	0300	0300	0300
6	0360	0260	0160	0310	0360	0300	0300	0300	0300	0300
5	0370	0270	0170	0320	0370	0300	0300	0300	0300	0300
4	0380	0280	0180	0330	0380	0300	0300	0300	0300	0300
3	0390	0290	0190	0340	0390	0300	0300	0300	0300	0300
2	0400	0300	0200	0350	0400	0300	0300	0300	0300	0300
1	0400	0300	0200	0350	0400	0300	0300	0300	0300	0300
	1	2	3	4	5	6	7	8	9	10

H.A.- RPS(*10), V.A.- MAP(mB*100)<< Advance Table(deg/100 BTDC) - "I" >>

10	0000	0500	0700	0800	0900	1000	1600	1700	1700	1800
9	0000	0700	0900	1000	1000	1000	2100	2100	2100	2100
8	0000	1000	1200	1200	1200	1200	2200	2300	2400	2400
7	0000	2000	2100	2100	2200	2300	2400	2500	2500	2500
6	0000	2100	2100	2100	2200	2400	2400	2500	2500	2500
5	0000	2100	2100	2100	2200	2400	2400	2500	2500	2600
4	0000	2100	2100	2100	2200	2400	2400	2500	2500	2600
3	0000	2100	2100	2100	2200	2400	2400	2500	2500	2600
2	0000	2000	2100	2100	2200	2400	2400	2500	2500	2600
1	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
	1	2	3	4	5	6	7	8	9	10

H.A.- RPS(*2), V.A.- MAP(mB*100) < Idle Ign. Map - "J" (deg/100 BTDC) >

10	0000	0000	0000	0000	0000	0500	0500	0500	0500	0500
9	0000	0000	0000	0000	0000	0500	0500	0800	1000	1600
8	0000	0000	0000	0000	0000	0500	0700	1000	1400	1900
7	0000	0000	0000	0000	0000	0600	0700	1200	1600	2100
6	0000	0000	0000	0400	0600	0600	0800	1200	1700	2100
5	0000	0000	0000	0400	0600	0600	0800	1400	1800	2100
4	0000	0000	0000	0400	0600	0600	0800	1600	2000	2100
3	0000	0000	0000	0400	0600	0600	0800	1600	2000	2100
2	0000	0000	0000	0400	0600	0600	0800	1300	1600	2000
1	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
	1	2	3	4	5	6	7	8	9	10

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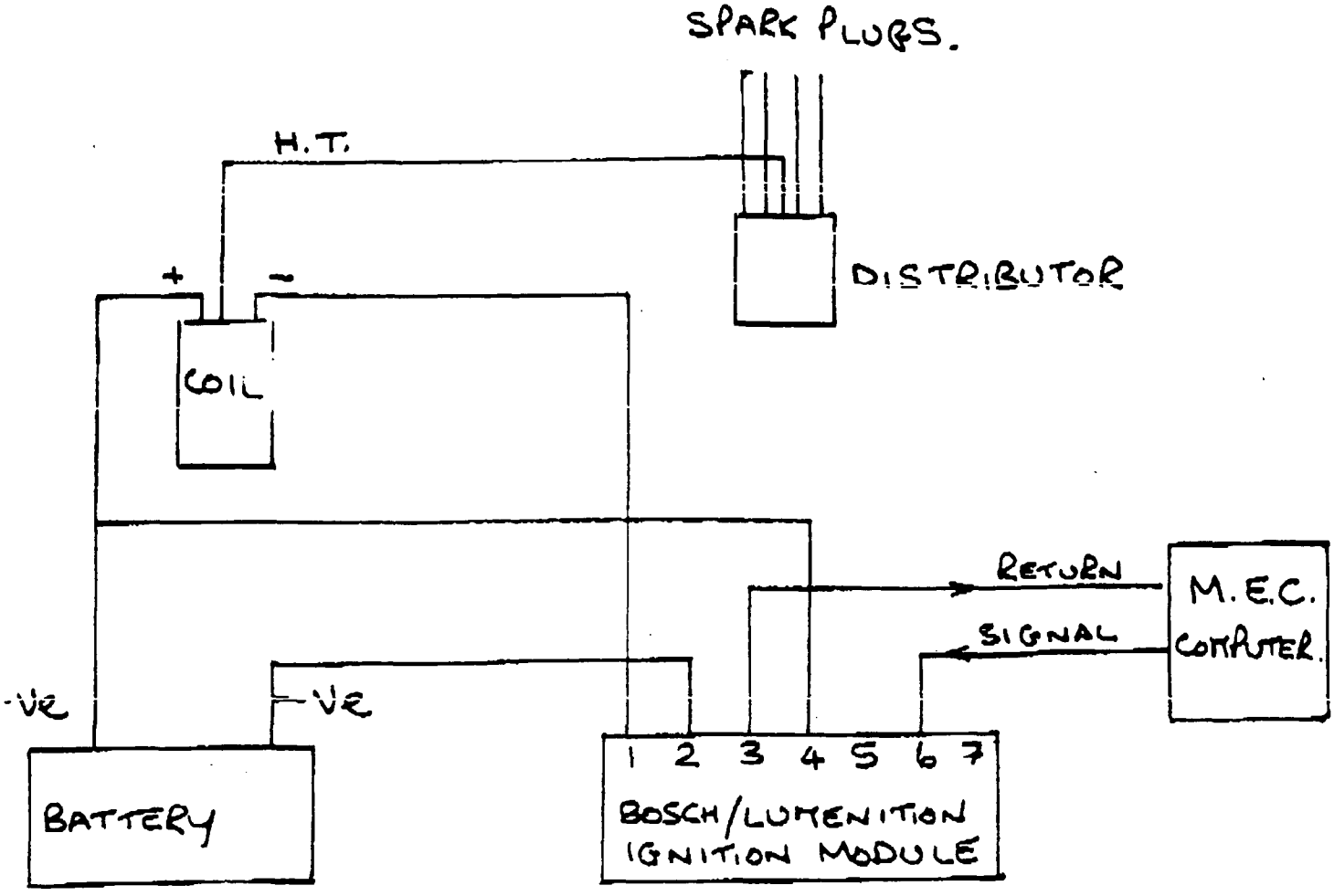
EEPROM REDUCED NOX STRATEGY JUNE 86 recalled
H.A.- RPS(*10), V.A.- MAP(mB*100) < E.G.R. 0 to 1000 >

10	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
9	0000	0240	0350	0450	0500	0550	0420	0000	0000	0000
8	0000	0250	0350	0430	0475	0500	0400	0000	0000	0000
7	0000	0260	0370	0440	0550	0650	0550	0000	0000	0000
6	0000	0240	0330	0400	0470	0560	0440	0000	0000	0000
5	0000	0220	0280	0320	0350	0370	0330	0000	0000	0000
4	0000	0200	0230	0230	0240	0260	0240	0000	0000	0000
3	0000	0000	0225	0225	0225	0000	0000	0000	0000	0000
2	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
1	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
	1	2	3	4	5	6	7	8	9	10

5 Two Line Temp. Comp. Tables (COMP./TEMP.), TEMP(KELVIN), COMP(%)

10	0200	0200	0200	0200	0200	0180	0160	0140	0100	0100
9	0270	0280	0290	0295	0300	0305	0310	0317	0323	0328
8	0200	0200	0200	0200	0200	0180	0160	0140	0100	0100
7	0270	0280	0290	0295	0300	0305	0310	0317	0323	0328
6	0350	0250	0200	0160	0140	0125	0115	0110	0100	0100
5	0270	0280	0285	0290	0295	0305	0310	0320	0330	0340
4	0100	0100	0100	0100	0100	0100	0100	0100	0100	0100
3	0100	0100	0100	0100	0100	0100	0100	0100	0100	0100
2	0000	0000	0000	0000	0000	0000	0020	0040	0070	0100
1	0270	0280	0285	0290	0295	0305	0310	0320	0330	0340
	1	2	3	4	5	6	7	8	9	10

To EPA. ANN ARBOR	
ATTENTION MR R. BRUETSCH	Fax No. Brighton (0273) 464124
~~Telex~~ / Fax No. 0101 313 668 4368	Telex No. 87383 RICSHAM G
from GRAHAM LEESON	Date 5.12.86
Subject METHANOL IGNITION SYSTEM	Page 2 of 2



If you do not receive all of the pages or the message is distorted
please call 0273 455611 ext 2334 and speak to fax operator

Fax No. [illegible]

from GRAHAM LEESON

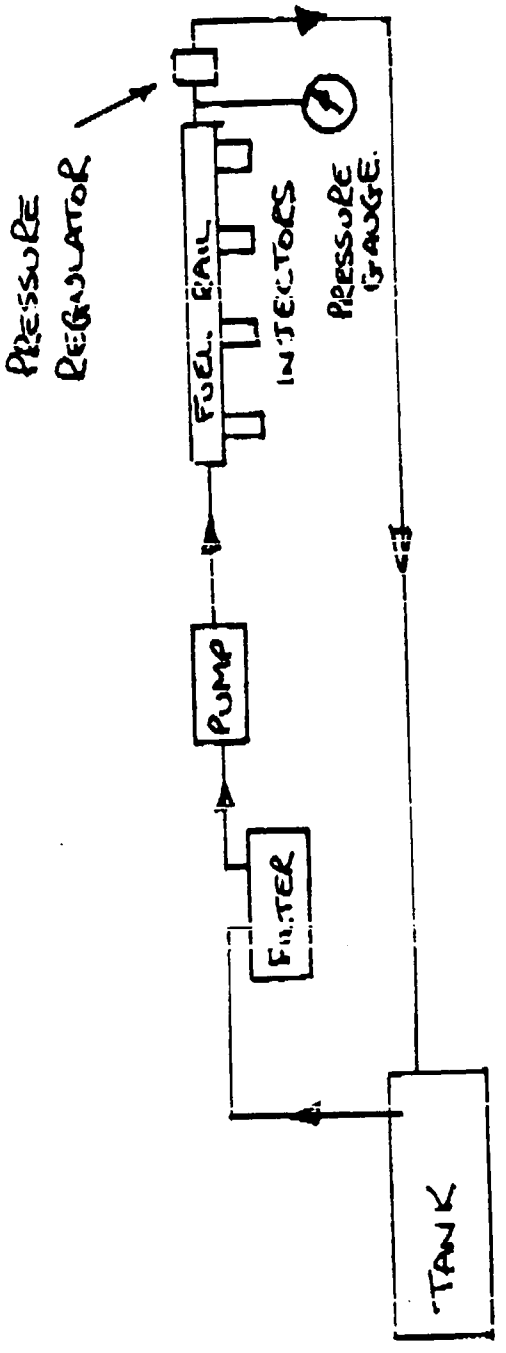
Subject METHANOL FUEL SYSTEM

Telex No. 87303 RICHHAM G

Date 5.12.1986

Page 1 of 2

ALL COMPONENTS TO BE METHANOL PROOF.



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C-9

Telex/ Facsimile Message

RICARDO

To EPA ANN ARBOR
ATTENTION ROB BRUETSCH

~~Telex~~ / Fax No. 0101 313 668 4368

from GRAHAM LEESON

Subject VW METHANOL ENGINE

Fax No. Brighton (0273) 464124
Telex No. 87383 RICSHAM G
Date 4.8.1987
Page 1 of 2

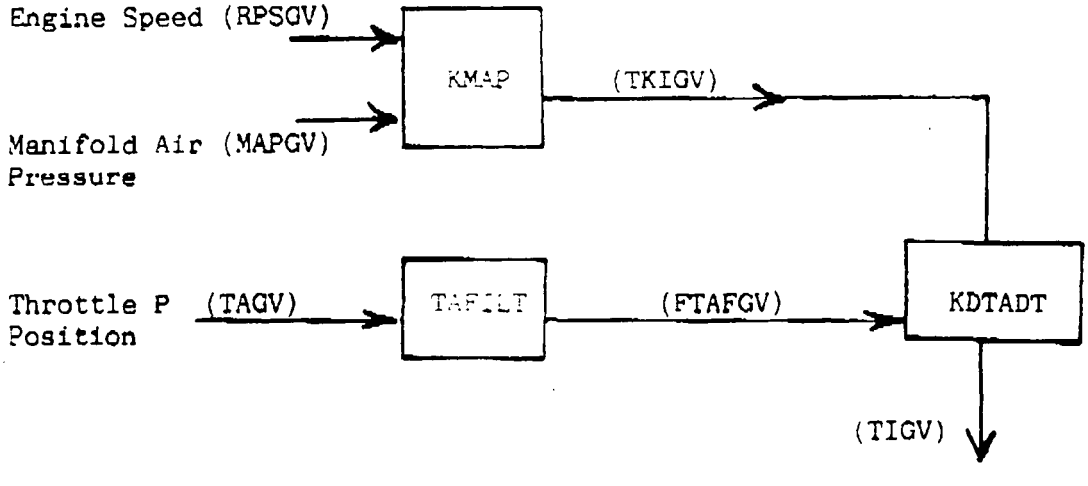
MEC FUEL CALCULATIONS.

In order to understand the fuel algorithms the user may need to identify the engine panel display values with the nodes on the fuelling strategy chart. the trace values with the fuelling strategy chart, and the total fuel calculated with the injector opening time.

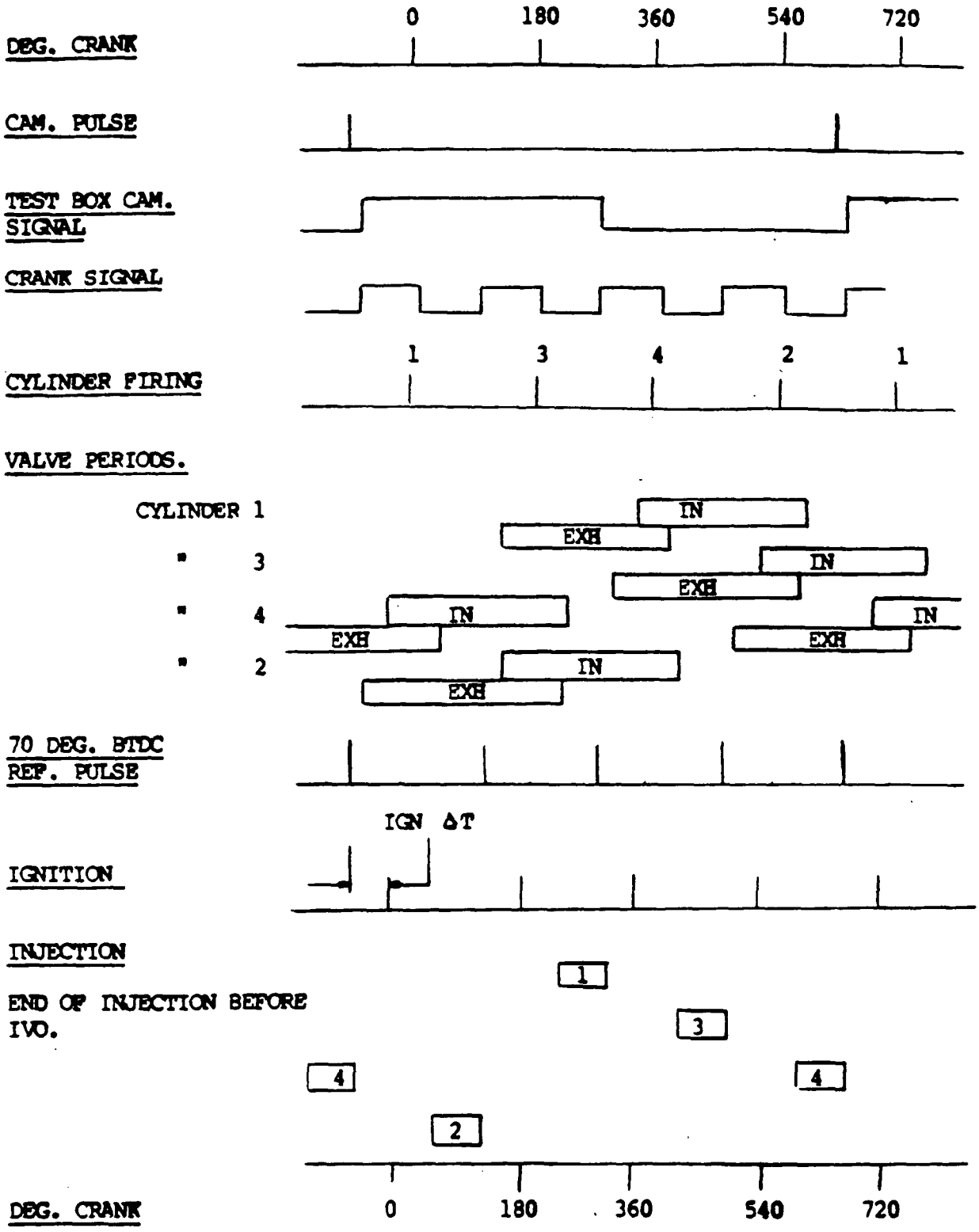
The fuel calculations are written in assembly code which allows only six characters for names of variables and procedures. This causes the names to be unpronouncable and brief but they have been used in the diagrams and descriptions to aid accuracy.

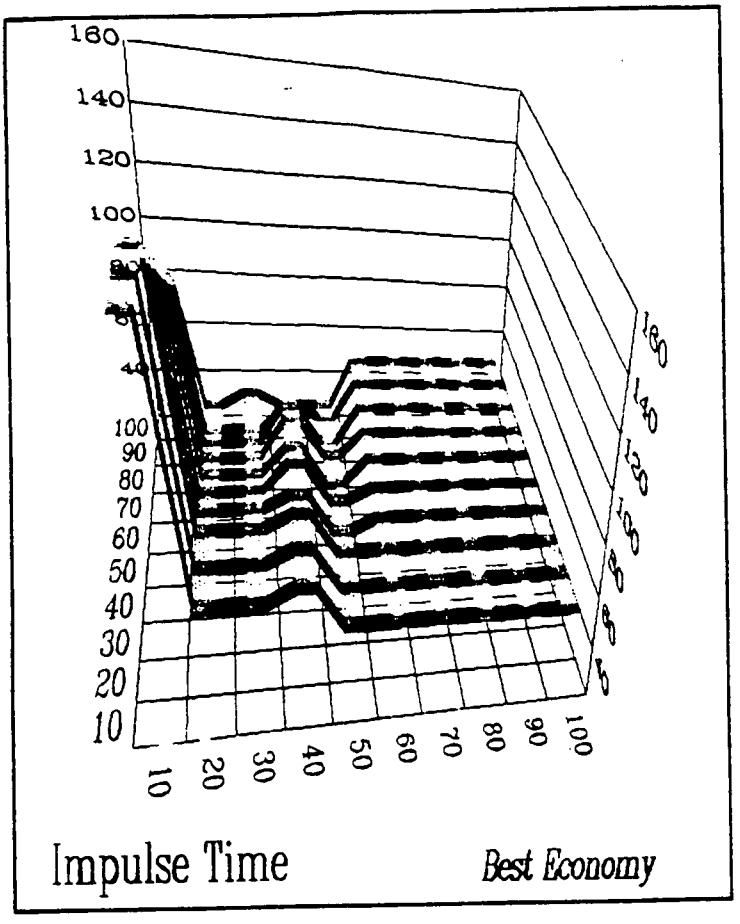
Throttle impulse calculation.

This adds fuel as the throttle is opened.



MEC SEQUENCE OF EVENTS

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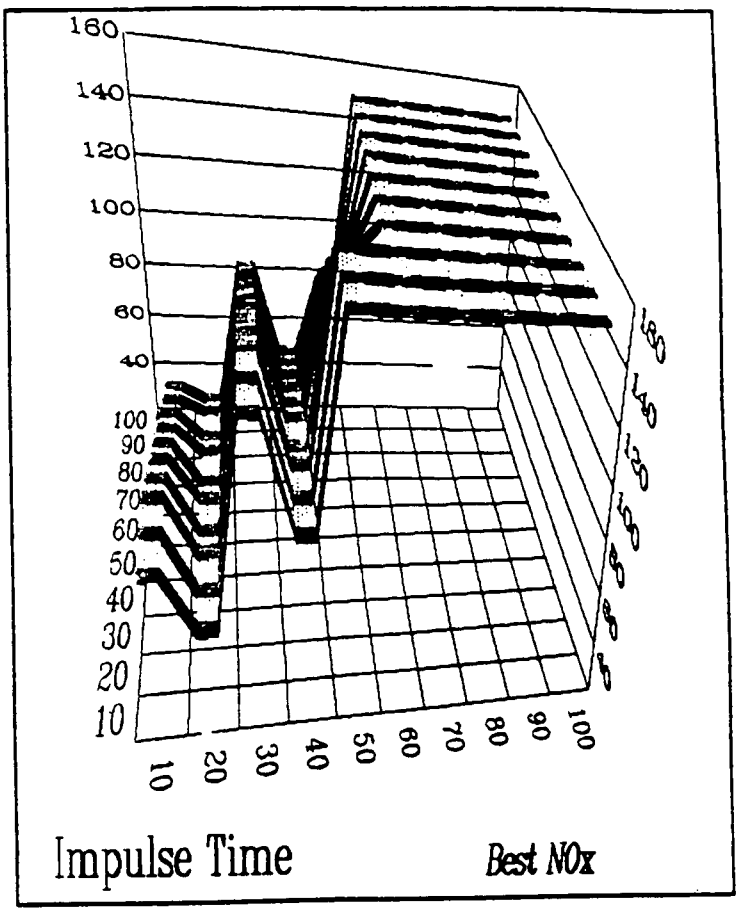
Impulse Time
Best Economy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Impulse Time
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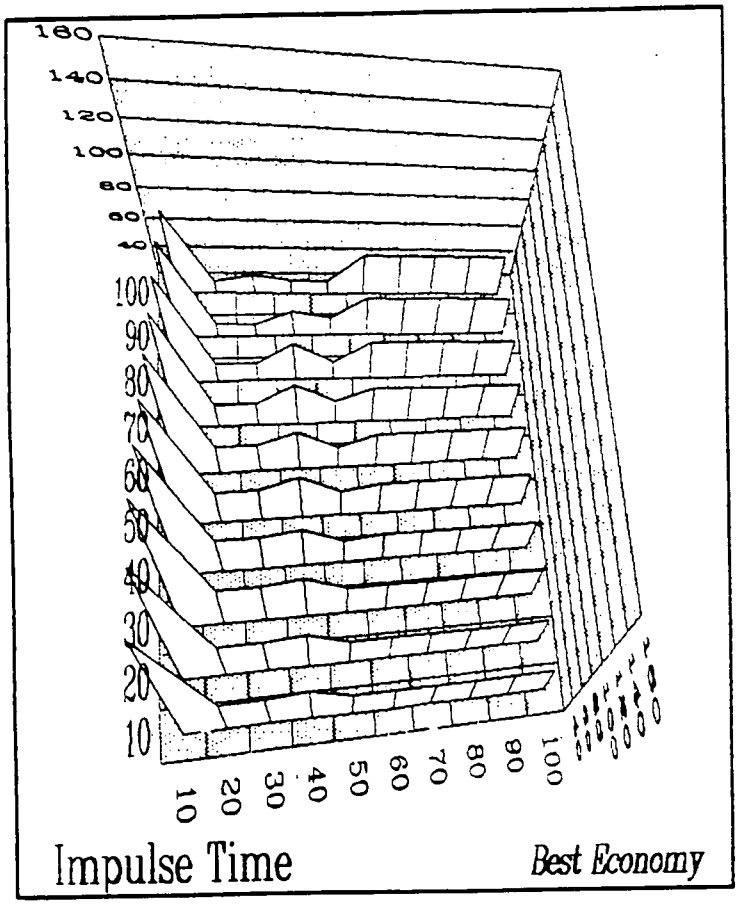
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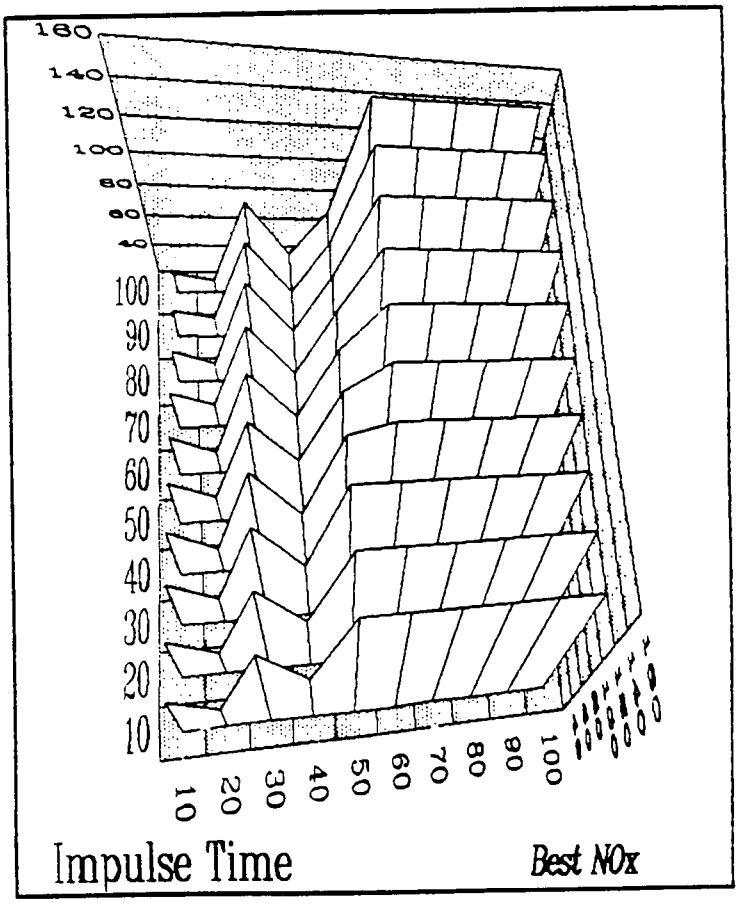
Impulse Time
Best Economy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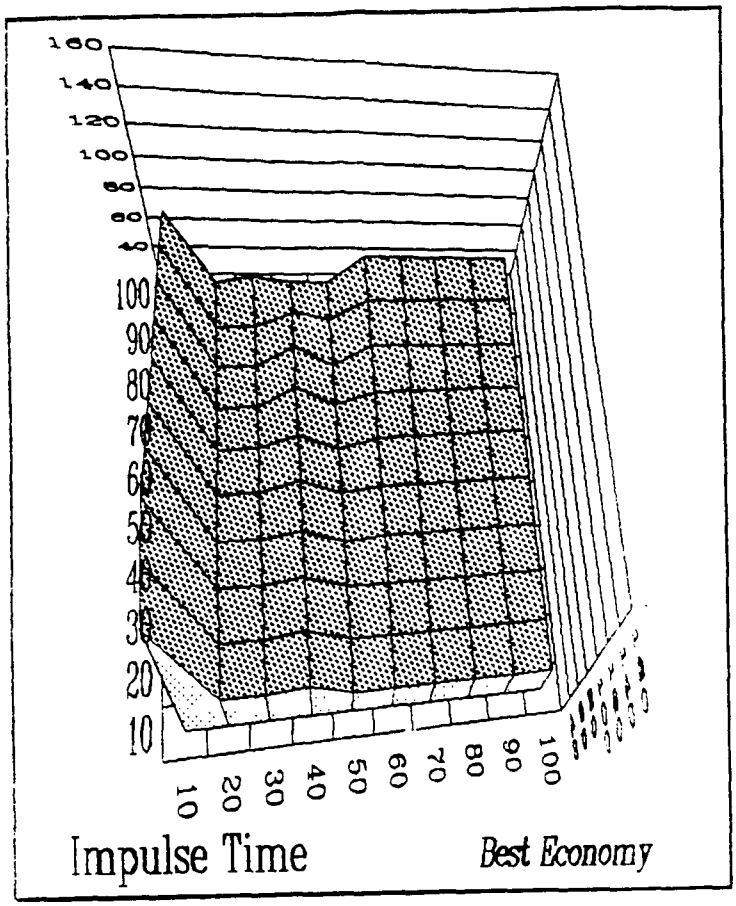
Impulse Time
Best NOx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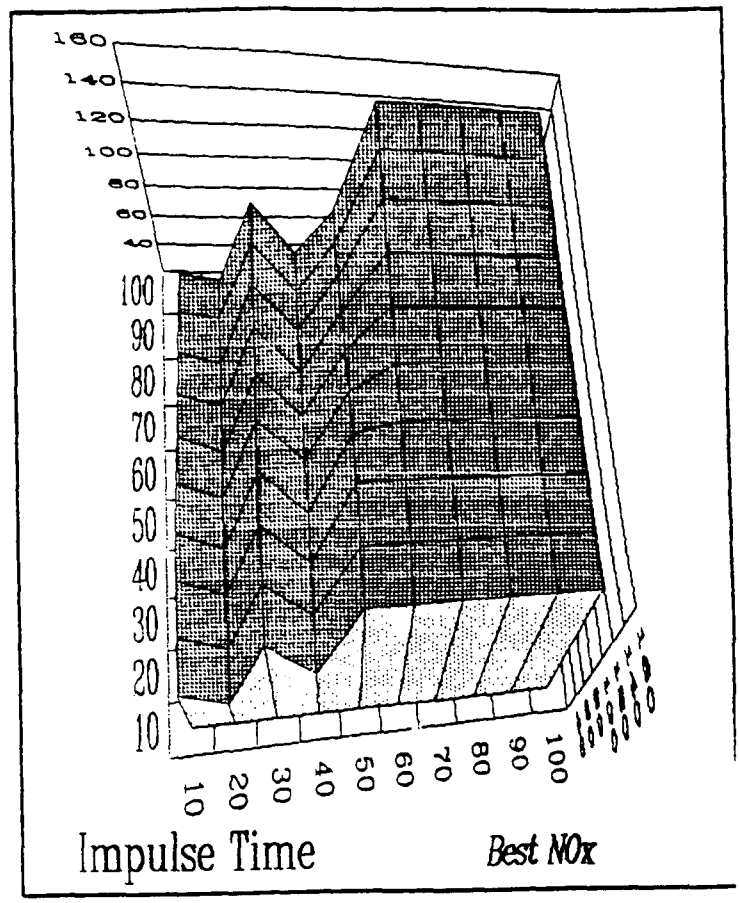
Impulse Time
Best Economy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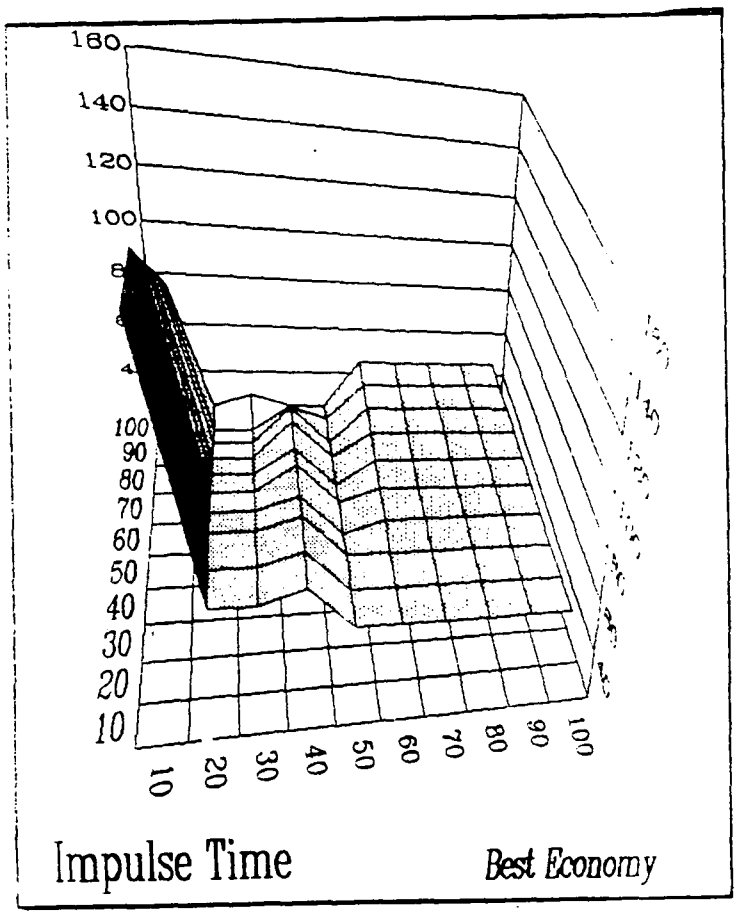
Impulse Time
Best NOx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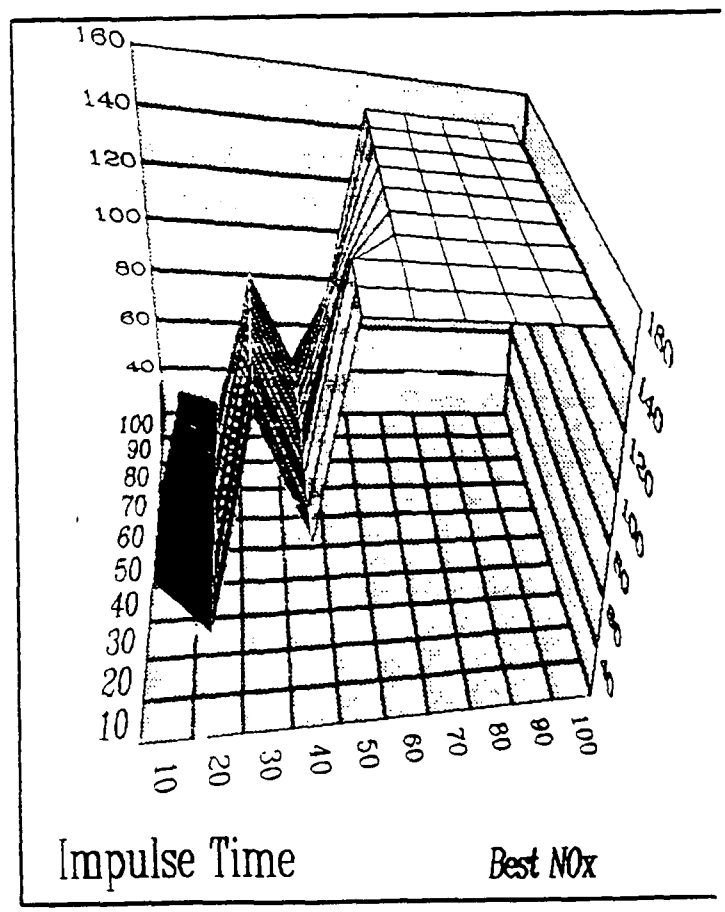
Impulse Time
Best Economy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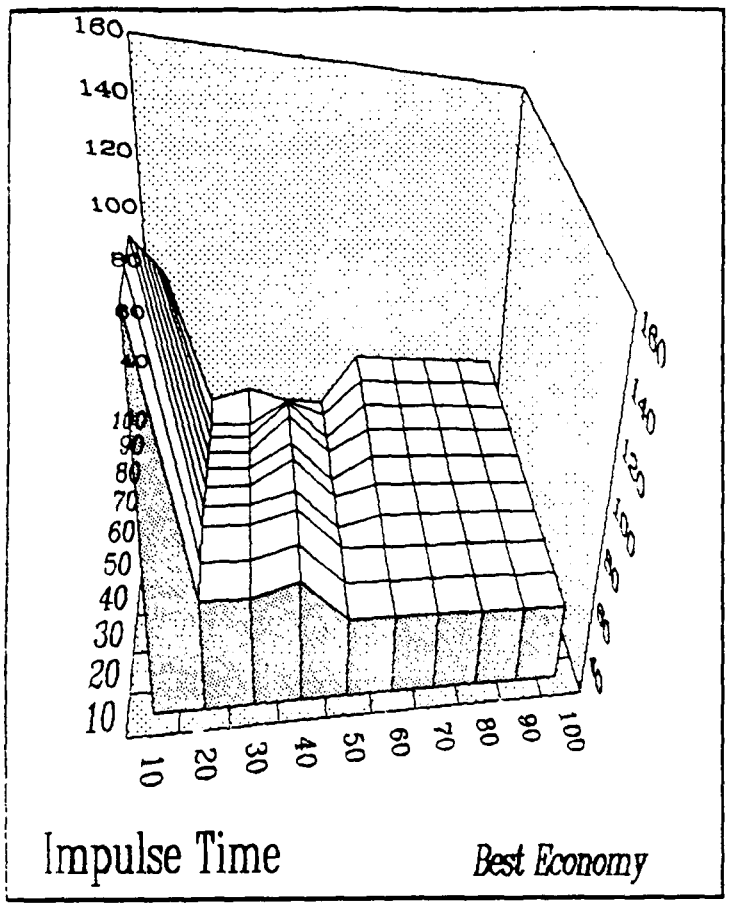
Impulse Time
Best NOx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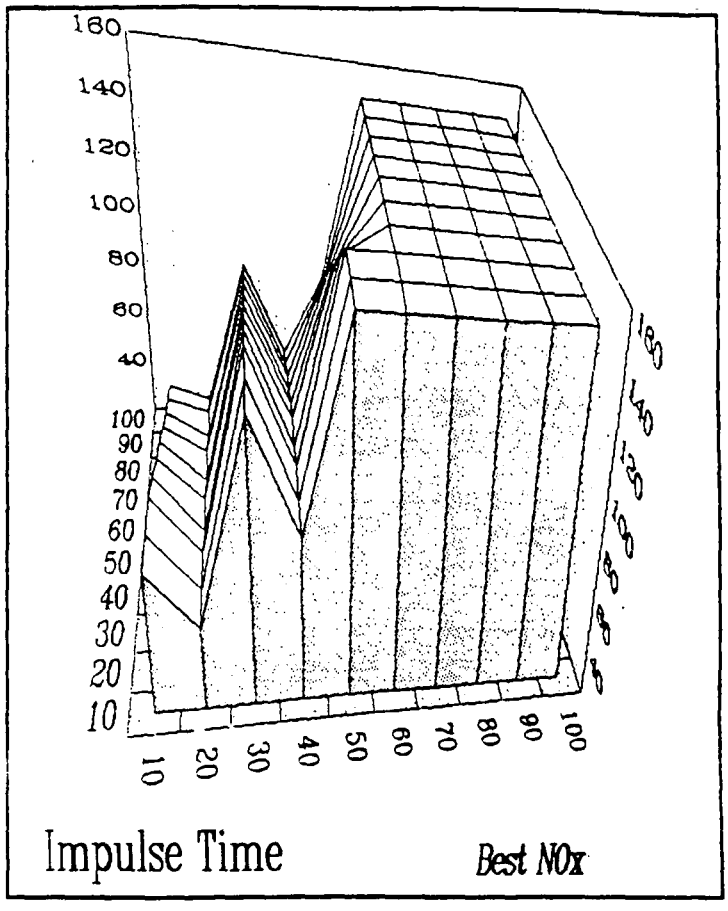
Impulse Time
Best Economy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Impulse Time
Best NOx

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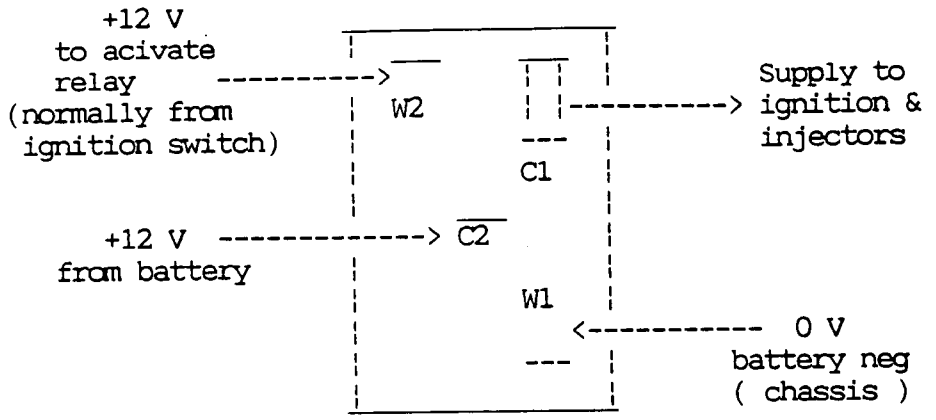
Wiring details of MEC injector and ignition relay



Relay type LUCAS 6RA
Pin view showing pin numbers.

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Appendix 1

CONFIGURATION OF PLUG/SOCKET INTERFACE WITH PROBES AND LOOM

ILLUSTRATION OF PREFERED PRATICE

```
   PROBE                          CONNECTION                 LOOM        MEC
            Receptacle                                   Plug
            Type   Pin Skt                               Type Pin Skt
PRT's       Cable   *    PT01E-10-6P><PT06E-10-6S        Cable     * ==>-
AN's          "     *          "     ><     "             "       * ==>¦
Ring Gear     "     *          "     ><     "             "       * ==>¦
Camshaft      "     *          "     ><     "             "       * ==>¦
Crankshaft    "     *          "     ><     "             "       * ==>¦ 55-WAY
Ignition      "     *          "     ><     "             "       * ==>¦
Knock & EGR   "     *          "     ><     "             "       * ==>¦
Map         <==========================<     "             "       * ==>¦
Throttle    <==========================<   1  AC Special            * ==>-
Injector     Plug   *    PT06E-10-6P><PT00E-10-6S Recept/Cha       * == XLR31
```

'K' Type t/c **SCREENED** comp-lead & miniature plugs to be used as std.

Connector Identification

PT01E-10-6P(SR) --------Receptacle Cable
PT06E-10-6S(SR) --------Plug Cable
PT00E-10-6S(SR) --------Receptacle Chassis
PT06E-10-6P(SR) --------Plug Cable
PT00E-22-55S(SR) -------Recptacle Chassis
PT06E-22-55P(SR) -------Plug Cable

Notes.
PT___ shell type
-10-shell size in mm
6 NO. of contacts
P pins
S skts
(SR) Strain Relief
The above part numbers are of Aviation Elect. & Radio Co, Horsham similar Mil-C-26482 spec connectors are available from Townsend Coates Leicester, with a different prefix. Refer to catalogue.

1 REVISED
Now using PT01E-10-6S PLUG (cable type), since addition of signal condition, connected direct to throttle-pot, which is terminated with a CHASSIS type PT00E-10-6P to match.

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(.ITEMLSTS.MEC.EPACON) MEC WIRING LOOM DETAILS 12-06-86

iss	date	change description	initials
1	12-06-86	Derived from NEBCON all information not relating to the EPA/METHANOL MEC loom deleted.	MGB

NOTES:

1 12V Connected direct to injectors via relay
2 Gen. interconnection between loom and pickups by AMPHENOL type plugs and sockets to MIL-C-26482--62GB series.
3 ** All these connections are made external to plug for convenience and these pins should NOT be used.
4 ***Fuel injector outputs are routed through own bulkhead fitting this applies to some vehicle applications ie. MEC in trunk.
5 SCREENED 4 - core 7/0.2 cable to be used throughout with exception of fuel injs. where 4-core 16/0.2 is to be used.
6 Screens connected to pins as indicated through bulk-head interface (i.e.Plug engine loom, Socket b/head) only.All screens grouped at M.E.C. and remote from plug and grounded to case (N.B. Ensure case is adequately grounded.
7 The cold start/warm-up air control valve is to be supplied via the (battery) relay.(N.B. there is no connection through the 55-way.).
8 Communication link between an ADM 3/5 terminal & MEC is detailed in attached sketch.
9 Separate supply to MEC (NOT through 55-way). Gauge of cable dependant on distance between battery and MEC ; in case of VW/Jetta(MEC sited in trunk, battery in engine comp't) 50/0.2 single core was used.
10 Some facilities provided for in the loom are not implemented on the EPA/Methanol MEC and should be ignored. These are Knock, Ring gear and spare PRT inputs .

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MEC "IGNITION DRIVE" Interface with "IGNITION MODULE".

```
                 +-------------------------------+
                 | (BOSCH)                       |
                 |    Amplifier Switch Device    |
                 +-------------------------------+
                            7-WAY PLUG.
          7      6      5      4      3      2      1

                 |      |      |      |      |      |
                 |      |      |      |      |      |
                 |      V      |      |      |      |
Amphenol         |  Redundant  |      |      |      |
Plug Pin         |  Not used   |      |      |      |
Wire Code        B             |      B      |      |
                Blu            |     Red     |      |
                 |             V      |      V      V
                 |          Coil(Batt) |  Battery  -ve
                 |            +12v     |   Earth   COIL
                 |                     |
                 |                     |
                 V                     V
                 k                     j
                MEC                   MEC
Ign. Drive          Ign. Drive
                Signal                Return
```

ADM Terminal (RS232) Link To MEC

```
3 Pin-Din                                  25 Way
  Locking                                 'D'Type
  Plug                                     Plug
 Pin No                                   Pin No.

  1-----------------------------------2
  2-----------------------------------7
  3-----------------------------------3
```

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ENGINE LOOM INTERFACE FRONT PANEL ITEMS.

PLUGS

```
E.G.R. ------------------------:
CAM, CRANK, RG ----------------:
IGN   -------------------------:
M.A.P. ------------------------:
AN 1 (PRT Water) --------------:- AMPHENOL 55 WAY
AN 2 (PRT Air) ----------------:
AN 3 (spare) ------------------:
Throttle ----------------------:
t/c 1 -------------------------  sub miniature thermocouple
t/c 2 -------------------------  sub miniature thermocouple
INJECTORS ---------------------\ 5 Pin XLR31 Type (ITT CANNON)
POWER -------------------------  12 Pin multipole connector.
RS232 Port1 -------------------  3 Pin Locking Din
RS232 Port2 -------------------  3 pin Locking Din
```

NB See Appendix 1 for PLUG & Socket configuration.

SUPPLIERS:-

PLUGS:-	AMPHENOL	F.C.Lane, Horsham OR Aviation Electrical & Radio Co Ltd 12 North Parade , Horsham
	XLR31	RS
	Multipole Con'r	RS
	DIN Locking Type	Stock

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AMPHENOL 55 way connector to Engine pin asignments

55 Way Pin No.	INTERCONNECTION CABLE	6 Way Pin No	SIGNAL Lead	SIGNAL Probe
A	RED	A	Blue	Platinum Resistance
B	BLUE	B	Yellow	Thermometer No.1
C	GREEN	C	Red	WATER
D	YELLOW	D	GRN or Wht	
E	RED	A	Blue	Platinum Resistance
F	BLUE	B	Yellow	Thermometer No.2
G	GREEN	C	Red	AIR FILTER
H	YELLOW	D	GRN or Wht	
J	RED	A	Blue	S
K	BLUE	B	Yellow	P
L	GREEN	C	Red	A
M	YELLOW	D	GRN or Wht	R
				E
T	RED	A		EGR Position Sensor
U	BLUE	B		
V	GREEN	C		
W	RED	A		Throttle Position
X	BLUE	B		Sensor
Y	GREEN	C		
Z	RED	A	Red	Signal Ring Gear
a	BLUE	B	Black	0v Orbit P/U
b	RED	A	Brown	+ve Camshaft
c	BLUE	B	Blue	0v Proximity
d	YELLOW	C	Black	Signal Detector
e	Screen PRT Air			
f	RED	A		+ve 12v Crankshaft
g	BLUE	B		0v 70 deg. REF
h	GREEN	C		Signal Orbit P/U
j	RED	A	Pin 3	Signal Ignition
k	BLUE	B	Pin 6	Return Module

RICARDO
CONSULTING ENGINEERS

AMPHENOL 55 way connector to Engine pin asignments

55 Way Pin No.	INTERCONNECTION CABLE	6 Way Pin No	SIGNAL Lead	SIGNAL Probe
m	RED	C	+ve sply	Manifold Pressure
n	BLUE	A	+ve sig	Transducer
p	GREEN	B	-ve sig	
q	YELLOW	D	-ve sply	
r	Screen PRT Water			NO CONNECTION
s	" Throttle			------"------
t	RED	A		Knock Detector
u	BLUE	B		
v	Screen Cam			NO CONNECTION
w	" An3			------"------
x	" Crank			------"------
z	Screen Ignition			NO CONNECTION
AA	Screen E.G.R			NO CONNECTION
BB	" M.A.P			------"------
DD	Screen Ring P/U			NO CONNECTION
EE	" Knock			------"------

	*** INTERCONNECTION CABLE	XLR31 Plug	SIGNAL Lead	SIGNAL Probe/device
	FOUR CORE SCREENED CABLE. 4 Injector system			
	RED	1	(cyl. No.4)	Fuel Inj. 4
	BLUE	2	(cyl. No.1)	1
	GREEN	3	(cyl. No.3)	3
	YELLOW	4	(cyl. No.2)	2

AUDI 4000

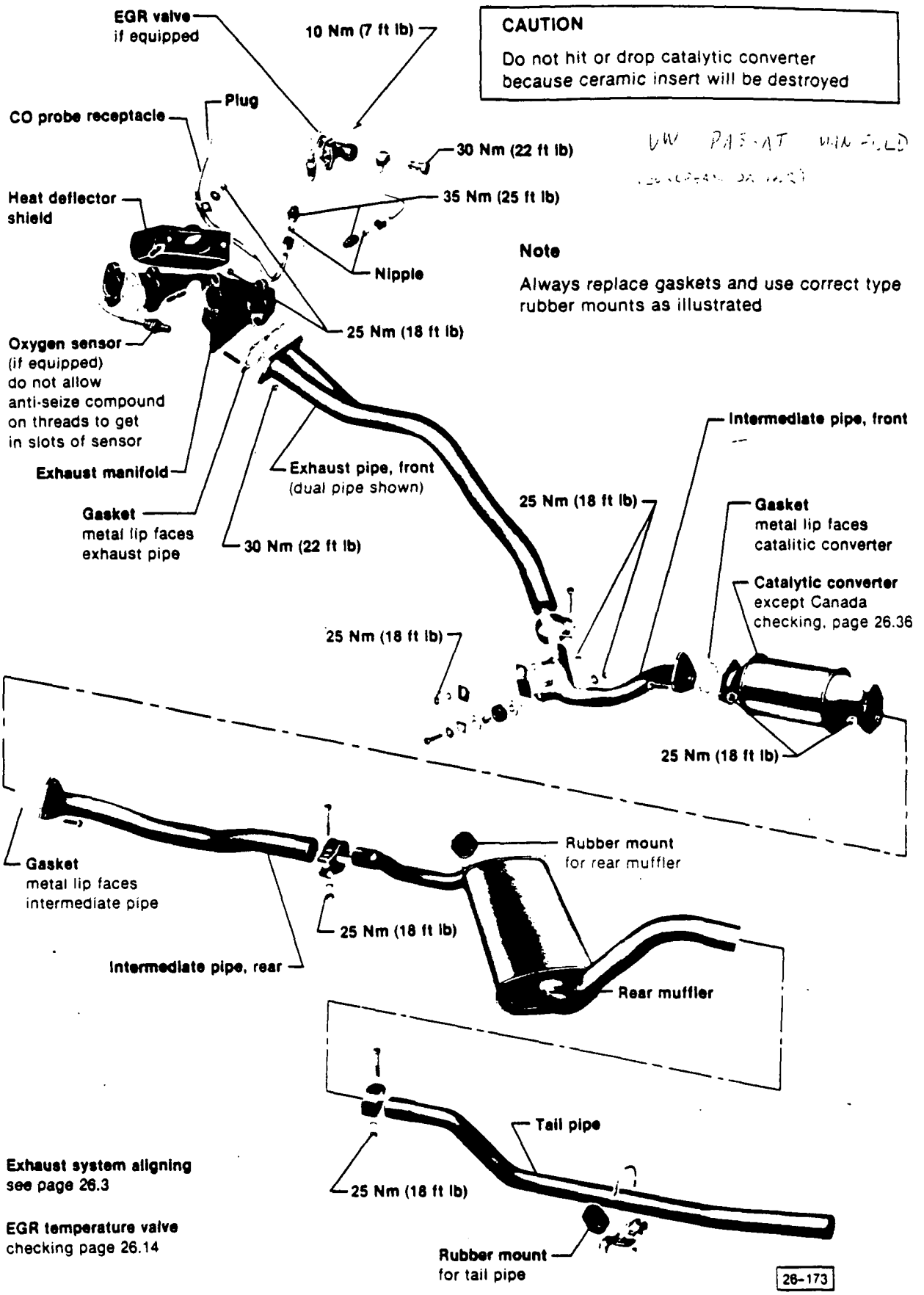
CAUTION

Do not hit or drop catalytic converter because ceramic insert will be destroyed

VW PASSAT

Note

Always replace gaskets and use correct type rubber mounts as illustrated



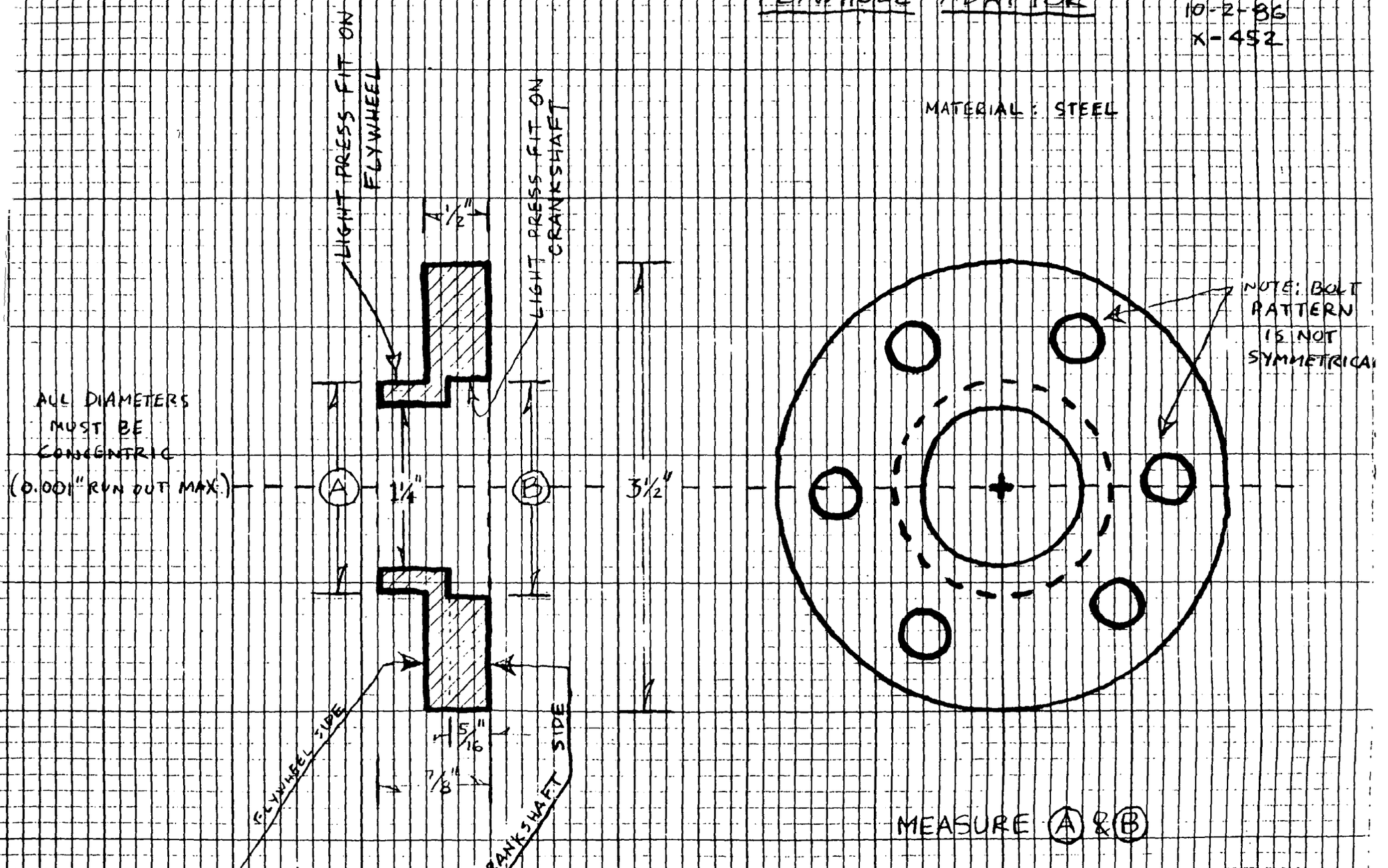
Exhaust system aligning
see page 26.3

EGR temperature valve
checking page 26.14

FLYWHEEL ADAPTOR

R. BRUETSCH
10-2-86
X-452

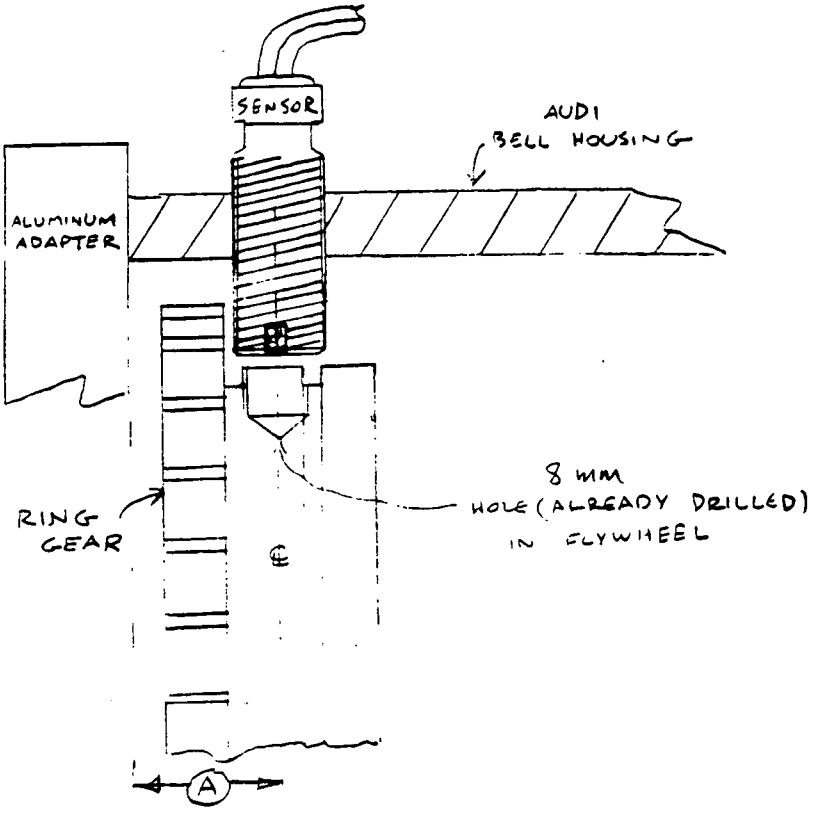
MATERIAL: STEEL

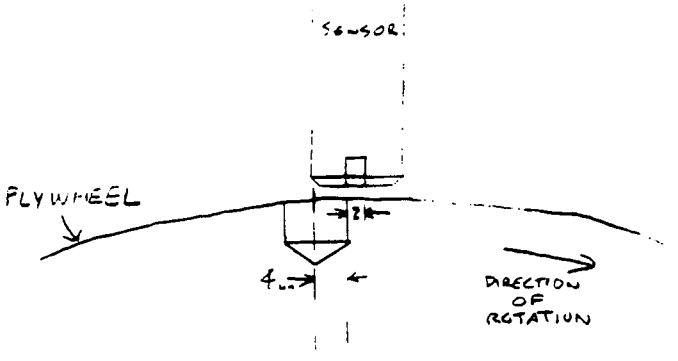


NEW FLYWHEEL BOLTS REQUIRED: GRADE 8 OR BETTER

REVISED RICARDO DRAWING

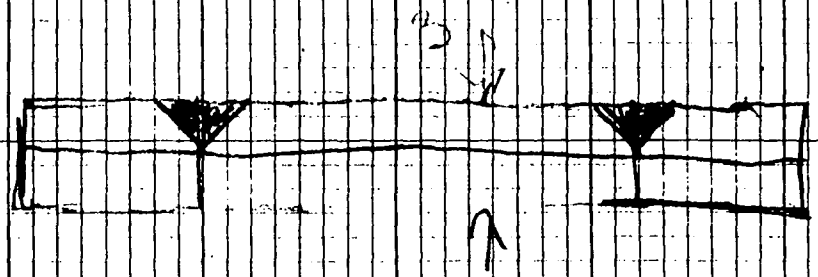
LOCATION OF ORBIT PICK-UP IN BELL-HOUSING

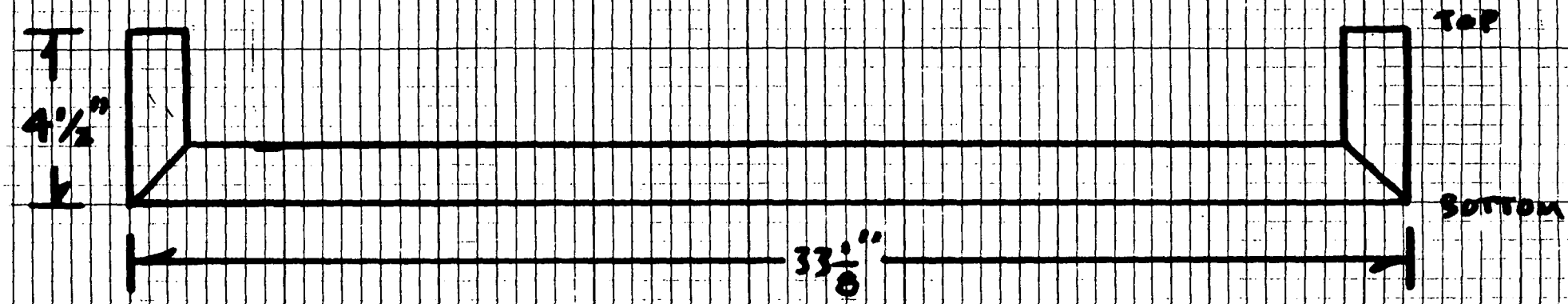




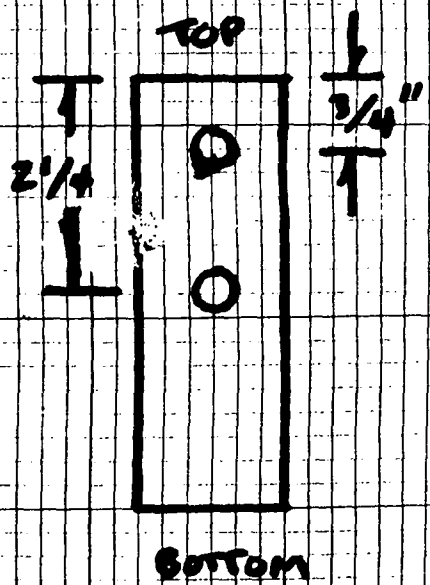
← REFERENCE EDGE
70° BTDC (F & NF)

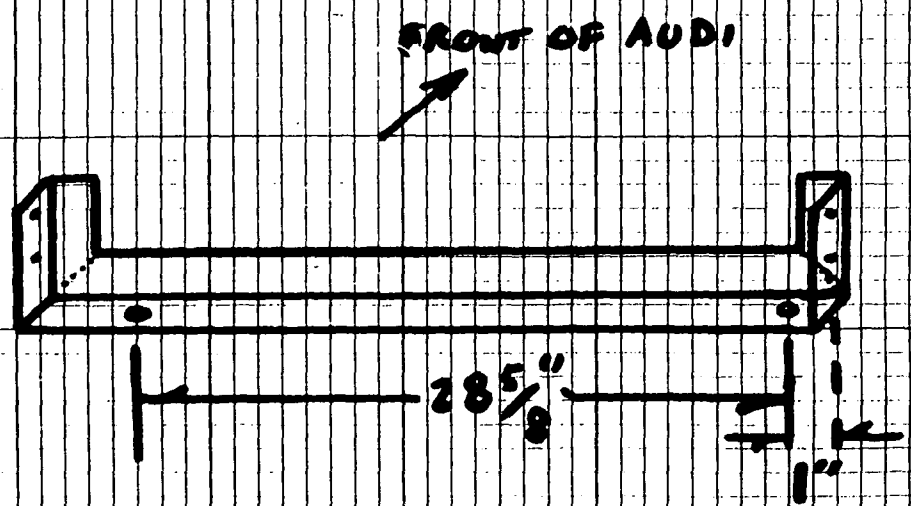
RADIATOR BRACKET





1½" × 1½" ∠ iron all holes 3/8" Ø





VW HRCC AUDI 5000
STARTING PROCEDURE

1. Flip MEC switch ON (plug in fuse at battery).

2. Power MEC by flipping switch on front of VDU.

3. Turn on ignition.

4. Press reset button on MEC (blue box).
   NOTE: Car has tendency to stall when reset button is pushed (give it a little fuel).

5. Set calibration by typing "R1" for best economy, or "R3" for low NOx (as a check, type "N" and VDU will tell you what EEPROM you are in).

6. Shift cookbook (5th gear @ 50 MPH).

7. If car stalls, stop trace and begin again at 3.

APPENDIX D

C-26

Telex/ Facsimile Message

RICARDO

To EPA ANN ARBOR

ATTENTION - ROB BRUETSCH

Telex/ Fax No. 0101 313 668 4368

from GRA HAM LEESON

Subject VW METHANOL ENGINE

Fax No. Brighton (0273) 464124

Telex No. 87383 RICSHAM G

Date 9.1.87

Page 1 of 1

IGNITION MAP TO GIVE 1ST REDUCED NOx STRATEGY I.E. 1.91 HC 19.9 CO 1.07 NOx (gm/mile).

IGNITION -°E

Mbar									
1000	5	9	13	14	15	16	17	17	18
900	13	15	17	18	19	21	21	21	21
800	18	19	20	21	21	22	23	24	24
700	20	21	21	22	23	24	25	25	25
600	21	21	21	23	24	24	25	25	25
500	21	21	21	23	24	24	25	25	26
400	21	21	21	23	24	24	25	25	26
300	21	21	21	23	24	24	25	25	26
200	21	21	21	23	24	24	25	25	26
100	0	0	0	0	0	0	0	0	0
	20	30	40	50	60	70	80	90	100

SPEED REV/SEC

Graham Leeson

If you do not receive all of the pages or the message is distorted please call 0273 455611 ext 2334 and speak to fax operator

```
**********************************************************************************
WARNING: CRITICAL CODE STORED IN VI FILE DIFFERS FROM ERRORS FOUND DURING THIS RUN.
CRITICAL CODE=0("      ") - PROGRAM FOUND "*"= 1,"**"= 0 - PLEASE "CORRECT" THIS VEHICLE.
**********************************************************************************
```

REPORT TIME: 11:17:45
DATE: OCT 6, 1987

VEHICLE SPECIFICATION REPORT - (REPORT) - DATE OF ENTRY : 1/ 7/87

VEHICLE SPECIFICATIONS

MANUFACTURER	VEHICLE ID	/ VER	REPRESENTED CARLINE	MODEL CODE	DRIVE CODE	SOURCE
AUDI	43A0131868	0		SEDAN	FRONT DRIVE STR. LEFT	EPA

VEHICLE TYPE	ACTUAL VEHICLE MODEL	MODEL YEAR	ACTIVE YEAR	DRIVE AXL WTS FULL TANK	DRIVE AXL WTS EMPTY TANK	CURB WEIGHT	INERTIA CLASS	EQUIV. TEST WEIGHT	H.P. METHOD	ETW C.D. VEH	O/D CODE	ACTUAL DYNO HP	RUNNING CHG NUMBER
NON-CER	AUDI 5000S	80	80	P	P	2625P	3000P	3250P	NO ENTRY			7.0	

ASSIGNED DF OR DURABILITY VEHICLE ID	ALT. MANUFACTURER	ODOMETER CORRECTION INITIAL	ODOMETER CORRECTION FACTOR	TIRE & RIM SIZES	TIRE - SPECIFICATIONS MFR	CONSTR	SWL N	SWL M	BLT N	BLT M	PSI FT	PSI RR	TD DP
				185/70R14									

ENGINE SPECIFICATIONS

DISPLACEMENT	BORE	STROKE	RATED HP	ENGINE TYPE	ENGINE CONFIGURATION	NO. CYL.	NO. CARBS	TOTAL BBLS	FUEL SYSTEM MFR/MODEL	FUEL INJ	TURBO/SUPER CHARGER	COOLING	COMP. RATIO	COAST DN TM
88.9E	3.13E	2.89E	79	OTTO SPARK	IN-LINE	4				YES		NONE	0.0	

IGNITION TIMING 1	IGNITION TIMING 2	TIM. TOL.	TIMING RPM	RPM TOL.	TIMING GEAR	% CO LEFT	% CO RIGHT	%CO COMB	CO TOL.	IDLE RPM	IDLE TOL.	IDLE GEAR	ENGINE FAMILY	ENGINE CODE

DRIVE TRAIN AND CONTROL SYSTEM SPECIFICATIONS

AXLE RATIO	N/V RATIO	ODOMETER	A/C INSTALLED	EXHAUST TYPE	CRANKCASE SYSTEM	TRANSMISSION CONFIG	MODIF	CODE	SHIFT INDIC. LIGHT	EVAPORATION SYSTEM	FUEL TYPE
0.0	0.0		$$$						-NO ENTRY		METHANOL

MAIN-TANK CAPACITY	MAIN-TANK VOLUME	AUX.-TANK CAPACITY	AUX.-TANK VOLUME	SHIFT SPEED	EVAPORATIVE EMISSION FAMILY	EVAPORATIVE EMISSION CODE	SALES CLASS
							NO SALES CLASS SPECIFIED

CONTROL SYSTEM TYPES

VEHICLE SPECIFICATION COMMENTS

* SEE COMMENTS

16418 0

DYNO SITE:D209 TEST # 871791 | 1980 LIGHT DUTY VEHICLE ANALYSIS | PROCESSED: 16:31:44 APR 10, 1987

a MFR.		VER-	MFR. REP.	RUN.	RETEST	ALT. H.P.	EQUIVALENT TEST	ACTUAL DYNO	TRANS.	OVER-DRIVE	/--------- TEST TYPE -------- EXPE
640	43A0131868	0		N							CVS 75-LATER

PREP DATE	CURB WEIGHT	DRV AXLE WEIGHT	GAUGE EMPTY	AXLE MEASURE	/--- IGNITION TIMING ---/ #1	#2	RPM	GEAR	/------ % CO ------/ IDLE	HIGH SPEED	IDLE RPM	GEAR	SOAK PERIOD	COASTDOWN TIME ACTUAL	ADJUSTED
04-09-87													21		0.0

/-------- AMBIENT TEST CONDITIONS ------/

BARO "HG	DEW POINT	AMB TEMP	TEMP UNIT	% REL HUM	S.HUM GR/LB	NOX FACTOR	ALDEHYDES	CVS RGE
28.93	48.0	74.0	D	39.7	51.36	0.9000		27C

/-------- DYNAMOMETER TEST CONDITIONS --------/

TEST DATE	HR	DYNO SITE	ACTUAL IW SET	DYNO TWHP	TIRE PSI	ODOMETER (MI)	SYSTEM MILES
04-10-87	12	D209	3250	5.0	45.00	75214.5	N/A

BAG 1 3.630 MILES 5.841 KM 8463. ROLL REVS. SECS. VMIX= 3256.0 CU.FT. DILUTION FACTOR = 18.572

SITE #A203	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	19	15.0	447.92	19	0.0	0.0	447.92 PPM	23.82	6.561	4.077			
NOX-CHEM	15	0.0	0.0	15	0.0	0.0	0.0 PPM	0.0	0.0	0.0	MPG	KPL	L/100KM
CO2	22	66.0	0.639	22	5.0	0.045	0.597 %	1007.37	277.531	172.450	13.0	5.55	18.0
CO	19	40.3	372.78	19	0.0	0.0	372.78 PPM	40.02	11.025	6.851			
METHANE	15	7.2	3.60	15	3.4	1.70	1.99 PPM	0.11	0.029	0.018			
HC-NM							445.92 PPM	23.71	6.532	4.059			

BAG 2 3.877 MILES 6.239 KM 9039. ROLL REVS. SECS. VMIX= 4747.0 CU.FT. DILUTION FACTOR = 25.901

SITE #A203	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	63.0	188.59	16	1.2	3.60	185.13 PPM	14.35	3.702	2.300			
NOX-CHEM	15	0.0	0.0	15	0.0	0.0	0.0 PPM	0.0	0.0	0.0	MPG	KPL	L/100KM
CO2	22	51.3	0.489	22	4.8	0.043	0.448 %	1100.59	283.893	176.403	13.6	5.80	17.2
CO	17	39.8	97.81	17	0.0	0.0	97.81 PPM	15.31	3.949	2.454			
METHANE	15	3.6	1.80	15	3.2	1.60	0.26 PPM	0.02	0.005	0.003			
HC-NM							184.87 PPM	14.33	3.696	2.297			

BAG 3 3.579 MILES 5.759 KM 8344. ROLL REVS. SECS. VMIX= 2761.0 CU.FT. DILUTION FACTOR = 19.272

SITE #A203	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	72.1	215.92	16	1.5	4.49	211.66 PPM	9.54	2.667	1.657			
NOX-CHEM	15	0.0	0.0	15	0.0	0.0	0.0 PPM	0.0	0.0	0.0	MPG	KPL	L/100KM
CO2	22	66.0	0.639	22	5.0	0.045	0.597 %	854.09	238.661	148.297	15.8	6.71	14.9
CO	19	37.2	342.76	19	0.0	0.0	342.76 PPM	31.20	8.719	5.417			
METHANE	15	5.5	2.75	15	3.4	1.70	1.14 PPM	0.05	0.014	0.009			
HC-NM							210.52 PPM	9.49	2.652	1.648			

WEIGHTED VALUES	HC	NM-HC	CO	CO2	NOX		MPG	KPL	L/100KM
GRAMS/MILE	4.013	4.000	6.72	270.	0.0	FUEL ECONOMY	14.0	6.0	16.8
BEFORE ROUNDING	4.01312	4.00040	6.7250	270.19	0.0		14.0380	5.9604	16.7773
GRAMS/KM	2.494	2.486	4.18	168.	0.0				
BEFORE ROUNDING	2.49363	2.48573	4.1787	167.89	0.0				

COMMENTS: RICARDO AUDI EE PROM 6 COLD START ONE STALL 6 FALSE STARTS BAG 1
NOX SAMPLES OVER 20 MIN. LIMIT UNABLE TO GET STABLE NOX READINGS

THE FUEL ECONOMY VALUE WAS CALCULATED USING CONSTANT FUEL PROPERTIES FROM PRE-1988 REGULATIONS.

DYNO SITE:D209 TEST # 871792 | 1980 LIGHT DUTY VEHICLE ANALYSIS | PROCESSED: 11:02:20 APR 15, 1987

a MFR.		VER-	MFR. REP.	RUN.	RETEST	ALT. H.P.	EQUIVALENT TEST	ACTUAL DYNO	TRANS.	OVER-DRIVE	/--------- TEST TYPE -------- EXPE
640	43A0131868	0	N								CVS 75-LATER

PREP DATE	CURB WEIGHT	DRV AXLE WEIGHT	GAUGE EMPTY	AXLE MEASURE	/--- IGNITION TIMING ---/ #1	#2	RPM	GEAR	/------ % CO ------/ IDLE	HIGH SPEED	IDLE RPM	GEAR	SOAK PERIOD	COASTDOWN TIME ACTUAL	ADJUSTED
													0		0.0

/-------- AMBIENT TEST CONDITIONS ------/

BARO "HG	WET BULB	AMB TEMP	TEMP UNIT	% REL HUM	S.HUM GR/LB	NOX FACTOR	ALDEHYDES	CVS RGE
29.06	59.9	74.2	F	42.9	55.60	0.9164		27C

/-------- DYNAMOMETER TEST CONDITIONS --------/

TEST DATE	HR	DYNO SITE	ACTUAL IW SET	DYNO TWHP	TIRE PSI	ODOMETER (MI)	SYSTEM MILES
04-14-87	09	D209	3250	5.0	45.00	75232.0	N/A

BAG 1 3.540 MILES 5.697 KM 8253. ROLL REVS. SECS. VMIX= 3203.0 CU.FT. DILUTION FACTOR = 18.553

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	19	15.6	465.88	19	0.0	0.0	465.88 PPM	24.37	6.884	4.278			
NOX-CHEM	15	78.1	39.23	15	1.8	0.91	38.36 PPM	6.10	1.723	1.071			
CO2	22	65.2	0.631	22	5.3	0.047	0.586 %	972.95	274.870	170.797			
CO	20	22.0	445.57	20	0.3	5.78	440.10 PPM	46.48	13.130	8.159			
METHANE	15	7.8	3.90	15	3.9	1.95	2.06 PPM	0.11	0.030	0.019			
HC-NM							463.82 PPM	24.26	6.854	4.259			

MPG	KPL	L/100KM
13.0	5.52	18.1

BAG 2 3.883 MILES 6.249 KM 9053. ROLL REVS. SECS. VMIX= 4767.0 CU.FT. DILUTION FACTOR = 26.010

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	59.7	178.69	16	1.2	3.60	175.23 PPM	13.64	3.513	2.183			
NOX-CHEM	15	41.0	20.70	15	1.1	0.56	20.17 PPM	4.77	1.229	0.764			
CO2	22	51.2	0.488	22	5.0	0.045	0.445 %	1098.44	282.899	175.786			
CO	17	39.1	96.10	17	0.0	0.0	96.10 PPM	15.10	3.890	2.417			
METHANE	15	4.0	2.00	15	3.9	1.95	0.13 PPM	0.01	0.003	0.002			
HC-NM							175.11 PPM	13.63	3.511	2.181			

MPG	KPL	L/100KM
13.7	5.83	17.1

BAG 3 3.574 MILES 5.752 KM 8334. ROLL REVS. SECS. VMIX= 2780.0 CU.FT. DILUTION FACTOR = 19.520

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	67.6	202.40	16	1.3	3.90	198.70 PPM	9.02	2.524	1.568			
NOX-CHEM	15	88.6	44.43	15	0.8	0.41	44.04 PPM	6.08	1.700	1.056			
CO2	22	65.3	0.632	22	5.1	0.046	0.589 %	848.23	237.307	147.456			
CO	19	37.0	340.83	19	0.0	0.0	340.83 PPM	31.24	8.740	5.431			
METHANE	15	5.8	2.90	15	4.0	2.00	1.00 PPM	0.05	0.013	0.008			
HC-NM							197.70 PPM	8.97	2.511	1.560			

MPG	KPL	L/100KM
15.9	6.76	14.8

WEIGHTED VALUES	HC	NM-HC	CO	CO2	NOX		MPG	KPL	L/100KM
GRAMS/MILE	3.934	3.923	7.11	269.	1.16	FUEL ECONOMY	14.1	6.0	16.7
BEFORE ROUNDING	3.93405	3.92303	7.1096	268.79	1.[illegible]589		14.0686	5.9859	16.7058
GRAMS/KM	2.445	2.438	4.42	167.	0.9[illegible]				
BEFORE ROUNDING	2.44451	2.43765	4.4177	167.02	0.90[illegible]				

COMMENTS: NOX SAMPLES RUN AT EOT EEPROM 6 COLD CRANK 7 STALLS BAG #1 IFALSE
START - 168 SEC STALL BAG #1 NOX SCALE SHIFT
CO SAMPLE #2 CORRECTED VALVE 39.1

THE FUEL ECONOMY VALUE WAS CALCULATED USING CONSTANT FUEL PROPERTIES FROM PRE-1988 REGULATIONS.

DYNO SITE:D209 TEST # 871793 | 1980 LIGHT DUTY VEHICLE ANALYSIS | PROCESSED: 15:15:47 APR 15, 1987

a MFR.	VER-	MFR. REP.	RUN.	RETEST	ALT. H.P.	EQUIVALENT TEST	ACTUAL DYNO	TRANS.	OVER-DRIVE	/--------- TEST TYPE -------- EXPE
640 43A0131868	0	N								CVS 75-LATER

PREP DATE	CURB WEIGHT	DRV AXLE WEIGHT	GAUGE EMPTY	AXLE MEASURE	/--- IGNITION TIMING ---/ #1	#2	RPM	GEAR	/------ % CO ------/ IDLE	HIGH SPEED	IDLE RPM	GEAR	SOAK PERIOD	COASTDOWN TIME ACTUAL	ADJUSTED
													0		0.0

/-------- AMBIENT TEST CONDITIONS ------/

BARO "HG	DEW POINT	AMB TEMP	TEMP UNIT	% REL HUM	S.HUM GR/LB	NOX FACTOR	ALDEHYDES	CVS RGE
28.89	44.6	74.3	D	34.6	45.16	0.8770		27C

/-------- DYNAMOMETER TEST CONDITIONS --------/

TEST DATE	HR	DYNO SITE	ACTUAL IW SET	DYNO TWHP	TIRE PSI	ODOMETER (MI)	SYSTEM MILES
04-15-87	08	D209	3250	5.0	45.00	75243.0	N/A

BAG 1 3.579 MILES 5.759 KM 8344. ROLL REVS. SECS. VMIX= 2987.0 CU.FT. DILUTION FACTOR = 17.875

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	19	13.0	388.08	19	0.2	5.96	382.46 PPM	18.65	5.213	3.239			
NOX-CHEM	15	77.8	39.08	15	5.4	2.74	36.49 PPM	5.18	1.447	0.899	MPG	KPL	L/100KM
CO2	22	68.6	0.666	22	5.2	0.046	0.623 %	963.53	269.241	167.299	13.5	5.75	17.4
CO	20	21.9	443.44	20	0.8	15.44	428.86 PPM	42.24	11.802	7.333			
METHANE	15	7.3	3.65	15	4.0	2.00	1.76 PPM	0.09	0.024	0.015			
HC-NM							380.69 PPM	18.57	5.189	3.224			

BAG 2 3.885 MILES 6.253 KM 9059. ROLL REVS. SECS. VMIX= 4751.0 CU.FT. DILUTION FACTOR = 25.945

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	60.2	180.19	16	1.4	4.19	176.15 PPM	13.67	3.517	2.186			
NOX-CHEM	15	38.6	19.50	15	4.2	2.13	17.45 PPM	3.94	1.013	0.630	MPG	KPL	L/100KM
CO2	22	51.3	0.489	22	5.2	0.046	0.444 %	1092.99	281.309	174.797	13.8	5.86	17.1
CO	19	10.9	97.28	19	0.0	0.0	97.28 PPM	15.24	3.922	2.437			
METHANE	15	4.6	2.30	15	4.2	2.10	0.28 PPM	0.02	0.006	0.003			
HC-NM							175.87 PPM	13.64	3.512	2.182			

BAG 3 3.589 MILES 5.776 KM 8368. ROLL REVS. SECS. VMIX= 2771.0 CU.FT. DILUTION FACTOR = 19.547

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	67.8	203.00	16	1.3	3.90	199.30 PPM	9.02	2.513	1.561			
NOX-CHEM	15	91.9	46.06	15	3.1	1.57	44.57 PPM	5.87	1.634	1.016	MPG	KPL	L/100KM
CO2	22	65.6	0.635	22	5.0	0.045	0.593 %	851.18	237.164	147.367	16.0	6.81	14.7
CO	19	32.7	299.60	19	0.0	0.0	299.60 PPM	27.37	7.626	4.739			
METHANE	15	6.0	3.00	15	4.4	2.20	0.91 PPM	0.04	0.012	0.007			
HC-NM							198.39 PPM	8.98	2.501	1.554			

WEIGHTED VALUES	HC	NM-HC	CO	CO2	NOX		MPG	KPL	L/100KM
GRAMS/MILE	3.592	3.581	6.56	267.	1.27	FUEL ECONOMY	14.3	6.1	16.5
BEFORE ROUNDING	3.59203	3.58100	6.5605	266.73	1.2727		14.2610	6.0596	16.5026
GRAMS/KM	2.232	2.225	4.08	166.	0.79				
BEFORE ROUNDING	2.23198	2.22513	4.0765	165.74	0.7908				

COMMENTS: NOX SAMPLED AT EOT NOX DATA BAD 1 FASE START 5 STALLS START OF TEST

THE FUEL ECONOMY VALUE WAS CALCULATED USING CONSTANT FUEL PROPERTIES FROM PRE-1988 REGULATIONS.

DYNO SITE:D209 TEST # 873925

| 1980 LIGHT DUTY VEHICLE ANALYSIS |

PROCESSED: 12:34:58 JUL 9, 1987

a MFR.	MFR. VER-	REP.	RUN.	RETEST	ALT. H.P.	EQUIVALENT TEST	ACTUAL DYNO	TRANS.	OVER-DRIVE	/--------- TEST TYPE -------- EXPE
640 43A0131868	0	N								CVS 75-LATER

PREP DATE	CURB WEIGHT	DRV AXLE WEIGHT	AXLE GAUGE EMPTY	AXLE MEASURE	/--- IGNITION TIMING ---/ #1	#2	RPM	GEAR	/------ % CO ------/ IDLE	HIGH SPEED	IDLE RPM	GEAR	SOAK PERIOD	COASTDOWN TIME ACTUAL	ADJUSTED
07-08-87													17		0.0

/-------- AMBIENT TEST CONDITIONS ------/

BARO "HG	DEW POINT	AMB TEMP	TEMP UNIT	% REL HUM	S.HUM GR/LB	NOX FACTOR	ALDEHYDES	CVS RGE
29.04	46.5	72.8	D	39.1	48.32	0.8886		27C

/-------- DYNAMOMETER TEST CONDITIONS --------/

TEST DATE	HR	DYNO SITE	ACTUAL IW SET	DYNO TWHP	TIRE PSI	ODOMETER (MI)	SYSTEM MILES
07-09-87	08	D209	3250	5.0	45.00	75472.7	N/A

BAG 1 3.576 MILES 5.755 KM 8337. ROLL REVS. SECS. VMIX= 3052.0 CU.FT. DILUTION FACTOR = 17.309

SITE #A203	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	19	15.7	468.87	19	0.7	20.85	449.22 PPM	22.39	6.261	3.891			
NOX-CHEM	15	41.1	20.75	15	6.8	3.45	17.50 PPM	2.57	0.719	0.447	MPG	KPL	L/100KM
CO2	22	68.6	0.666	22	5.0	0.045	0.624 %	987.32	276.119	171.573	12.8	5.42	18.4
CO	19	63.7	607.68	19	0.0	0.0	607.68 PPM	61.15	17.101	10.626			
METHANE	15	10.0	5.01	15	3.6	1.80	3.31 PPM	0.17	0.046	0.029			
HC-NM							445.91 PPM	22.22	6.215	3.862			

BAG 2 3.893 MILES 6.265 KM 9077. ROLL REVS. SECS. VMIX= 4798.0 CU.FT. DILUTION FACTOR = 25.164

SITE #A203	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	58.0	173.59	16	2.8	8.39	165.54 PPM	12.97	3.332	2.070			
NOX-CHEM	15	22.0	11.14	15	6.8	3.45	7.83 PPM	1.81	0.464	0.288	MPG	KPL	L/100KM
CO2	22	51.4	0.490	22	4.7	0.042	0.449 %	1117.20	286.970	178.315	13.1	5.58	17.9
CO	19	27.9	254.11	19	0.0	0.0	254.11 PPM	40.20	10.325	6.416			
METHANE	15	4.7	2.35	15	3.5	1.75	0.67 PPM	0.05	0.013	0.008			
HC-NM							164.87 PPM	12.92	3.318	2.062			

BAG 3 3.619 MILES 5.824 KM 8438. ROLL REVS. SECS. VMIX= 2802.0 CU.FT. DILUTION FACTOR = 18.525

SITE #A203	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	72.7	217.72	16	2.5	7.49	210.63 PPM	9.64	2.663	1.655			
NOX-CHEM	15	34.5	17.44	15	6.7	3.40	14.22 PPM	1.92	0.530	0.329	MPG	KPL	L/100KM
CO2	22	65.6	0.635	22	4.7	0.042	0.596 %	864.59	238.903	148.447	15.0	6.39	15.7
CO	19	69.0	663.03	19	0.0	0.0	663.03 PPM	61.25	16.925	10.517			
METHANE	15	7.3	3.65	15	3.3	1.65	2.09 PPM	0.10	0.026	0.016			
HC-NM							208.54 PPM	9.54	2.637	1.638			

WEIGHTED VALUES	HC	NM-HC	CO	CO2	NOX		MPG	KPL	L/100KM
GRAMS/MILE	3.751	3.727	13.53	272.	0.53	FUEL ECONOMY	13.5	5.7	17.4
BEFORE ROUNDING	3.75113	3.72736	13.5324	271.53	0.5346		13.4919	5.7362	17.4329
GRAMS/KM	2.331	2.316	8.41	169.	0.33				
BEFORE ROUNDING	2.33084	2.31607	8.4086	168.72	0.3322				

COMMENTS: AUDI STRAIGHT PIPE NOX SAMPLED CAST 5 STALLS 1 FALSE START BAG 1
FTP W/AIR FUEL RATIO METER PROM #5 NOX VALUES QUESTIONABLE-VOID

THE FUEL ECONOMY VALUE WAS CALCULATED USING CONSTANT FUEL PROPERTIES FROM PRE-1988 REGULATIONS.

DYNO SITE:D209 TEST # 875035

1980 LIGHT DUTY VEHICLE ANALYSIS

PROCESSED: 12:32:47 AUG 28, 1987

MFR.	VER	MFR. REP.	RUN.	RETEST	ALT. H.P.	EQUIVALENT TEST	ACTUAL DYNO	TRANS.	OVER-DRIVE	TEST TYPE
040 43A0131868	0	N								EXPE CVS 75-LATER

PREP DATE	CURB WEIGHT	DRV AXLE WEIGHT	GAUGE	AXLE MEASURE	IGNITION TIMING #1	#2	RPM	GEAR	% CO IDLE	HIGH SPEED	IDLE RPM	GEAR	SOAK PERIOD	COASTDOWN TIME ACTUAL	ADJUSTED
08 26-87			EMPTY										24		0.0

AMBIENT TEST CONDITIONS

BARO "HG	DEW POINT	AMB TEMP	UNIT	% REL HUM	S.HUM GR/LB	NOX FACTOR	ALDEHYDES	CVS RGE
29.08	47.9	73.5	D	40.3	50.90	0.8983		27C

DYNAMOMETER TEST CONDITIONS

TEST DATE	HR	DYNO SITE	ACTUAL IW SET	DYNO TWHP	TIRE PSI	ODOMETER (MI)	SYSTEM MILES
08-27-87	15	D209	3250	5.0	45.00	75556.2	N/A

BAG 1 3.609 MILES 5.808 KM 8415. ROLL REVS. SECS. VMIX= 2889.0 CU.FT. DILUTION FACTOR = 16.346

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC FID	19	16.1	480.84	19	0.2	5.96	475.25 PPM	22.42	6.212	3.860			
NOX CHEM	15	35.9	17.92	15	0.7	0.35	17.59 PPM	2.47	0.685	0.426	MPG	KPL	L/100KM
CO2	22	72.0	0.708	22	4.8	0.045	0.666 %	996.49	276.102	171.562	12.8	5.43	18.4
CO	19	66.8	639.95	19	0.0	0.0	639.95 PPM	60.96	16.889	10.494			
METHANE	15	9.9	4.96	15	3.8	1.90	3.17 PPM	0.15	0.041	0.026			
HC-NM							472.08 PPM	22.27	6.171	3.834			

BAG 2 3.936 MILES 6.334 KM 9177. ROLL REVS. SECS. VMIX= 4779.0 CU.FT. DILUTION FACTOR = 24.444

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC FID	16	61.5	184.09	16	1.9	5.69	178.63 PPM	13.94	3.542	2.201			
NOX-CHEM	15	10.8	5.39	15	1.5	0.75	4.67 PPM	1.09	0.276	0.171	MPG	KPL	L/100KM
CO2	22	51.8	0.501	22	4.9	0.046	0.458 %	1132.80	287.807	178.835	13.0	5.52	18.1
CO	19	31.2	285.32	19	0.0	0.0	285.32 PPM	44.96	11.422	7.097			
METHANE	15	5.1	2.55	15	3.7	1.85	0.78 PPM	0.06	0.015	0.010			
HC-NM							177.85 PPM	13.88	3.526	2.191			

BAG 3 3.641 MILES 5.859 KM 8489. ROLL REVS. SECS. VMIX= 2782.0 CU.FT. DILUTION FACTOR = 18.563

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	76.5	229.15	16	2.0	5.99	223.48 PPM	10.15	2.789	1.733			
NOX-CHEM	15	25.0	12.47	15	1.3	0.65	11.86 PPM	1.60	0.441	0.274	MPG	KPL	L/100KM
CO2	22	65.0	0.635	22	4.7	0.044	0.594 %	856.32	235.195	146.143	15.3	6.50	15.4
CO	19	66.3	634.73	19	0.0	0.0	634.73 PPM	58.22	15.990	9.936			
METHANE	15	7.7	3.85	15	3.8	1.90	2.06 PPM	0.09	0.026	0.016			
HC-NM							221.43 PPM	10.06	2.763	1.717			

WEIGHTED VALUES	HC	NM-HC	CO	CO2	NOX		MPG	KPL	L/100KM
GRAMS/MILE	3.885	3.861	13.80	271.	0.41	FUEL ECONOMY	13.5	5.8	17.4
BEFORE ROUNDING	3.88473	3.86117	13.7977	270.98	0.4051		13.4986	5.7509	17.3883
GRAMS/KM	2.414	2.399	8.57	168.	0.25				
BEFORE ROUNDING	2.41386	2.39922	8.5735	168.38	0.2517				

COMMENTS: AUDI FROM 5 #1

THE FUEL ECONOMY VALUE WAS CALCULATED USING CONSTANT FUEL PROPERTIES FROM PRE-1988 REGULATIONS.

DYNO SITE:D209 TEST # 875036

1980 LIGHT DUTY VEHICLE ANALYSIS

PROCESSED: 12:32:40 AUG 28, 1987

MFR.		VER-	MFR. REP.	RUN.	RETEST	ALT. H.P.	EQUIVALENT TEST	ACTUAL DYNO	TRANS.	OVER-DRIVE	TEST TYPE
640	43A0131868	0		N							EXPE CVS 75-LATER

PREP DATE	CURB WEIGHT	DRV AXLE WEIGHT	GAUGE	AXLE MEASURE	IGNITION TIMING #1	#2	RPM	GEAR	% CO IDLE	HIGH SPEED	IDLE RPM	GEAR	SOAK PERIOD	COASTDOWN TIME ACTUAL	ADJUSTED
08-27-87			EMPTY										16		0.0

AMBIENT TEST CONDITIONS

BARO "HG	DEW POINT	AMB TEMP	% REL HUM	S.HUM GR/LB	NOX FACTOR	ALDEHYDES	CVS RGE
29.10	46.9	73.0 D	39.4	48.96	0.8910		27C

DYNAMOMETER TEST CONDITIONS

TEST DATE	DR	DYNO SITE	ACTUAL IW SET	DYNO TWHP	TIRE PSI	ODOMETER (MI)	SYSTEM MILES
08 28 87	08	D209	3250	5.0	45.00	75570.9	N/A

BAG 1 3.559 MILES 5.728 KM 8298. ROLL REVS. SECS. VMIX= 2942.0 CU.FT. DILUTION FACTOR = 16.845

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	19	16.7	498.80	19	0.3	8.94	490.40 PPM	23.56	6.620	4.113			
NOX-CHEM	15	37.0	18.47	15	7.8	3.89	14.81 PPM	2.10	0.591	0.367	MPG	KPL	L/100KM
CO2	22	69.0	0.677	22	4.9	0.046	0.634 %	966.01	271.431	168.659	12.8	5.44	18.4
CO	19	71.5	689.43	19	0.0	0.0	689.43 PPM	66.87	18.790	11.676			
METHANE	15	10.8	5.41	15	3.9	1.95	3.57 PPM	0.17	0.048	0.030			
HC-NM							486.83 PPM	23.39	6.572	4.083			

BAG 2 3.894 MILES 6.267 KM 9079. ROLL REVS. SECS. VMIX= 4833.0 CU.FT. DILUTION FACTOR = 24.852

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	65.6	196.39	16	1.7	5.09	191.50 PPM	15.11	3.881	2.412			
NOX-CHEM	15	10.0	4.99	15	0.4	0.20	4.80 PPM	1.12	0.287	0.178	MPG	KPL	L/100KM
CO2	22	50.3	0.486	22	4.7	0.044	0.444 %	1112.22	285.629	177.482	12.9	5.48	18.2
CO	19	36.3	334.08	19	0.0	0.0	334.08 PPM	53.23	13.671	8.495			
METHANE	15	5.6	2.80	15	3.8	1.90	0.98 PPM	0.08	0.020	0.012			
HC-NM							190.52 PPM	15.04	3.862	2.399			

BAG 3 3.597 MILES 5.789 KM 8387. ROLL REVS. SECS. VMIX= 2806.0 CU.FT. DILUTION FACTOR = 18.395

SITE #A203

	EXHAUST SAMPLE RANGE	METER	CONC.	BACKGROUND SAMPLE RANGE	METER	CONC.	CORRECTED CONCENTRATIONS	MASS EMISSIONS GMS.	GMS/MI	GMS/KM	AUX. FIELD1	AUX. FIELD2	AUX. CODE
HC-FID	16	80.2	240.29	16	1.3	3.90	236.61 PPM	10.84	3.014	1.873			
NOX-CHEM	15	23.8	11.87	15	0.0	0.0	11.87 PPM	1.61	0.447	0.278	MPG	KPL	L/100KM
CO2	22	64.3	0.628	22	4.8	0.045	0.586 %	852.01	236.858	147.177	14.9	6.32	15.8
CO	19	78.2	761.11	19	0.0	0.0	761.11 PPM	70.41	19.575	12.163			
METHANE	15	8.1	4.06	15	3.9	1.95	2.21 PPM	0.10	0.028	0.017			
HC-NM							234.40 PPM	10.74	2.986	1.855			

WEIGHTED VALUES	HC	NM-HC	CO	CO2	NOX		MPG	KPL	L/100KM
GRAMS/MILE	4.206	4.178	16.34	269.	0.39	FUEL ECONOMY	13.4	5.7	17.6
BEFORE ROUNDING	4.20629	4.17837	16.3380	269.36	0.3932		13.3667	5.6873	17.5829
GRAMS/KM	2.614	2.596	10.15	167.	0.24				
BEFORE ROUNDING	2.61367	2.59632	10.1520	167.37	0.2443				

COMMENTS: AUDI PROM 5 #2 4 STALLS BAG 1 START

THE FUEL ECONOMY VALUE WAS CALCULATED USING CONSTANT FUEL PROPERTIES FROM PRE-1988 REGULATIONS.

1-2

D-8

TEST #'s 87-1292

FORMALDEHYDE WORKSHEET

DATE: 4-14-87

	Units		BAG 1	BAG 2	BAG 3	~~HFET~~
CH_2O	mg/mi	Primary	450.8	545.87	300.23	
		Secondary	20.11	28.15	16.41	
		TOTAL	470.91	574.02	316.64	
CH_2O	mg	Primary	1595.4	2119.1	1073.	
		Secondary	71.17	109.3	58.65	
		TOTAL	1666.57	2228.4	1131.65	
Distance	mi		3.54	3.88 ~~27~~	3.57	
			(0.5)	(1.0)	(0.5)	
		wt. mi.	1.77	3.88	1.78	= 7.43
TOTAL CH_2O	mg		1666.57	2228.4	1131.65	
			(0.43)	(1.00)	(0.57)	
		wt. CH_2O	716.625	2228.4	645.040	= 3590.06
Wt. Emissions =		wt. CH_2O / wt. mi				= 483.18

ANALYSIS TEST DATE: 4-14-87

VEHICLE: Audi

VEHICLE CONFIG.: Prom #6

D-9

TEST #'s 87-1793

FORMALDEHYDE WORKSHEET

DATE: 4-15-87

	Units		BAG 1	BAG 2	BAG 3	~~HPET~~
CH_2O	mg/mi	Primary	323.99	430.44	293.12	
		Secondary	16.26	13.88	15.21	
		TOTAL	340.25	444.32	308.33	
CH_2O	mg	Primary	1338.1	1672.1	1051.8	
		Secondary	58.19	53.93	54.59	
		TOTAL	1396.29	1736.03	1106.39	
Distance	mi		3.58	3.88	3.59	
			(0.5)	(1.0)	(0.5)	
		wt. mi.	1.79	3.88	1.79	= 7.46
TOTAL CH_2O	mg		1396.29	1736.03	1106.39	
			(0.43)	(1.00)	(0.57)	
		wt. CH_2O	600.405	1736.03	630.642	= 2967.08
Wt. Emissions =		wt. CH_2O / wt. mi				= 397.73

ANALYSIS TEST DATE: 4-15-87

VEHICLE: Audi

VEHICLE CONFIG.: Prom #6

D-10

Questionable data

FORMALDEHYDE WORKSHEET

TEST #'s 87-3925

DATE: 7-10-87

	Units		BAG 1	BAG 2	BAG 3	HFET
CH_2O	mg/mi	Primary	530.63	454.21	11.76	
		Secondary	0		0	
		TOTAL	530.63	454.21	11.76	
CH_2O	mg	Primary	1897	1768	42.57	
		Secondary	0	0	0	
		TOTAL	1897	1768	42.57	
Distance	mi		3.575	3.892	3.618	
			(0.5)	(1.0)	(0.5)	
		wt. mi.	1.79	3.892	1.81	= 7.49
TOTAL CH_2O	mg		1897	1768	42.57	
			(0.43)	(1.00)	(0.57)	
		wt. CH_2O	815.71	1768	24.26	= 2607.97
Wt. Emissions =		wt. CH_2O / wt. mi				= 348.19

ANALYSIS TEST DATE: 7-10-87

VEHICLE: Audi

VEHICLE CONFIG.: w/ A/F ratio meter
Straight pipe

D-11

TEST #'s 87-5035

FORMALDEHYDE WORKSHEET

DATE: 8-27-87

	Units		BAG 1	BAG 2	BAG 3	HFET
H_2O	mg/mi	Primary	444.92	404.71	258.26	
		Secondary	22.52	22.47	21.28	
		TOTAL	467.44	427.18	279.54	
H_2O	mg	Primary	1605.50	1592.60	940.12	
		Secondary	81.27	88.43	77.46	
		TOTAL	1686.77	1681.03	1017.58	
Distance	mi		3.61	3.93	3.64	
			(0.5)	(1.0)	(0.5)	
		wt. mi.	=1.80	3.93	1.82	=7.55
TOTAL CH_2O	mg		1686.77	1681.03	1017.58	
			(0.43)	(1.00)	(0.57)	
		wt. CH_2O	725.31	1681.03	580.02	=2986.36
Gr. Emissions =		wt. CH_2O / wt. mi				=395.54
PPM			15.737	9.4368	9.5694	
			.797	.5240	.7885	
		TOTALS:	16.534	9.9608	10.3579	

ANALYSIS TEST DATE: ~~8-30-87~~ 9-3-87

VEHICLE: Audi

VEHICLE CONFIG.: #1 Prom #5 RN-2TAU

D-12

TEST #'s 87-5036

DATE:

FORMALDEHYDE WORKSHEET

	Units		BAG 1	BAG 2	BAG 3	HEET
	mg/mi	Primary	290.84	451.41	307.84	
		Secondary	23.74	0	0	
		TOTAL	414.58	451.41	307.84	
H_2O	mg	Primary	1390.7	1757.4	1107.1	
		Secondary	84.46	0	0	
		TOTAL	1475.16	1757.4	1107.1	
istance	mi		3.56	3.89	3.60	
			(0.5)	(1.0)	(0.5)	
		wt. mi.	1.78	3.89	1.80	= 7.47
TAL CH_2O	mg		1475.16	1757.4	1107.1	
			(0.43)	(1.00)	(0.57)	
		wt. CH_2O	634.32	1757.4	631.05	= 3022.77
. Emissions =		wt. CH_2O / wt. mi				= 404.65
PPM			13.386	10.297	11.173	
			.813	0	0	
		TOTALS:	14.199	10.297	11.173	

ANALYSIS TEST DATE: 9-9-87

VEHICLE: Audi

VEHICLE CONFIG.: #2 Prom 5
RN-ZTAD

COMPOSITE TEST RESULTS FROM 2658Z-MXX

TEST NUMBER	BAGS	% OF. METH	MILES	<---CURRENT TEST RESULTS ---> H C	C O	CO2	NOX	<--- H C	PROPOSED TEST CALCULATIONS (GRAMS/MILE) ---> C O	CO2	NOX	OMHCE	CH3OH	HCHO	METH-ANOL M P G	FACTOR	GAS EQUIV M P G
871791	3	100.	11.086	4.013	6.725	270.18	0.0	0.472	6.725	270.25	0.0	5.194	10.903	0.00001	13.83	2.0105	27.81
871792	3	100.	10.997	3.934	7.109	268.79	1.459	0.463	7.110	268.93	1.459	5.091	10.689	0.00001	13.88	2.0105	27.91
871793	3	100.	11.053	3.592	6.561	266.75	1.273	0.423	6.562	267.10	1.274	4.649	9.761	0.00001	14.08	2.0105	28.30
873925	3	100.	11.088	3.751	13.532	271.54	0.535	0.441	13.532	271.69	0.536	4.856	10.195	0.0	13.34	2.0105	26.81
875035	3	100.	11.186	3.885	13.798	270.99	0.405	0.457	13.798	270.89	0.405	5.028	10.556	0.0	13.33	2.0105	26.80
875036	3	100.	11.050	4.206	16.338	269.36	0.393	0.495	16.338	269.34	0.394	5.444	11.430	0.0	13.17	2.0105	26.48

BAG BY BAG TEST RESULTS FROM 2658Z-MXX

TEST NUMBER	B A G	% OF. METH	MILES	<---CURRENT TEST RESULTS ---> H C	C O	CO2	NOX	<--- PROPOSED TEST CALCULATIONS (GRAMS/BAG) ---> H C	C O	CO2	NOX	OMHCE	CH3OH	HCHO
871791	BAG=1	100.	3.630	23.816	40.018	1007.37	0.0	2.802	40.018	1006.85	0.0	30.82164.702		0.00004
871791	BAG=2	100.	3.877	14.351	15.308	1100.59	0.0	1.689	15.308	1101.68	0.0	18.57438.993		0.00004
871791	BAG=3	100.	3.579	9.543	31.201	854.09	0.0	1.123	31.201	853.60	0.0	12.35225.931		0.00003
871792	BAG=1	100.	3.540	24.368	46.476	972.95	6.098	2.867	46.482	974.09	6.10031.53566.201			0.00004
871792	BAG=2	100.	3.883	13.641	15.103	1098.44	4.772	1.605	15.103	1099.11	4.77217.65537.064			0.00004
871792	BAG=3	100.	3.574	9.020	31.239	848.23	6.077	1.061	31.239	847.99	6.07811.67624.510			0.00003
871793	BAG=1	100.	3.579	18.655	42.235	963.53	5.177	2.195	42.250	964.17	5.18124.14650.690			0.00004
871793	BAG=2	100.	3.885	13.667	15.239	1092.99	3.938	1.608	15.239	1095.55	3.94117.68937.135			0.00004
871793	BAG=3	100.	3.589	9.018	27.371	851.18	5.866	1.061	27.371	850.89	5.86811.67324.505			0.00003
873925	BAG=1	100.	3.576	22.389	61.147	987.32	2.571	2.635	61.148	986.79	2.57628.98760.853			0.0
873925	BAG=2	100.	3.893	12.970	40.198	1117.20	1.807	1.526	40.197	1118.51	1.81316.79035.248			0.0
873925	BAG=3	100.	3.619	9.638	61.252	864.59	1.918	1.134	61.252	864.71	1.92212.47726.192			0.0
875035	BAG=1	100.	3.609	22.421	60.956	996.49	2.472	2.638	60.956	997.23	2.47329.01960.921			0.0
875035	BAG=2	100.	3.936	13.940	44.957	1132.80	1.085	1.640	44.956	1132.02	1.08618.04437.881			0.0
875035	BAG=3	100.	3.641	10.153	58.219	856.32	1.605	1.195	58.219	855.83	1.60613.14227.589			0.0
875036	BAG=1	100.	3.559	23.560	66.873	966.01	2.103	2.772	66.873	966.71	2.10930.49664.020			0.0
875036	BAG=2	100.	3.894	15.114	53.234	1112.22	1.118	1.778	53.234	1111.94	1.11919.56341.068			0.0
875036	BAG=3	100.	3.597	10.842	70.413	852.01	1.608	1.276	70.413	851.71	1.60814.03329.459			0.0

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APPENDIX D

HRCC-Audi Cold FTP Bag Data

Test No. Bag 1	871791 GMS	871792 GMS	871793 GMS	Average GMS	Error Range GMS	Percent Error
HC-FID	23.82	24.37	18.65	22.28	±2.86	12.8
NOx-Chem	--	6.10	5.18	5.64	±0.46	8.2
CO_2	1007.37	972.95	963.53	981.28	±21.92	2.2
CO	40.02	46.48	42.24	42.91	±3.23	7.5
Methane	0.11	0.11	0.09	0.10	±0.01	9.7
HC-NM	23.71	24.26	18.57	22.18	±2.84	12.8
Bag 2	**GMS**	**GMS**	**GMS**	**GMS**	**GMS**	**Error**
HC-FID	14.35	13.64	13.67	13.89	±0.36	2.6
NOx-Chem	--	4.77	3.94	4.36	±0.42	9.5
CO_2	1100.59	1098.44	1092.49	1097.34	±3.80	0.3
CO	15.31	15.10	15.24	15.22	±0.10	0.7
Methane	0.02	0.01	0.02	0.02	±0.0005	25.0
HC-NM	14.33	13.63	13.64	13.87	±0.35	2.5
Bag 3	**GMS**	**GMS**	**GMS**	**GMS**	**GMS**	**Error**
HC-FID	9.54	9.02	9.02	9.19	±0.26	2.8
NOx-Chem	--	6.08	5.87	5.98	±0.10	1.8
CO_2	854.09	848.23	851.18	851.16	±2.93	0.3
CO	31.20	31.24	27.37	29.94	±1.94	6.5
Methane	0.05	0.05	0.04	0.05	±0.0005	10.0
HC-NM	9.49	8.97	8.98	9.15	±0.26	2.8

HRCC-Audi Weighted Emissions/Fuel Economy

Test No.	871791	871792	871793	Average	Error Range	Percent
HC-FID	4.013	3.934	3.592	3.846	±0.21	5.5
NOx-Chem	4.000	3.923	3.581	3.835	±0.21	5.5
CO_2	270.	269.	267.	269.	±1.5	0.6
CO	6.72	7.11	6.56	6.80	±0.275	4.0
NOx	--	1.46	1.27	1.36	±0.095	7.0
MPG	14.038	14.069	14.261	14.123	±0.112	0.8

APPENDIX D (cont'd)

EPA Measured Audi/HRCC Performance Data

0-50 MPH Tests	
1.	12.22 seconds
2.	12.26
3.	13.07
4.	13.11
5.	12.94
6.	13.31
7.	13.11
8.	13.15
9.	13.19
10.	13.24
11.	13.47
12.	12.64
13.	13.74
14.	13.05
15.	12.82
Avg.	13.02
S.D.	.78

30-50 MPH Tests	
1.	7.16 seconds
2.	7.43
3.	7.09
4.	7.32
5.	7.08
6.	6.90
7.	7.02
8.	6.93
9.	7.25
10.	6.96
11.	7.24
12.	7.06
Avg.	7.12
S.D.	.43