ERDC Project No. 2511

Intensive Field Trial of Ethanol/Petrol Blend in Vehicles

Volume 2
Appendices A-I

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APPENDIX A:COLD DRIVABILITY

Test Fuel Preparation

The petrol for the cold drivability was sourced from a large turnover Mobil Service Station at Auburn NSW.

The containers for the neat test fuel were filled directly from bowser. At the same time the containers for the E10 test fuel were firstly each charged to 10% of their nominal volume with anhydrous ethanol and then immediately topped up to their nominal capacity with neat petrol from the same bowser. Care was taken to ensure that the anhydrous ethanol comprised 10% v/v of the total. Two containers, one of 20 ℓ capacity and one of 10 ℓ were prepared for each test and fuel. Three sets of containers were also prepared as spares.

At the time of filling, a sample of both the Leaded and Unleaded petrol was taken directly from the bowser. Samples from two E10 containers were also taken. Fuel remaining in the two sampled E10 containers was not used for testing but was retained for reference, if required, on conclusion of the trial. The results of the fuel analysis are shown in Figure A-1.

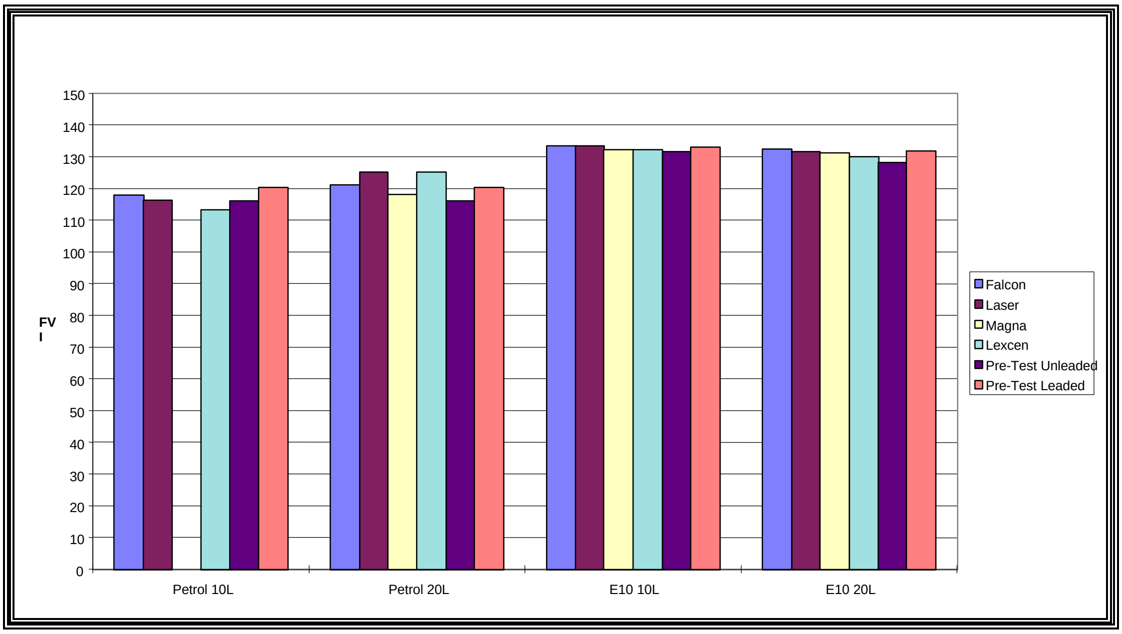


FIGURE A-1: FVI ANALYSIS OF COLD WEATHER TEST FUEL

All containers of test fuels were stored under refrigerated conditions (approximately 8°C) at NSW EPA's facility, Lidcombe, NSW, until they were needed for testing. The 10 ℓ containers were kept at EPA until required by NRMA for filling the test vehicle.

All 20 ℓ containers were transferred to the Londonderry test site 48 hours before the start of the first test and stored in the refrigerated container at -4.5°C.

Vehicle Preparation

The protocol applied in preparing each of the test vehicles for the cold-start and cold drivability was as follows:

- ♦ Mechanical Service

  The vehicle is serviced immediately prior to each test. The first is a full service, except that pre-existing engine tune is not altered, with the test vehicle fuelled on neat petrol. The second service is simply a verification of the vehicle condition, but after the fuel tank has been drained before charging with E10.

  Details of the respective services are as follows:

  ~ First Test Service

  - Drain the engine and refill with 15w40 grade oil;
  - Drain the radiator and refill with anti-freeze solution;
  - Top up transmission oil level;
  - Record the state of engine tune, but make no adjustment;
  - Check battery condition, both voltage at engine stop and specific gravity of electrolyte;
  - Check operation of choke;
  - Fit a vacuum gauge and, if required, a tachometer;
  - Drain the vehicle's fuel tank completely;
  - Charge tank with 10 litres of neat petrol test fuel, after sampling assigned container; and
  - Measure CO% at both idle and fast idle.

  ~ Second Test Service

  - Record the state of the engine's tune, but no adjustment;
  - Check battery condition, both voltage at engine stop and specific gravity of electrolyte;
  - Drain the vehicle's fuel tank;
  - Charge tank with 10 litres E10 of test fuel, after sampling the assigned container; and
  - Measure CO% at both idle and fast idle.

Temperature Preconditioning

After each service, the vehicle was driven to the Londonderry test site on the 10 litres of test fuel. This drive of approximately 50 Km formed part of the SAE protocol for the cold weather test, by stabilising the engine's coolant temperature before cold temperature soak.

On arrival at the test site, the test vehicle was placed into the coldroom, already at the pre-set temperature of -4.25 °C for a one-hour cold soak. The test vehicle was then removed from the coldroom ready to be filled with the test fuel. Immediately prior to filling the vehicle, two 1 litre fuel samples were taken for later analysis. The vehicle was then filled with the remaining 18 ℓ of the test fuel, being neat petrol for the first test, and driven over a distance of approximately 7-km.

A thermocouple was attached to the cylinder block and the battery voltage recorded. The vehicle was then placed back in the coldroom and cold soaked for a minimum of 12 hours at a return air temperature of -4.25°C.

After a minimum of 12 hours the block temperature was measured and, providing it was less than minus1°C, the soaked test vehicle was removed from the cold room. The battery voltage was then noted together with the ambient weather conditions.

Due to the relatively high absolute humidity (Figure A-2), substantial ice formation occurred on all parts of the vehicle. This was removed from window and rear view mirror areas using de-icing fluid. Unfortunately, in some instances, condensation/ice also formed inside instruments such as speedometers, making them difficult to read.

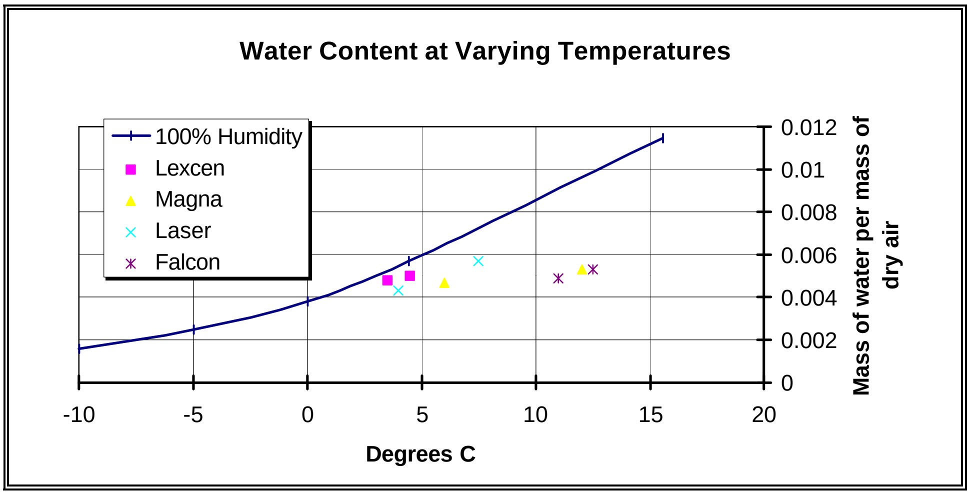


FIGURE A-2: ABSOLUTE HUMIDITY

The vehicle was then towed 0.4 Km to the test road, over which route the cold start and cold drivability tests were then immediately commenced and carried out as per the protocol described in section 6.4.2.1.

Immediately following the first drivability test on neat petrol the test vehicle was returned to NRMA for the second service. Following that second service the same procedure as followed the first was carried out, i.e. the 50 km stabilising drive, soak, 20 litres of test fuel, cold soak > 12 hours, and cold startability and drivability.

Performance Evaluation

The test protocol adopted for evaluating Cold-Start Drivability was based on Cold-Start Drivability procedures from SAE, Co-ordinating Research Council (CRC), and Federal Chamber of Automotive Industries (FCAI).

Cold Startability

Evaluating cold startability involved assessing the start time of the test vehicle following the 12-hour cold soak. The practice used for starting each engine was taken from the cold start procedure recommended by the vehicle's operating manual. The total cranking time was recorded then, 5 seconds after starting, idle rpm and idle vacuum were also recorded. The Cold Drivability was then commenced.

Cold Drivability

The main symptoms of vehicle drivability problems are characterised in SAE J1312 Jan 93 as in Table A-1. Throughout each test cycle, a vehicle's drivability phenomena are graded as described in Table A-2.

TABLE APPENDIX A:-1: DRIVABILITY PHENOMENA

Startability	- the ease of engine starting;
Idle stability	- the degree of smoothness of the engine in engine idling condition
Stalling	- engine failure to continue running;
Stumble	- a short, sharp reduction in acceleration;
Hesitation	- temporary delay in response to the throttle being opened; and,
Surging	- is a fluctuation of engine power output while under steady load.

TABLE APPENDIX A:-2: DRIVABILITY GRADING

5	Excellent	No problem, Insensible
4	Good	Problem hardly sensed
3	Average	Not without problem
2	Poor	Problem distinctly sensed
1	Extremely poor	Uncomfortable

The cold drivability cycle, carried out over a distance of 1 kilometre, involved accelerating and decelerating within a speed range of 0-60 Km/hr. Over this period the vehicle's performance was noted and at the end of the cycle it was brought to a standstill and idled. For each test, the drivability cycle is carried out four times.

Figure A-3 shows the drivability cycle for the test vehicles. It should be noted that, due to differences in acceleration, distances travelled for each part of the cycle will vary.

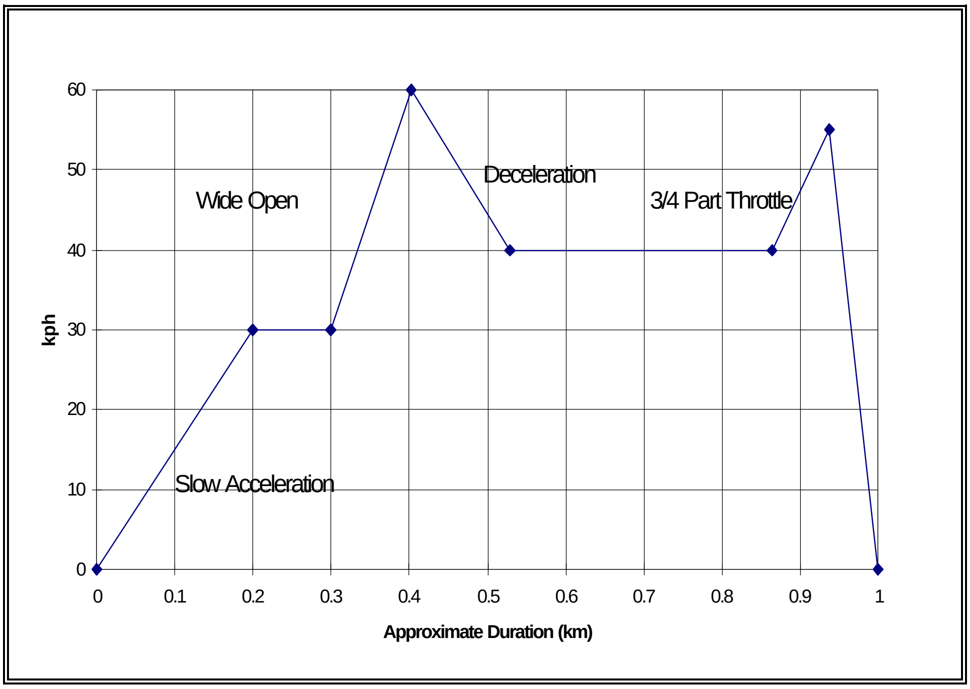


FIGURE A-3: COLD DRIVABILITY TEST CYCLE

Throughout each cycle, a vehicle's drivability is graded as described in Table A-2. Of the four cycles comprising a test each has an additional weighting factor applied to its grade as follows:

- First cycle 9
- Second cycle 5
- Third cycle 2
- Fourth cycle 1

These declining weights compensate for the vehicles operating temperatures increasing throughout the test. After the relevant weighting factor has been applied to the grading of each phenomenon, they are totalled for the four drivability cycles. The total then constitutes the test result for a particular fuel.

Data Sheets

Depression after starting	Starting time (sec)		
	ist time	2nd time	3rd time

	Good	Safety	Stall	Back fire	After fire	rpm	Dep. kPa	Remarks
After start	☐	☐	☐			☐	☐	
At racing	☐		☐	☐	☐			
After racing	☐	☐	☐			☐	☐	
At shift to D	☐	☐	☐					

Cold Drivability Test Result

Cycle	km	Gear	Running method	Speed km/hr	Good	Stall	Slow resp	Stumble	Surge	Back fire	After fire	Knock Accel/Decel	Knock Accel	Knock High speed	Safety	rpm	Dep. kPa	Accel. time	Remarks
1	O	1st.2nd	1/2 slow acc	0-30	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐				
		3rd (2nd)	Constant	30	☐	☐	☐		☐							☐	☐		
	0.3		WOT	30-60	☐	☐	☐	☐	☐	☐		☐	☐	☐				☐	
		Top	Decel	60-40	☐	☐			☐		☐								
			Constant	40	☐	☐	☐		☐							☐	☐		
	0.8		3/4 PT	40-55	☐	☐	☐	☐	☐	☐		☐	☐	☐					
			Decel	55-0	☐	☐			☐		☐								
	1.0	N or D	Idle-stop	30sec	☐	☐									☐	☐	☐		
2		1st.2nd	1/2 slow acc	0-30	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐				
		3rd (2nd)	Constant	30	☐	☐	☐		☐							☐	☐		
	1.3		WOT	30-60	☐	☐	☐	☐	☐	☐		☐	☐	☐				☐	
		Top	Decel	60-40	☐	☐			☐		☐								
			Constant	40	☐	☐	☐		☐							☐	☐		
	1.8		3/4 PT	40-55	☐	☐	☐	☐	☐	☐		☐	☐	☐					
			Decel	55-0	☐	☐			☐		☐								
	2.0	N or D	Idle-stop	30sec	☐	☐									☐	☐	☐		
3		1st.2nd	1/2 slow acc	0-30	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐				
		3rd (2nd)	Constant	30	☐	☐	☐		☐							☐	☐		
	2.3		WOT	30-60	☐	☐	☐	☐	☐	☐		☐	☐	☐				☐	
		Top	Decel	60-40	☐	☐			☐		☐								
			Constant	40	☐	☐	☐		☐							☐	☐		
	2.8		3/4 PT	40-55	☐	☐	☐	☐	☐	☐		☐	☐	☐					
			Decel	55-0	☐	☐			☐		☐								
	3.0	N or D	Idle-stop	30sec	☐	☐									☐	☐	☐		
4		1st.2nd	1/2 slow acc	0-30	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐				
		3rd (2nd)	Constant	30	☐	☐	☐		☐							☐	☐		
	3.3		WOT	30-60	☐	☐	☐	☐	☐	☐		☐	☐	☐				☐	
		Top	Decel	60-40	☐	☐			☐		☐								
			Constant	40	☐	☐	☐		☐							☐	☐		
	3.8		3/4 PT	40-55	☐	☐	☐	☐	☐	☐		☐	☐	☐					
			Decel	55-0	☐	☐			☐		☐								
	4.0	N or D	Idle-stop	30sec	☐	☐									☐	☐	☐		
5	O	1st.2nd	1/2 slow acc	0-30	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐				
		3rd (2nd)	Constant	30	☐	☐	☐		☐							☐	☐		
	4.3		WOT	30-60	☐	☐	☐	☐	☐	☐		☐	☐	☐				☐	
		Top	Decel	60-40	☐	☐			☐		☐								
			Constant	40	☐	☐	☐		☐							☐	☐		
	4.8		3/4 PT	40-55	☐	☐	☐	☐	☐	☐		☐	☐	☐					
			Decel	55-0	☐	☐			☐		☐								
	5.0	N or D	Idle-stop	30sec	☐	☐									☐	☐	☐		

FIGURE A-4: EXAMPLE DATA SHEET

Magna		Good		Stall		Slow resp		Stumble		Surge		Back fire		after fire		AccDecc		Accel		High Speed		Safety		rpm		Dep. KPa		Accel Time		Comments	
		Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	PETROL	PETROHOL
Cycle 1	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							RAN FAULTLESSLY FOR	RAN FAULTLESSLY FOR
	30	5	5	5	5	5	5			5	5														1800		14			FULL CYCLE	FULL CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5								6.25		
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													2000	2700						NOT AT A CONSTANT 40KM/H LONG
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5										ENOUGH TO READ DEP. (KPa)
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	1000	950	15	14				
Cycle 2	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							RAN FAULTLESSLY FOR	RAN FAULTLESSLY FOR
	30	5	5	5	5	5	5			5	5													1800	1700	15	17			FULL CYCLE	FULL CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							5.49	5.06	ACCLERATION TIME STOPPED AFTER	
	60-40	5	5	5	5					5	5			5	5															ACCELERATOR PEDAL LIFTOFF	
	40	5	5	5	5	5	5			5	5														1100					(POSSIBLE DELAY AND THEREFORE	NOT AT A CONSTANT 40KM/H LONG
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5									INCREASED TIME)	ENOUGH TO READ DEP. (KPa)
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	800	800	16	15				
Cycle 3	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							RAN FAULTLESSLY FOR	RAN FAULTLESSLY FOR
	30	5	5	5	5	5	5			5	5													1800	1700	16	16			FULL CYCLE	FULL CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							4.71	4.95		
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													1600	1200	17	10				
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	750	750	16	16				
Cycle 4	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							RAN FAULTLESSLY FOR	RAN FAULTLESSLY FOR
	30	5	5	5	5	5	5			5	5													1750	1700	17	16			FULL CYCLE	FULL CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							4.79	4.24		
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													1600	1200	15	15				
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	750	750	16	16				
Cycle 5	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							RAN FAULTLESSLY FOR	RAN FAULTLESSLY FOR
	30	5	5	5	5	5	5			5	5													1800	1700	16	15			FULL CYCLE	FULL CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							4.65	3.49		TO 50KM.HR NOT 60KM/HR
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5														1200		15				
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	750	700	16.5	16				

FIGURE A-5: MAGNA COLD DRIVABILITY RESULTS

Lexcen		Good		Stall		Slow resp		Stumble		Surge		Back fire		after fire		AccDecc		Accel		High Speed		Safety		rpm		Dep. KPa		Accel Time		Comments	
		Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	PETROL	PETROHOL
Cycle 1	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							VEHICLE RAN IMPECCABLY	VEHICLE RAN IMPECCABLY
	30	5	5	5	5	5	5			5	5													1500	1600	15	17			THROUGHOUT CYCLE	THROUGHOUT CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							3.17	3.32	SLIGHTLY UPHILL	SLIGHTLY UPHILL
	60-40	5	5	5	5					5	5			5	5															AUTO KICKED DOWN (30-60)	AUTO KICKED DOWN (30-60)
	40	5	5	5	5	5	5			5	5													1600	1350	12	17				
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	900	900	17	18				
Cycle 2	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							VEHICLE RAN IMPECCABLY	VEHICLE RAN IMPECCABLY
	30	5	5	5	5	5	5			5	5													1600	1600	18	17			THROUGHOUT CYCLE	THROUGHOUT CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							3.03	2.92		
	60-40	5	5	5	5					5	5			5	5															AUTO KICKED DOWN (30-60)	AUTO KICKED DOWN (30-60)
	40	5	5	5	5	5	5			5	5													1300	1050	18	18				
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	850	850	18	18				
Cycle 3	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							VEHICLE RAN IMPECCABLY	VEHICLE RAN IMPECCABLY
	30	5	5	5	5	5	5			5	5													1600	1550	19	19			THROUGHOUT CYCLE	THROUGHOUT CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							2.54	2.88		
	60-40	5	5	5	5					5	5			5	5															AUTO KICKED DOWN (30-60)	AUTO KICKED DOWN (30-60)
	40	5	5	5	5	5	5			5	5													1650	1500	15	16				SLIGHTLY UPHILL
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	800	850	18	19				
Cycle 4	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							VEHICLE RAN IMPECCABLY	VEHICLE RAN IMPECCABLY
	30	5	5	5	5	5	5			5	5													1600	1550	18	19			THROUGHOUT CYCLE	THROUGHOUT CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							2.52	2.97		
	60-40	5	5	5	5					5	5			5	5															AUTO KICKED DOWN (30-60)	AUTO KICKED DOWN (30-60)
	40	5	5	5	5	5	5			5	5													1300	1100	18	19				
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	800	800	18	18				
Cycle 5	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							VEHICLE RAN IMPECCABLY	VEHICLE RAN IMPECCABLY
	30	5	5	5	5	5	5			5	5													1600	1550	18	20			THROUGHOUT CYCLE	THROUGHOUT CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							2.91	2.61	SLIGHTLY UPHILL	
	60-40	5	5	5	5					5	5			5	5															AUTO KICKED DOWN (30-60)	AUTO KICKED DOWN (30-60)
	40	5	5	5	5	5	5			5	5													1250	1100	19	18				
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	800	800	18	18				

FIGURE A-6: LEXCEN COLD DRIVABILITY RESULTS

Laser		Good		Stall		Slow resp		Stumble		Surge		Back fire		after fire		AccDecc		Accel		High Speed		Safety		rpm		Dep. KPa		Accel Time		Comments	
		Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	PETROL	PETROHOL
Cycle 1	0-30	5	5	5	5	2	5	2	2	5	5	5	5	5	5	5	5	1	1	5	5	5	5							STUMBLE AND HESITSATION ON	PINGING, STUMBLE
	30	5	5	5	5	5	5			5	5													1700	1240	16	15			ACCELERATION	
	30-60	5	5	5	5	2	5	2	5	5	5	5	5			5	5	1	1	5	5							8.3	12.99	PINGING - ACCELERATION TIME ON	SLIGHTLY UPHILL
	60-40	5	5	5	5					5	5			5	5															SLIGHT UPHILL- MAY HAVE ASLO	
	40	5	5	5	5	5	5			5	5													1050		10				BEEN TO 50 KM/HR - CLUSTER MISTED	NOT AT CONSTANT 40KM/HR LONG
	40-55	5	5	5	5	2	5	2	5	5	5	5	5			5	5	1	1	5	5									PINGING	ENOUGH TO GET READING
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	840	1200	19	21				
Cycle 2	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	2	2	5	5	5	5							RAN WELL EXCEPT	PINGING
	30	5	5	5	5	5	5			5	5														1350		15			PINGING 30KM/HR IN 3RD	
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	2	2	5	5							7.71	8.1		PINGING
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													1050	1150	15	13			PINGING 40KM/HR IN 5TH	
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	2	2	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	800	810	20	21				
Cycle 3	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	3	5	5	5	5							RAN WELL THROUGH CYCLE	PINGING
	30	5	5	5	5	5	5			5	5													1350	1450	16	15			EXCEPT SLIGHT PINGING	
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	3	3	5	5							7.43	7.5		PINGING LESS
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													1050	10550	15				STILL PINGING NOT AS BAD	NO TIME FOR DEP READING
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	3	4	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	890	900	21	21				
Cycle 4	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5	5	5	5							RAN WELL THROUGH CYCLE	SLIGHT PINGING
	30	5	5	5	5	5	5			5	5													1490	1480	18	20			EXCEPT VERY SLIGHT PINGING	
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	4	4	5	5							7.36	7.06		
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													1080	1060	15					NO TIME FOR DEP READING
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	4	5	5	5										STOPPED PINGING
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	910	900		21				
Cycle 5	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5							RAN FAULTLESSLY THROUGHOUT	RAN FAULTLESSLY THRIUGH
	30	5	5	5	5	5	5			5	5													1400	1400	20	20			CYCLE	THE CYCLE
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							8.28	7.61	SLIGHTLY UPHILL (THEREFORE	SLIGHTLY UPHILL
	60-40	5	5	5	5					5	5			5	5															SLOWER ACCELERATION TIME)	
	40	5	5	5	5	5	5			5	5													1050	1050	15					NO TIME FOR DEP READING
	40-55	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5										
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	920	910	21	21				

FIGURE A-7: LASER COLD DRIVABILITY RESULTS

Falcon		Good		Stall		Slow resp		Stumble		Surge		Back fire		after fire		AccDecc		Accel		High Speed		Safety		rpm		Dep. KPa		Accel Time		Comments	
		Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	Pet	Eth	PETROL	PETROHOL
Cycle 1	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5								
	30	5	5	5	5	5	5			5	5													1500	1000	17	15			RPM IN SECIND GEAR	STUMBLE
	30-60	5	5	5	5	5	5	2	3	5	5	5	5			5	5	1	5	5	5							8.09	9.15	PINGING, STUMLE	NO PINGING, STUMBLE
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													1000	1000	18	17				
	40-55	5	5	5	5	5	5	2	3	5	5	5	5			5	5	1	5	5	5									STUMBLE	STUMBLE
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	650	1000	19	20				
Cycle 2	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5								
	30	5	5	5	5	5	5			5	5													1000	1000	18	17				
	30-60	5	5	5	5	5	5	3	3	5	5	5	5			5	5	2	5	5	5							8.53	7.54	HEAVEY PINGING, STUMBLE	INITIAL HESITATION & STUMBLE
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													1000	1000	15	16				
	40-55	5	5	5	5	5	5	3	3	5	5	5	5			5	5	2	5	5	5									SLIGHT STUMBLE	SLIGHT STUMBLE
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	700	900	17	20				
Cycle 3	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5								
	30	5	5	5	5	5	5			5	5													1000	1000	15	15				
	30-60	5	5	5	5	5	5	5	3	5	5	5	5			5	4	5	5	5	5							8.34	9.12		SLIGHT STUMBLE
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													1000	1900	12	13				
	40-55	5	5	5	5	9	5	4	5	5	5	5	5			5	4	5	5	5	5									VERY SLIGHT STUMBLE	
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	750	750	17	17				
Cycle 4	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5								RAN WELL THROUGH ENTIRE CYCLE
	30	5	5	5	5	5	5			5	5													1000	1000	16	14				
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							6.76	6.61		
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													1000	1000	15	15				
	40-55	5	5	5	5	5	5	4	5	5	5	5	5			5	5	5	5	5	5									VERY SLIGHT STUMBLE	
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	750	750	17	17				
Cycle 5	0-30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5								RAN WELL THROUGH ENTIRE CYCLE
	30	5	5	5	5	5	5			5	5													1000	1000	17	14				
	30-60	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	5	5	5							6.8	6.25		
	60-40	5	5	5	5					5	5			5	5																
	40	5	5	5	5	5	5			5	5													1000	1000	13	15				
	40-55	5	5	5	5	5	5	4	5	5	5	5	5			5	5	5	5	5	5									VERY SLIGHT STUMBLE	
	55-0	5	5	5	5					5	5			5	5																
	idle	5	5	5	5																	5	5	750	750	17	17				

FIGURE A-8: FALCON COLD DRIVABILITY RESULTS

Vehicle Parameters

Falcon

		Petrol	E10
NRMA Service	Idle RPM	700	800
	Dwell		
	Timing	6	6
	DP rpm		
	Idle CO%	1.98	1.51
	Fast Idle CO%	1	0.57
	Specific Gravity	1.25	1.25
	Battery Voltage	13	12.7
Test Day	Battery Voltage	11.9	12.4
	Weather		
	Amb. Temp. (°C)	12.5	11
	Humidity (%)	58	66
	Wind Velocity	negligible	negligible
	Wind Direction		
	Tyre Pressure (kPa)	200	200
	Test Start Time	6.35	6.40
	Soak Duration (hr)	14	14.4
	Soak Temp. (°C)	-4.25	-4.25
Cold Startability	Cranking Time (sec)	1	2
5 sec after starting	Idle rpm	700	700
	Idle Vacuum (kPa)	15	15
After Cold Drivability	Idle rpm	750	750
	Idle Vacuum(kPa)	17	17

Cold Drivability		Petrol					E10				
Defect Item		4	3	2	1	Total	4	3	2	1	Total
Idling Stability		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Slow Response		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Stumble		3x1	2x2	2x5	0x9	17	0x1	5x2	1x5	0x9	10
Surge		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Back fire		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
After fire		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Knock	Accel/Decel	2x1	0x2	2x5	2x9	30	0x1	0x2	0x5	0x9	10
	Low Speed	0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
	High Speed	0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Startability (restart)		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Stall		0x18	0x18	0x18	0x18		0x18	0x18	0x18	0x18	

Laser

		Petrol	E10
NRMA Service	Idle RPM	980	970
	Dwell		
	Timing	4	5
	DP rpm	1500	1500
	Idle CO%	1.39	0.26
	Fast Idle CO%	0.46	0.77
	Specific Gravity	1.28	1.28
	Battery Voltage	12.48	12.63
Test Day	Battery Voltage	12.84	12.8
	Weather	Fine	Fine
	Amb. Temp. (°C)	4	7.5
	Humidity (%)	84	87
	Wind Velocity	0	0
	Wind Direction		
	Tyre Pressure (kPa)	200	200
	Test Start Time	6.45	6.45
	Soak Duration (hr)	14	14.25
	Soak Temp. (°C)	-4	-4
Cold Startability	Cranking Time (sec)	9	2
5 sec after starting	Idle rpm	100	1130
	Idle Vacuum (kPa)	17	17
After Cold Drivability	Idle rpm	910	900
	Idle Vacuum(kPa)	21	21

Cold Drivability		Petrol					E10				
Defect Item		4	3	2	1	Total	4	3	2	1	Total
Idling Stability		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Slow Response		0x1	0x2	3x5	0x9	15	0x1	0x2	0x5	0x9	
Stumble		0x1	0x2	3x5	0x9	15	0x1	0x2	1x5	0x9	5
Surge		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Back fire		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
After fire		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Knock	Accel/Decel	3x1	3x2	3x5	3x9	51	3x1	2x2	3x5	3x9	49
	Low Speed	0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
	High Speed	0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Startability (restart)		0x1	0x2	0x5	0x9		0x1	0x2	0x5	0x9	
Stall		0x18	0x18	0x18	0x18		0x18	0x18	0x18	0x18	

Magna

		Petrol	E10
NRMA Service	Idle RPM	800	820
	Dwell		
	Timing	13	13
	DP rpm	900	900
	Idle CO%	2.3	1.23
	Fast Idle CO%		0.68
	Specific Gravity	1.2	1.27
	Battery Voltage	12.8	12.73
Test Day	Battery Voltage	12.87	12.8
	Weather	Partly cloudy	Partly cloudy
	Amb. Temp. (°C)	6	12
	Humidity (%)	79	62
	Wind Velocity	0	0-5
	Wind Direction		NW
	Tyre Pressure (kPa)	190	190
	Test Start Time	7.00	6.30
	Soak Duration (hr)	13.5	13
	Soak Temp. (°C)	(-3)to(-4)	(-3)to(-4)
Cold Startability	Cranking Time (sec)	2	2
5 sec after starting	Idle rpm	1200	1250
	Idle Vacuum (kPa)	14	15
After Cold Drivability	Idle rpm	800	800
	Idle Vacuum(kPa)	19	18

Cold Drivability		Petrol					E10				
Defect Item		4	3	2	1	Total	4	3	2	1	Total
Idling Stability		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Slow Response		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Stumble		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Surge		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Back fire		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
After fire		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Knock	Accel/Decel	0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
	Low Speed	0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
	High Speed	0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Startability (restart)		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Stall		0x18	0x18	0x18	0x18	0	0x18	0x18	0x18	0x18	0

Lexcen

		Petrol	E10
NRMA Service	Idle RPM	800	900
	Dwell		
	Timing		
	DP rpm		
	Idle CO%	2.9	1.81
	Fast Idle CO%	0.6	0.52
	Specific Gravity	1.27	1.25
	Battery Voltage	12.9	12.8
Test Day	Battery Voltage	12.19	12.34
	Weather	Fine	Fine
	Amb. Temp. (°C)	4.5	3.5
	Humidity (%)	92	92
	Wind Velocity	0	0
	Wind Direction	-	-
	Tyre Pressure (kPa)	210	210
	Test Start Time	6.45 a.m.	6.40 a.m.
	Soak Duration (hr)	14.5	13.25
	Soak Temp. (°C)	-4.25	-4.25
Cold Startability	Cranking Time (sec)	2	2
5 sec after starting	Idle rpm	1000	1050
	Idle Vacuum (kPa)	15	17
After Cold Drivability	Idle rpm	800	800
	Idle Vacuum(kPa)	19	19

Cold Drivability		Petrol					E10				
Defect Item		4	3	2	1	Total	4	3	2	1	Total
Idling Stability		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Slow Response		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Stumble		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Surge		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Back fire		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
After fire		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Knock	Accel/Decel	0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
	Low Speed	0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
	High Speed	0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Startability (restart)		0x1	0x2	0x5	0x9	0	0x1	0x2	0x5	0x9	0
Stall		0x18	0x18	0x18	0x18	0	0x18	0x18	0x18	0x18	0

APPENDIX B:HOT DRIVABILITY & HOT FUEL HANDLING

The purpose of this trial was to evaluate the performance characteristics of 10% v/v ethanol petrol blend (E10) as compared to those of neat petrol under hot climate conditions.

Hot Drivability

The hot drivability protocol used for the trial was provided by FCAI. The protocol is designed to evaluate drivability in a vehicle placed under specific demands/criteria when in a hot climate environment and consists of two parts. The salient parts of this protocol are:

- Warm-up before test

  For the engine warm-up, the test vehicle is driven over 5 km at either 100 km/h with 4th speed (or range D) or in case road conditions make this impossible, at 70 km/h with 3rd speed (or range 2).

- Judging standard for sensory test

  The judging standard used for this sensory test is on the basis of the absolute evaluation. "Absolute evaluation" means the evaluation which is not conducted by comparing with any other particular vehicle, but according to the 5-grade method which is also used by the sections concerned in where the grade 3.0 or higher is acceptable in the evaluation.

  Actually, after providing additional grades at intermediate points that are positioned exactly halfway between each set of points, for example, at 1.5 between 1 and 2, the judgement is conducted according to 9 grades in total.

- The basic grades for judgement are in

  Table Appendix B:-1.

TABLE APPENDIX B:-1: DRIVABILITY GRADING

5	Excellent	No problem, Insensible
4	Good	Problem hardly sensed
3	Average	Not without problem
2	Poor	Problem distinctly sensed
1	Extremely poor	Uncomfortable

- Description of the phenomena that may occur and testing method

  Words to express descriptions of the phenomena and testing method, etc. are shown in Figure Appendix B:-1 and the test result should be entered on the check sheet of the attached "Results of Sensory Test".

  However, the attached sheets are used merely for reference, and it is not necessary to follow the attached sheets entirely and all problems encountered should be freely pointed out.

Drivability Classification

Test Item	Description of Phenomenon or Expressing Word	Testing Method and Supplementary Explanation	Related Word
Idling stability	The degree of smoothness of engine idling condition and the degree of vibration and noise trnsmitted to steering wheel, transmission shift lever and seats, etc.	Manual transmission vehicles should be tested with the gearbox in neutral position; Automatic transmission vehicles in both neutral and drive positions, just after the start of engine and again after running.	
Acceleration performance	Whether the highest acceleration at WOTis appropriate to the vehicle type. Whether the acceleration feeling which suits to throttle opening at PT is obtained when compared with that at WOT.	Acceleration in each gear should be tested,both from rest and whilst under way.	Acceleration feeling
Hesitation (Slow response)	Delay in vehicle response when the accelarator pedal is operated.	Should be tested at starting, and under acceleration & deceleration while underway. Should be tested within 1 second after accelerating.	Response
Stumble	Distinct insufficiency of power under acceleration.	Should be tested under acceleration and again within 1 second after accelerating.	Response
Surge	Low frequencyvehicle vibration (10Hz or less) in vehicle FR and RR directions at cruising and whilst both accelerating and decelerating.	Should be tested at cruising (regular surge), at PT accelerating (accelerating surge) and at engine braking (decelaration surge).	Vibration in vehicle lengthwise direction.
Knock	Knocking sound from engine Burning ... Gas knock Metal knock ... Mechanical knock	Intensity and duration of knocking sound at slightly sudden starting acceleration and whilst accelerating in 4th gear (or range D;) t WOT aceleration should also be tested.	
After-fire	Burst at exhaust system	Change from WOT acceleration to completely closed deceleration in either 2nd or 3rd gear (or in range D). Vehicle speed should be at 80% of the speed obtinable with max. engine revolutions or by unloaded engine running (with the same engine revolutions)with the vehicle at rest. Intensity and lasting time of after-fire should be tested.	Slight noise Explosion-like sound
Run-on	Engine continues to run after ignition key is turned off.	Just after warm-up before test, run-on occurring time should be measured with the car standing and ignition off.	

*FIGURE APPENDIX B:-1: DRIVABILITY CLASSIFICATION {**PRIVATE COMMUNICATION** 1996 ID: 12}*

Hot Fuel Handling - Australian Heat Test Method

The hot fuel handling protocol used for the trial was also provided by FCAI. The protocol is designed to evaluate vapour lock resistance and is applicable to testing in both the environmental chamber and under road test. The test conditions and criteria are:

- Conditions
  - ~ Fuel quantity - 30 ℓ
    Fuel temp (at fill) - to be recorded
  - ~ WOT upshift (M/T) at an engine speed corresponding to 0.85 N(max).
    N(max) = Maximum recommended engine speed.
  - ~ Dead soak - in tent (windbreak) or shed
  - ~ Ambient temperature - 35°C min on road test
  - ~ Wind direction to be from rear of vehicle during hot soak
  - ~ A/C to be on for entire test cycle. Air engaged in "FRESH" position
  - ~ Wind speed max -5 m/s (18 kph, 10 knots)

- Acceptability criteria
  - ~ T1/T*, T2/T* ≤ 1.5
  - ~ Speed down is unacceptable
  - ~ Surge - Driver rating: - Marginal level = 3 if surge is felt through driver's seat
    - Unacceptable = 2.5

Sample Test Sheets

Hot Drivability Test Result

Test item	Gear	Condition Speedkm/hr		Good	Safety	Slow resp	Stumble	Surge	Jerk	Shock	rpm	Dep. kPa	Remarks
Hot idle	N or D	Idling stop	A/C off										
			A/C On										
Constant	D (A/T	Creep running											
	2nd	20											
		30											
	3rd 2 2nd	40											
		60											
	Top D	80											
		100											
		120											
Surge max Gear	( )	( )											
Tip-in 1/8-1/4 PT Slow acceleration	2nd	20 const											
		40 → 20											
	(EFI)	Cut 200 → Return 100											
	3rd	40 const											
		60 → 40											
	(EFI)	Cut 200 → Return 100											
	Top	60 const											
		80 → 60											
		80 const											
		100 → 80											

Test item	Gear	Condition Depression Speed	Amount	Speedkm/hr	Good	Slow resp	Stumble	Surge	Back fire	After fire	Accel/ Decel	Knock Accel	Knock High speed	Safety	rpm	Dep. kPa	Accel. time	Remarks
WOT & PT	2nd D	Slow	1/4	20 const → 60 → 50														
			2/4															
			1/4															
		Rapid	4/4															
Rapid: Approx. 0.5 sec. Full close to full open	3rd (2nd) D	Slow	1/4	30 const → 60 → 50														
			2/4															
			1/4															
		Rapid	4/4															
		Slow	4/4	60 const → 100 → 90														
		Rapid	2/4															
Slow: Approx. 1-2 sec Full close to full open	Top D	Slow	1/4	60 const → 90 → 80														
			2/4															
			1/4															
		Rapid	2/4															
		Slow	4/4	60 const → 100 → 90														
Constant Vacuum	3rd (2nd)	0.6		50 const → 90														
		0.3																
		0.15																

FIGURE APPENDIX B:-2: HD AND HFH TEST RECORDING SHEET 1

Hot Drivability Test Result

Test item	Gear	Condition Speedkm/hr	A/C	Good	Shock	Jerk	Rabbit hops	Deceleration	Remarks
Acceleration and Deceleration 1/4 - 2/4 PT Rapid acceleration Engine brake	1st	20 const 15 25	ON	☐			☐		
			OFF	☐			☐		
	2nd	30 cons 40 20 45 25 50 30 55 35 20	ON	☐	☐	☐	☐	☐	
			OFF	☐	☐	☐	☐	☐	
	3rd	40 cons 50 30 55 35 60 40 65 45 30	ON	☐	☐	☐	☐	☐	
			OFF	☐	☐	☐	☐	☐	

Test item	Gear	Condition Speedkm/hr	Good	Stumble	Surge	Shockl	After fire	Decelar'n	Run-on time secs	Remarks
Secondary shock	3rdD(2nd)	50 cons 120	☐	☐						
Deceleration	Top D	120 cons 60	☐		☐		☐	☐		
	3rdD(2nd)	100 cons 30	☐		☐		☐	☐		
	2nd	Cut 200 Return 100	☐		☐	☐				
Run-on	N or D	Top 80km/hr x 4km	☐						☐	

Test item		Gear	Condition Speedkm/hr			Good	Safety	Slow response	Stumble	Surge	Back fire	After fire	Knock Accel/ Decel	Knock Accel	Knock High speed	Accelar'n	Restarting time (sec) 1st time	2nd time	3rd time	rpm	Dep kPa
Engine off soak	Restart	N or D	Connect clutch after 15 minutes			☐	☐										☐	☐	☐	☐	☐
	h - l Surge max gear speed	3rd,2,(2nd)	40			☐					☐									☐	☐
		( )	( )			☐					☐									☐	☐
	WOT & PT Slow: approx 1-2 s Rapid: Approx 0.5s	3rd D	Slow	4/4	40 cons 80 70	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐				☐	☐
		3rd (2nd) D		2/4		☐	☐	☐	☐	☐						☐					
				1/4		☐	☐	☐	☐	☐						☐					
			Rapid	4/4		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐						

Operatability of accelerator linkage

(1) Depressing force ....

(2) Stroke ....

(3) Good returning ....

(4) Pedal angle ....

(5) Ease of use ....

FIGURE APPENDIX B:-3: HD AND HFH RECORDING SHEET 2

Test Data - Broken Hill

Hot Driveability Test Result - Magna 1995 - Neat					Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat
														Knock								
Test Item	Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High spee	Accel Tim	Rabbit hop	Decel	RPM	Dep. kPa	
Hot Idle	D	Idling Stop		A/C off	3	3														800	21.2	6
				A/C on	2.75															950	19	2.75
Constant	D	Creep Running			2.75				3											750	15.5	5.75
		20			3				3											1100	16	6
		30			3				3											1500	17.5	6
	2	40			3				3											1500	13	6
	D	60			3				3											1950	14	6
		80			3				3											2000	10	6
		100			3				3											2300	8	6
		120			3				3											2700	4.5	6
Surge Max Gear	-	-																				0
Tip - in	D	20 const			3		3	3		3	3											15
		40 -> 20			3		3	3		3	3											15
		Cut 200 rp	Return 100 rpm																			0
1/8 - 1/4 PT	D	40 const			3		3	3		3	3											15
		60 -> 40			2.75		3	3		2.75	2.75											14.25
		Cut 200	Return 100																			0
Slow	D	60 const			3		3	3		3	3											15
Acceleration		80 -> 60			3		3	3		3	3											15
		80 const			3		3	3		3	3											15
		100 -> 80			3		3	3		3	3											15
WOT & PT	D	Slow	1/4	20 const -> 60 -> 50	3	3	3	3	3			3	3	3	3	3						30
			2/4		3	3	3	3	3													15
			1/4		3	3	3	3	3													15
		Rapid	4/4		3	3	3	3	3			3	3	3	3	3						30
Rapid:	D	Slow	1/4	30 const -> 60 -> 50	3	3	3	3	3			3	3	3	3	3						30
Approx 0.5			2/4		3	3	3	3	3													15
sec			1/4		3	3	3	3	3													15
Full close		Rapid	4/4		3	3	3	3	3			3	3	3	3	3	4.58					30
to open		Slow	4/4	60 const -> 100 -> 90	3	3	3	3	3			3	3	3	3	3						30
		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
Slow	D	Slow	1/4	60 const -> 90 -> 80																		0
Approx 1-2			2/4		3	3	3	3	3													15
sec			1/4																			0
Full close		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
to open		Slow	4/4	60 const -> 100 -> 90	3	3	3	3	3			3	3	3	3	3						30
Constant Vacuum	D	0.6		50 const -> 90	3	3	3	3	3													15
		0.3			3	3	3	3	3													15
		0.15			3	3	3	3	3													15
Acceleration	1	20 const -> 15 -> 25		A/C on	3					3	3							3				12
& Deceleration				A/C off	3					3	3							3				12
1/4-2/4 PT	2	30 const->20->40->2		A/C on	3					3	3							3	3			15
Rapid Acceleration				A/C off	3					3	3							3	3			15
Engine Brake	3	40 const->30->50->3		A/C on	3					3	3							3	3			15
				A/C off	3					3	3							3	3			15
Secondary Shock	D	50 cons -> 120			3			3														6
Deceleration	D	120 cons -> 60			3				3				3						3			12
	2	100 cons -> 60			3				3				3						3			12
	2	cut 200 -> return 100																				0
Run on	D	Top 80km/hr x 4km			3																	3
																						652.75
					131.25	51	72	75	78	41.75	41.75	24	30	24	24	24		18	18			652.75

FIGURE APPENDIX B:-4: MAGNA 1995 - NEAT PETROL - HD

Hot Driveability Test Result - Magna 1995 - E10						E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10
														Knock								
Test Item	Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratı	High spee(	Accel Tim(	Rabbit hop	Decel	RPM	Dep. kPa	
Hot Idle	D	Idling Stop		A/C off	3	3														850	21	6
				A/C on	3															1000	19.5	3
Constant	D	Creep Running			3				3											850	16.5	6
		20			3				3											1100	16	6
		30			3				3											1500	20	6
	2	40			3				3											2100	17.5	6
	D	60			3				3											2900	16	6
		80			3				3											2000	10.5	6
		100			3				3											2200	8	6
		120			3				3											2650	7	6
Surge Max Gear	-	-																				0
Tip - in	D	20 const			3		3	3		3	3											15
		40 -> 20			3		3	3		3	3											15
		Cut 200 rp	Return 100 rpm																			0
1/8 - 1/4 PT	D	40 const			3		3	3		3	3											15
		60 -> 40			3		3	3		3	3											15
		Cut 200	Return 100																			0
Slow	D	60 const			3		3	3		3	3											15
Acceleration		80 -> 60			3		3	3		3	3											15
		80 const			3		3	3		3	3											15
		100 -> 80			3		3	3		3	3											15
WOT & PT	D	Slow	1/4	20 const -	3	3	3	3	3			3	3	3	3	3						30
			2/4		3	3	3	3	3													15
			1/4		3	3	3	3	3													15
		Rapid	4/4		3	3	3	3	3			3	3	3	3	3						30
Rapid:	D	Slow	1/4	30 const -	3	3	3	3	3			3	3	3	3	3						30
Approx 0.5			2/4		3	3	3	3	3													15
sec			1/4		3	3	3	3	3													15
Full close		Rapid	4/4		3	3	3	3	3			3	3	3	3	3	4.06					30
to open		Slow	4/4	60 const -	3	3	3	3	3			3	3	3	3	3						30
		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
Slow	D	Slow	1/4	60 const -> 90 -> 80																		0
Approx 1-2			2/4		3	3	3	3	3													15
sec			1/4																			0
Full close		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
to open		Slow	4/4	60 const -	3	3	3	3	3			3	3	3	3	3						30
Constant Vacuum	D	0.6		50 const -	3	3	3	3	3													15
		0.3			3	3	3	3	3													15
		0.15			3	3	3	3	3													15
Acceleration	1	20 const -> 15 -> 25		A/C on	3					3	3							3				12
& Deceleration				A/C off	3					3	3							3				12
1/4-2/4 PT	2	30 const->20->40->25		A/C on	3					3	3							3	3			15
Rapid Acceleration				A/C off	3					3	3							3	3			15
Engine Brake	3	40 const->30->50->35		A/C on	3					3	3							3	3			15
				A/C off	3					3	3							3	3			15
Secondary Shock	D	50 cons -> 120			3			3														6
Deceleration	D	120 cons -> 60			3				3				3						3			12
	2	100 cons -> 60			3				3				3						3			12
	2	cut 200 -> return 100																				0
Run on	D	Top 80km/hr x 4km			3																	3
																						654
					132	51	72	75	78	42	42	24	30	24	24	24		18	18			654

FIGURE APPENDIX B:-5: MAGNA 1995 - E10 - HD TEST RESULTS

Hot Driveability Test Result - Lexcen - Neat					Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat
														Knock								
Test Item	Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Accelerati	High spee	Accel Tim	Rabbit hop	Decel	RPM	Dep. kPa	
Hot Idle	D	Idling Stop		A/C off	3.5	3.5														750	19.5	7
				A/C on	3.5															750	17	3.5
Constant	D	Creep Running			3.5				3.5											1000	18	7
		20			3.5				3.5											1100	18	7
		30			3.5				3.5											1400	18.5	7
	2	40			3.5				3.5											1850	19	7
	D	60			3.5				3.5											2700	17.5	7
		80			3.5				3.5											1500	11.5	7
		100			3.5				3.5											1800	10.5	7
		120			3.5				3.5											2100	7.5	7
Surge Max Gear	-	-																				0
Tip - in	D	20 const			3.5		3.5	3.5		3.5	3.5											17.5
		40 -> 20			3.5		3.5	3.5		3.5	3.5											17.5
		Cut 200 rp	Return 100 rpm																			0
1/8 - 1/4 PT	D	40 const			3.5		3.5	3.5		3.5	3.5											17.5
		60 -> 40			3.5		3.5	3.5		3.5	3.5											17.5
		Cut 200	Return 100																			0
Slow	D	60 const			3.5		3.5	3.5		3.5	3.5											17.5
Acceleration		80 -> 60			3.5		3.5	3.5		3.5	3.5											17.5
		80 const			3.5		3.5	3.5		3.5	3.5											17.5
		100 -> 80			3.5		3.5	3.5		3.5	3.5											17.5
WOT & PT	D	Slow	1/4	20 const -> 60 -> 50	3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
			2/4		3.5	3.5	3.5	3.5	3.5													17.5
			1/4		3.5	3.5	3.5	3.5	3.5													17.5
		Rapid	4/4		3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
Rapid:	D	Slow	1/4	30 const -> 60 -> 50	3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
Approx 0.5			2/4		3.5	3.5	3.5	3.5	3.5													17.5
sec			1/4		3.5	3.5	3.5	3.5	3.5													17.5
Full close		Rapid	4/4		3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5	3.76					35
to open		Slow	4/4	60 const -> 100 -> 90	3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
		Rapid	2/4		3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
Slow	D	Slow	1/4	60 const -> 90 -> 80																		0
Approx 1-2			2/4		3.5	3.5	3.5	3.5	3.5													17.5
sec			1/4																			0
Full close		Rapid	2/4		3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
to open		Slow	4/4	60 const -> 100 -> 90	3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
Constant Vacuum	D	0.6		50 const -> 90	3.5	3.5	3.5	3.5	3.5													17.5
		0.3			3.5	3.5	3.5	3.5	3.5													17.5
		0.15			3.5	3.5	3.5	3.5	3.5													17.5
Acceleration	1	20 const -> 15 -> 25		A/C on	3.5					3.5	3.5							3.5				14
& Deceleration				A/C off	3.5					3.5	3.5							3.5				14
1/4-2/4 PT	2	30 const->20->40->2		A/C on	3.5					3.5	3.5							3.5	3.5			17.5
Rapid Acceleration				A/C off	3.5					3.5	3.5							3.5	3.5			17.5
Engine Brake	3	40 const->30->50->3		A/C on	3.5					3.5	3.5							3.5	3.5			17.5
				A/C off	3.5					3.5	3.5							3.5	3.5			17.5
Secondary Shock	D	50 cons -> 120			3.5			3.5														7
Deceleration	D	120 cons -> 60			3.5				3.5				3.5						3.5			14
	2	100 cons -> 60			3.5				3.5				3.5						3.5			14
	2	cut 200 -> return 100																				0
Run on	D	Top 80km/hr x 4km			3.5																	3.5
																						763
					154	59.5	84	87.5	91	49	49	28	35	28	28	28		21	21			763

FIGURE APPENDIX B:-6: LEXCEN - NEAT PETROL - HD TEST RESULTS

Hot Driveability Test Result - Lexcen - E10						E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10
														Knock								
Test Item	Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High spee	Accel Tim	Rabbit hop	Decel	RPM	Dep. kPa	
Hot Idle	D	Idling Stop		A/C off	3.5	3.5														800	19.5	7
				A/C on	3.5															800	18.5	3.5
Constant	D	Creep Running			3.5				3.5											900	19.5	7
		20			3.5				3.5											1100	18.5	7
		30			3.5				3.5											1500	20	7
	2	40			3.5				3.5											1900	20	7
	D	60			3.5				3.5											2600	19.5	7
		80			3.5				3.5											1400	12.5	7
		100			3.5				3.5											1750	11.5	7
		120			3.5				3.5											2100	9	7
Surge Max Gear	-	-																				0
Tip - in	D	20 const			3.5		3.5	3.5		3.5	3.5											17.5
		40 -> 20			3.5		3.5	3.5		3.5	3.5											17.5
		Cut 200 rp	Return 100 rpm																			0
1/8 - 1/4 PT	D	40 const			3.5		3.5	3.5		3.5	3.5											17.5
		60 -> 40			3.5		3.5	3.5		3.5	3.5											17.5
		Cut 200	Return 100																			0
Slow	D	60 const			3.5		3.5	3.5		3.5	3.5											17.5
Acceleration		80 -> 60			3.5		3.5	3.5		3.5	3.5											17.5
		80 const			3.5		3.5	3.5		3.5	3.5											17.5
		100 -> 80			3.5		3.5	3.5		3.5	3.5											17.5
WOT & PT	D	Slow	1/4	20 const -	3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
			2/4		3.5	3.5	3.5	3.5	3.5													17.5
			1/4		3.5	3.5	3.5	3.5	3.5													17.5
		Rapid	4/4		3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
Rapid:	D	Slow	1/4	30 const -	3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
Approx 0.5			2/4		3.5	3.5	3.5	3.5	3.5													17.5
sec			1/4		3.5	3.5	3.5	3.5	3.5													17.5
Full close		Rapid	4/4		3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5	2.91					35
to open		Slow	4/4	60 const -	3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
		Rapid	2/4		3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
Slow	D	Slow	1/4	60 const -> 90 -> 80																		0
Approx 1-2			2/4		3.5	3.5	3.5	3.5	3.5													17.5
sec			1/4																			0
Full close		Rapid	2/4		3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
to open		Slow	4/4	60 const -	3.5	3.5	3.5	3.5	3.5			3.5	3.5	3.5	3.5	3.5						35
Constant Vacuum	D	0.6		50 const -	3.5	3.5	3.5	3.5	3.5													17.5
		0.3			3.5	3.5	3.5	3.5	3.5													17.5
		0.15			3.5	3.5	3.5	3.5	3.5													17.5
Acceleration	1	20 const -> 15 -> 25		A/C on	3.5					3.5	3.5							3.5				14
& Deceleration				A/C off	3.5					3.5	3.5							3.5				14
1/4-2/4 PT	2	30 const->20->40->25		A/C on	3.5					3.5	3.5							3.5	3.5			17.5
Rapid Acceleration				A/C off	3.5					3.5	3.5							3.5	3.5			17.5
Engine Brake	3	40 const->30->50->35		A/C on	3.5					3.5	3.5							3.5	3.5			17.5
				A/C off	3.5					3.5	3.5							3.5	3.5			17.5
Secondary Shock	D	50 cons -> 120			3.5			3.5														7
Deceleration	D	120 cons -> 60			3.5				3.5				3.5						3.5			14
	2	100 cons -> 60			3.5				3.5				3.5						3.5			14
	2	cut 200 -> return 100																				0
Run on	D	Top 80km/hr x 4km			3.5																	3.5
																						763
					154	59.5	84	87.5	91	49	49	28	35	28	28	28		21	21			763

FIGURE APPENDIX B:-7: LEXCEN - E10 - HD TEST RESULTS

Hot Driveability Test Result - Falcon - Neat

Test Item	Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Knock Acel/Dece	Acceleratio	High speed	Accel Time	Rabbit hop	Decel	RPM	Dep. kPa	
					Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat
Hot Idle	D	Idling Stop		A/C off	3	3														880	19.5	6
				A/C on	3															784	18.25	3
Constant	D	Creep Running			3				3											720	17.5	6
		20			3				2.5											1200	19.5	5.5
		30			3				2.5											1760	19.5	5.5
	2	40			3				3											2200	19	6
	D	60			3				3											2040	16.5	6
		80			3				3											2160	14	6
		100			3				3											2668	14.5	6
		120			3				3											3232	12.5	6
Surge Max Gear	-	-																				0
Tip - in	D	20 const			3		3	3		3	3											15
		40 -> 20			3		3	2.5		3	3											14.5
		Cut 200 rp	Return 100 rpm																			0
1/8 - 1/4 PT	D	40 const			3		3	3		3	3											15
		60 -> 40			3		3	3		3	3											15
		Cut 200	Return 100																			0
Slow	D	60 const			3		3	3		3	3											15
Acceleration		80 -> 60			3		3	3		3	3											15
		80 const			3		3	3		3	3											15
		100 -> 80			3		3	3		3	3											15
WOT & PT	D	Slow	1/4	20 const -> 60 -> 50	3	3	3	3	3			3	3	3	3	3						30
			2/4		3	3	3	3	3													15
			1/4		3	3	3	3	2.5													14.5
		Rapid	4/4		3	3	3	3	3			3	3	3	2.25	3						29.25
Rapid:	D	Slow	1/4	30 const -> 60 -> 50	3	3	3	3	3			3	3	3	3	3						30
Approx 0.5			2/4		3	3	3	3	3													15
sec			1/4		3	3	3	3	3													15
Full close		Rapid	4/4		3	3	3	3	3			3	3	3	2.25	3	7.85					29.25
to open		Slow	4/4	60 const -> 100 -> 90	3	3	3	3	3			3	3	3	3	3						30
		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
Slow	D	Slow	1/4	60 const -> 90 -> 80																		0
Approx 1-2			2/4		3	3	3	3	3													15
sec			1/4																			0
Full close		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
to open		Slow	4/4	60 const -> 100 -> 90	3	3	3	3	3			3	3	3	2.25	3						29.25
Constant Vacuum	D	0.6		50 const -> 90	3	3	3	3	3													15
		0.3			3	3	3	3	3													15
		0.15			3	3	3	3	3													15
Acceleration	1	20 const -> 15 -> 25		A/C on	3					3	3							2.5				11.5
& Deceleration				A/C off	3					3	3							2.5				11.5
1/4-2/4 PT	2	30 const->20->40->2		A/C on	3					3	3							2.5	2.25			13.75
Rapid Acceleration				A/C off	3					3	3							2.5	2.25			13.75
Engine Brake	3	40 const->30->50->3		A/C on	3					3	2.25							2.75	3			14
				A/C off	3					3	2.25							2.75	3			14
Secondary Shock	D	50 cons -> 120			3			3														6
Deceleration	D	120 cons -> 60			3				3				3						3			12
	2	100 cons -> 60			3				3				3						3			12
	2	cut 200 -> return 100																				0
Run on	D	Top 80km/hr x 4km			3																	3
																						644.25
					132	51	72	74.5	76.5	42	40.5	24	30	24	21.75	24		15.5	16.5			644.25

FIGURE APPENDIX B:-8: FALCON - NEAT PETROL - HD TEST RESULTS

Hot Driveability Test Result -Falcon - E10						E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10
														Knock								
Test Item	Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High speed	Accel Time	Rabbit hop	Decel	RPM	Dep. kPa	
Hot Idle	D	Idling Stop		A/C off	3	3														960	19.8	6
				A/C on	3															776	17.5	3
Constant	D	Creep Running			3				3											920	19	6
		20			3				2.5											1200	17	5.5
		30			3				2.5											1560	17	5.5
	2	40			3				2.75											1480	20	5.75
	D	60			3				3											2120	16	6
		80			3				3											2120	12.5	6
		100			3				3											2680	14	6
		120			3				3											3200	15.5	6
Surge Max Gear	-	-																				0
Tip - in	D	20 const			3		3	3		3	3											15
		40 -> 20			3		3	2.75		3	3											14.75
		Cut 200 rp	Return 100 rpm																			0
1/8 - 1/4 PT	D	40 const			3		3	3		3	3											15
		60 -> 40			3		3	2.75		3	3											14.75
		Cut 200	Return 100																			0
Slow	D	60 const			3		3	3		3	3											15
Acceleration		80 -> 60			3		3	3		3	3											15
		80 const			3		3	3		3	3											15
		100 -> 80			3		3	3		3	3											15
WOT & PT	D	Slow	1/4	20 const -	3	3	3	3	3			3	3	3	3	3						30
			2/4		3	3	3	3	2.75													14.75
			1/4		3	3	3	3	3													15
		Rapid	4/4		3	3	3	3	2.5			3	3	3	3	3						29.5
Rapid:	D	Slow	1/4	30 const -	3	3	3	3	3			3	3	3	3	3						30
Approx 0.5			2/4		3	3	3	3	3													15
sec			1/4		3	3	3	3	3													15
Full close		Rapid	4/4		3	3	3	3	3			3	3	3	3	3	7.26					30
to open		Slow	4/4	60 const -	3	3	3	3	3			3	3	3	3	3						30
		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
Slow	D	Slow	1/4	60 const -> 90 -> 80																		0
Approx 1-2			2/4		3	3	3	3	3													15
sec			1/4																			0
Full close		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
to open		Slow	4/4	60 const -	3	3	3	3	3			3	3	3	3	3						30
Constant Vacuum	D	0.6		50 const -	3	3	3	3	3													15
		0.3			3	3	3	3	3													15
		0.15			3	3	3	3	3													15
Acceleration	1	20 const -> 15 -> 25		A/C on	3					3	3							2.25				11.25
& Deceleration				A/C off	3					3	3							2.5				11.5
1/4-2/4 PT	2	30 const->20->40->25		A/C on	3					3	3							2.5	2.25			13.75
Rapid Acceleration				A/C off	3					3	3							2.5	2.25			13.75
Engine Brake	3	40 const->30->50->35		A/C on	3					3	3							2.75	2.5			14.25
				A/C off	3					3	3							3.25	2.75			15
Secondary Shock	D	50 cons -> 120			3			3														6
Deceleration	D	120 cons -> 60			3				3				3						3			12
	2	100 cons -> 60			3				2.75				3						3			11.75
	2	cut 200 -> return 100																				0
Run on	D	Top 80km/hr x 4km			3																	3
																						646.75
					132	51	72	74.5	75.75	42	42	24	30	24	24	24		15.75	15.75			646.75

FIGURE APPENDIX B:-9: FALCON - E10 - HD TEST RESULTS

Hot Driveability Test Result - Magna '85 - Neat					Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat	Neat
Test Item	Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High spee	Accel Time	Rabbit hop	Decel	RPM	Dep. kPa	
Hot Idle	D	Idling Stop		A/C off	3	3														800	20.5	6
				A/C on	3															650	17.5	3
Constant	D	Creep Running			3				3											600	18	6
		20			3				3											1250	14.5	6
		30			3				2.75											1600	17	5.75
	2	40			3				3											1400	15	6
	D	60			3				3											2000	14.5	6
		80			3				3											1800	11	6
		100			3				3											2200	10	6
		120			3				3											2800	7	6
Surge Max Gear	-	-																				0
Tip - in	D	20 const			3		3	3		3	3											15
		40 -> 20			3		3	3		3	3											15
		Cut 200 rp	Return 100 rpm																			0
1/8 - 1/4 PT	D	40 const			3		3	3		3	3											15
		60 -> 40			3		3	3		3	3											15
		Cut 200	Return 100																			0
Slow	D	60 const			3		3	3		3	3											15
Acceleration		80 -> 60			3		3	3		3	3											15
		80 const			3		3	3		3	3											15
		100 -> 80			3		3	3		3	3											15
WOT & PT	D	Slow	1/4	20 const -> 60 -> 50	3	3	3	3	3			3	3	3	3	3						30
			2/4		3	3	3	3	3													15
			1/4		3	3	3	3	3													15
		Rapid	4/4		3	3	3	3	3			3	3	3	3	3						30
Rapid:	D	Slow	1/4	30 const -> 60 -> 50	3	3	3	3	3			3	3	3	3	3						30
Approx 0.5			2/4		3	3	3	3	3													15
sec			1/4		3	3	3	3	3													15
Full close		Rapid	4/4		3	3	3	3	3			3	3	3	3	3	7.8					30
to open		Slow	4/4	60 const -> 100 -> 90	3	3	3	3	3			3	3	3	3	3						30
		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
Slow	D	Slow	1/4	60 const -> 90 -> 80																		0
Approx 1-2			2/4		3	3	3	3	3													15
sec			1/4																			0
Full close		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
to open		Slow	4/4	60 const -> 100 -> 90	3	3	3	3	3			3	3	3	3	3						30
Constant Vacuum	D	0.6		50 const -> 90	3	3	3	3	3													15
		0.3			3	3	3	3	3													15
		0.15			3	3	3	3	3													15
Acceleration	1	20 const -> 15 -> 25		A/C on	3					3	3							3				12
& Deceleration				A/C off	3					3	3							3				12
1/4-2/4 PT	2	30 const->20->40->25		A/C on	3					3	3							3	3			15
Rapid Acceleration				A/C off	3					3	3							3	3			15
Engine Brake	3	40 const->30->50->35		A/C on	3					3	3							3	3			15
				A/C off	3					3	3							3	3			15
Secondary Shock	D	50 cons -> 120			3			3														6
Deceleration	D	120 cons -> 60			3				3				3						3			12
	2	100 cons -> 60			3				3				3						3			12
	2	cut 200 -> return 100																				0
Run on	D	Top 80km/hr x 4km			3																	3
																						653.75
					132	51	72	75	77.75	42	42	24	30	24	24	24		18	18			653.75

FIGURE APPENDIX B:-10: MAGNA 1985 - NEAT PETROL - HD TEST RESULTS

Hot Driveability Test Result -Magna '85 - E10						E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10	E10
Test Item	Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High speec	Accel Tim	Rabbit hop	Decel	RPM	Dep. kPa	
Hot Idle	D	Idling Stop		A/C off	3	3														700	18.5	6
				A/C on	3															600	16	3
Constant	D	Creep Running			3				3											800	14.5	6
		20			3				3											1100	15	6
		30			3				3											1550	16	6
	2	40			3				3											1350	13	6
	D	60			3				3											1900	15	6
		80			3				3											1800	8.5	6
		100			3				3											2200	13	6
		120			3				3											2700	5	6
Surge Max Gear	-	-																				0
Tip - in	D	20 const			3		3	3		3	3											15
		40 -> 20			3		3	3		3	3											15
		Cut 200 rp	Return 100 rpm																			0
1/8 - 1/4 PT	D	40 const			3		3	3		3	3											15
		60 -> 40			3		3	3		3	3											15
		Cut 200	Return 100																			0
Slow	D	60 const			3		3	3		3	3											15
Acceleration		80 -> 60			3		3	3		3	3											15
		80 const			3		3	3		3	3											15
		100 -> 80			3		3	3		3	3											15
WOT & PT	D	Slow	1/4	20 const ->	3	3	3	3	3			3	3	3	3	3						30
			2/4		3	3	3	3	3													15
			1/4		3	3	3	3	2.75													14.75
		Rapid	4/4		3	3	3	3	3			3	3	3	3	3						30
Rapid:	D	Slow	1/4	30 const ->	3	3	3	3	3			3	3	3	3	3						30
Approx 0.5			2/4		3	3	3	3	3													15
sec			1/4		3	3	3	3	3													15
Full close		Rapid	4/4		3	3	3	3	3			3	3	3	3	3	8.82					30
to open		Slow	4/4	60 const ->	3	3	3	3	3			3	3	3	3	3						30
		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
Slow	D	Slow	1/4	60 const -> 90 -> 80																		0
Approx 1-2			2/4		3	3	3	3	3													15
sec			1/4																			0
Full close		Rapid	2/4		3	3	3	3	3			3	3	3	3	3						30
to open		Slow	4/4	60 const ->	3	3	3	3	2.75			3	3	3	3	3						29.75
Constant Vacuum	D	0.6		50 const ->	3	3	3	3	3													15
		0.3			3	3	3	3	3													15
		0.15			3	3	3	3	3													15
Acceleration	1	20 const -> 15 -> 25		A/C on	3					3	3							3				12
& Deceleration				A/C off	3					3	3							3				12
1/4-2/4 PT	2	30 const->20->40->25		A/C on	3					3	3							3	3			15
Rapid Acceleration				A/C off	3					3	3							3	3			15
Engine Brake	3	40 const->30->50->35		A/C on	3					3	3							3	3			15
				A/C off	3					3	3							3	3			15
Secondary Shock	D	50 cons -> 120			3			3														6
Deceleration	D	120 cons -> 60			3				3				3						3			12
	2	100 cons -> 60			3				3				3						3			12
	2	cut 200 -> return 100																				0
Run on	D	Top 80km/hr x 4km			3																	3
																						653.5
					132	51	72	75	77.5	42	42	24	30	24	24	24		18	18			653.5

FIGURE APPENDIX B:-11: MAGNA 1985 - E10 - HD TEST RESULTS

Test Data - Bourke

Hot Driveability Test Result - Falcon ULP

														Knock							
Test Item		Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High spee	Accel	Rabbit hop	Decel	
Hot Idle		D	Idling Stop		A/C off	5	5														10
					A/C on	5															5
Constant		D	Creep Running			5				5											10
		2	40			5				4.5											9.5
		D	60			5				4.5											9.5
			80			5				4.5											9.5
			100			5				4.5											9.5
			120			5				4.5											9.5
Surge Max Gear		-	-																		0
Tip - in		D	20 const			5		5	5		5	5									25
			40 -> 20			5		5	4		5	5									24
			Cut 200 rp	Return 100 rpm		5		5	3.5		5	5									23.5
1/8 - 1/4 PT		D	40 const			5		5	5		5	5									25
			60 -> 40			5		5	5		5	5									25
			Cut 200	Return 100		5		5	4		5	5									24
Slow		D	60 const			5		5	5		3.5	5									23.5
Acceleration			80 -> 60			5		5	5		3.5	5									23.5
			80 const			5		5	5		5	5									25
			100 -> 80			5		5	4		5	5									24
WOT & PT		D	Slow	4/4	20 const -> 60 -> 50	5		5	5	5			5	5	5	5	5	5			50
				2/4		5		5	5	5								5			25
				1/4		5		5	5	5								5			25
			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
Rapid:		D	Slow	4/4	30 const -> 60 -> 50	5		5	5	5			5	5	5	5	5	5			50
Approx 0.5				2/4		5		5	5	5								5			25
sec				1/4		5		5	5	5								5			25
Full close			Rapid	4/4		5		5	5	5			5	5	5	5	5				45
to open			Slow	4/4	60 const -> 100 -> 90	5		5	5	5			5	5	5	5	5	5			50
			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
Slow		D	Slow	4/4	60 const -> 90 -> 80	5		5	4	5			5	5	5	5	5	5			49
Approx 1-2				2/4		5		5	4	5								5			24
sec				1/4		5		5	4	5								5			24
Full close			Rapid	2/4		5		5	4	5			5	5	5	5	5				44
to open			Slow	4/4	60 const -> 100 -> 90	5		5	5	5			5	5	5	5	5				45
Constant Vacuum		D	0.6		50 const -> 90	5		5	5	5											20
			0.3			5		5	5	5											20
			0.15			5		5	5	5											20
Acceleration		1	20 const -> 15 -> 25		A/C on	5													5		10
& Deceleration					A/C off	5													5		10
1/4-2/4 PT		2	30 const->20->40->2		A/C on	5					5	5							5	5	25
Rapid Acceleration					A/C off	5					5	5							5	5	25
Engine Brake		3	40 const->30->50->3		A/C on	5					5	5							5	5	25
					A/C off	5					5	5							5	5	25
Secondary Shock		D	50 cons -> 120			5			5												10
Deceleration		D	120 cons -> 60			5				5				5						5	20
		2	100 cons -> 60			5				5				5						5	20
		2	cut 200 -> return 100			5				5		5									15
Run on		D	Top 80km/hr x 4km			5															5
Engine	Restart	D	Connect Clutch after 15 minutes			5	5														10
Soak	R-D surge	2	40			5				4											9
	max gearspeed					5				5											10
	WOT&PT	D	Slow	4/4	40 cons->80->70	5	5	5	5	5			5	5	5	5	5	5			55
	Slow:	D		2/4		5	5	5	4	5								5			29
	approx1-2s			1/4		5	5	5	5	5								5			30
	rapid		Rapid	4/4		5	5	5	5	5			5	5	5	5	5				50
	approx 0.5s																				1329
						270	30	160	155.5	161.5	67	75	55	65	55	55	55	65	30	30	1329

FIGURE APPENDIX B:-12: FALCON - NEAT PETROL - HD TEST RESULTS

Hot Driveability Test Result - Falcon E10

															Knock					
Test Item		Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High speed	Accel	Rabbit hop	Decel	
Hot Idle		D	Idling Stop		A/C off	5	5														10
					A/C on	5															5
Constant		D	Creep Running			5				5											10
		2	40			5				5											10
		D	60			5				5											10
			80			5				5											10
			100			5				5											10
			120			5				5											10
Surge Max Gear		-	-																		0
Tip - in		D	20 const			5		5	5		5	5									25
			40 -> 20			5		5	5		5	5									25
			Cut 200 rp	Return 100 rpm		5		5	5		5	5									25
1/8 - 1/4 PT		D	40 const			5		5	5		5	5									25
			60 -> 40			5		5	5		5	5									25
			Cut 200	Return 100		5		5	5		5	5									25
Slow		D	60 const			5		5	5		5	5									25
Acceleration			80 -> 60			5		5	5		5	5									25
			80 const			5		5	5		5	5									25
			100 -> 80			5		5	5		5	5									25
WOT & PT		D	Slow	4/4	20 const -:	5		5	5	5			5	5	5	5	5	5			50
				2/4		5		5	5	5								5			25
				1/4		5		5	5	5								5			25
			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
Rapid:		D	Slow	4/4	30 const -:	5		5	5	5			5	5	5	5	5	5			50
Approx 0.5				2/4		5		5	5	5								5			25
sec				1/4		5		5	5	5								5			25
Full close			Rapid	4/4		5		5	5	5			5	5	5	5	5				45
to open			Slow	4/4	60 const -:	5		5	5	5			5	5	5	5	5	5			50
			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
Slow		D	Slow	4/4	60 const -:	5		5	5	5			5	5	5	5	5	5			50
Approx 1-2				2/4		5		5	5	5								5			25
sec				1/4		5		5	5	5								5			25
Full close			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
to open			Slow	4/4	60 const -:	5		5	5	5			5	5	5	5	5				45
Constant Vacuum		D	0.6		50 const -:	5		5	5	5											20
			0.3			5		5	5	5											20
			0.15			5		5	5	5											20
Acceleration		1	20 const -> 15 -> 25		A/C on	5													5		10
& Deceleration					A/C off	5													5		10
1/4-2/4 PT		2	30 const->20->40->25		A/C on	5					5	5							5	5	25
Rapid Acceleration					A/C off	5					5	5							5	5	25
Engine Brake		3	40 const->30->50->35		A/C on	5					5	5							5	5	25
					A/C off	5					5	5							5	5	25
Secondary Shock		D	50 cons -> 120			5			5												10
Deceleration		D	120 cons -> 60			5				5				5						5	20
		2	100 cons -> 60			5				5				5						5	20
		2	cut 200 -> return 100			5				5		5									15
Run on		D	Top 80km/hr x 4km			5															5
Engine	Restart	D	Connect Clutch after 15 minutes			5	5														10
Soak	R-D surge	2	40			5				3.5											8.5
	max gearspeed					5				5											10
	WOT&PT	D	Slow	4/4	40 cons->8	5	5	5	5	5			5	5	5	5	5	5			55
	Slow:	D		2/4		5	5	5	5	5								5			30
	approx1-2s			1/4		5	5	5	5	5								5			30
	rapid		Rapid	4/4		5	5	5	5	5			5	5	5	5	5				50
	approx 0.5s																				
						270	30	160	165	163.5	70	75	55	65	55	55	55	65	30	30	1343.5

FIGURE APPENDIX B:-13: FALCON - E10 - HD TEST RESULTS

Hot Driveability Test Result - Camry ULP

																Knock					
Test Item		Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Accelerati	High spee	Accel	Rabbit hop	Decel	
Hot Idle		D	Idling Stop		A/C off	5	5														10
					A/C on	5															5
Constant		D	Creep Running			5				4.5											9.5
		2	40			5				4.5											9.5
		D	60			5				3.5											8.5
			80			5				4.5											9.5
			100			5				4.5											9.5
			120			5				4.5											9.5
Surge Max Gear		2	60							3.5											3.5
Tip - in		D	20 const			5		4.5	3.5		5	5									23
			40 -> 20			5		5	5		5	5									25
			Cut 200 rp	Return 100 rpm		5		4	4		4	5									22
1/8 - 1/4 PT		D	40 const			5		4	4		4	5									22
			60 -> 40			5		4	4		4	5									22
			Cut 200	Return 100		5		5	5		5	5									25
Slow		D	60 const			5		4.5	4.5		4.5	4.5									23
Acceleration			80 -> 60			5		4.5	4.5		4.5	4.5									23
			80 const			5		4.5	5		5	5									24.5
			100 -> 80			5		4.5	5		5	5									24.5
WOT & PT		D	Slow	4/4	20 const -	5		5	5	5			5	5	5	5	5	5			50
				2/4		5		5	5	5								5			25
				1/4		5		5	5	5								5			25
			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
Rapid:		D	Slow	4/4	30 const -	5		5	5	5			5	5	5	5	5	5			50
Approx 0.5				2/4		5		5	5	5								5			25
sec				1/4		5		5	5	5								5			25
Full close			Rapid	4/4		5		5	5	5			5	5	5	5	5				45
to open			Slow	4/4	60 const -	5		5	5	5			5	5	5	5	5	5			50
			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
Slow		D	Slow	4/4	60 const -	5		5	5	5			5	5	5	5	5	5			50
Approx 1-2				2/4		5		5	5	5								5			25
sec				1/4		5		5	5	5								5			25
Full close			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
to open			Slow	4/4	60 const -	5		5	5	5			5	5	5	5	5				45
Constant Vacuum		D	0.6		50 const -	5		5	5	5											20
			0.3			5		5	5	5											20
			0.15			5		5	5	5											20
Acceleration		1	20 const -> 15 -> 25		A/C on	5													5		10
& Deceleration					A/C off	5													5		10
1/4-2/4 PT		2	30 const->20->40->25		A/C on	5					3.5	5							5	5	23.5
Rapid Acceleration					A/C off	5					4	5							5	5	24
Engine Brake		3	40 const->30->50->35		A/C on	5					4	5							5	5	24
					A/C off	5					4	5							5	5	24
Secondary Shock		D	50 cons -> 120			5			3.5												8.5
Deceleration		D	120 cons -> 60			5				5				5						5	20
		2	100 cons -> 60			5				5				5						5	20
		2	cut 200 -> return 100			5				5		5									15
Run on		D	Top 80km/hr x 4km			5															5
Engine	Restart	D	Connect Clutch after 15 minutes			5	5														10
Soak	R-D surge	2	40			5				3											8
	max gearspeed					5				3											8
	WOT&PT	D	Slow	4/4	40 cons->	5	5	5	5	5			5	5	5	5	5	5			55
	Slow:	D		2/4		5	5	5	5	3.5								5			28.5
	approx1-2s			1/4		5	5	5	5	3.5								5			28.5
	rapid		Rapid	4/4		5	5	5	3.5	5			5	5	5	5	5				48.5
	approx 0.5s																				
						270	30	154.5	156.5	157.5	61.5	74	55	65	55	55	55	65	30	30	1314

FIGURE APPENDIX B:-14: CAMRY - NEAT PETROL - HD TEST RESULTS

Hot Driveability Test Result - Camry E10

															Knock						
Test Item		Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High speed	Accel	Rabbit hop	Decel	
Hot Idle		D	Idling Stop		A/C off	5	5														10
					A/C on	5															5
Constant		D	Creep Running			5				5											10
		2	40			5				5											10
		D	60			5				4											9
			80			5				5											10
			100			5				5											10
			120			5				5											10
Surge Max Gear		2	60							4											4
Tip - in		D	20 const			5		5	5		5	5									25
			40 -> 20			5		4	5		5	5									24
			Cut 200 rp	Return 100 rpm		5		5	5		5	5									25
1/8 - 1/4 PT		D	40 const			5		5	4		5	5									24
			60 -> 40			5		5	4		5	5									24
			Cut 200	Return 100		5		5	5		5	5									25
Slow		D	60 const			5		5	5		5	5									25
Acceleration			80 -> 60			5		5	5		5	5									25
			80 const			5		5	5		5	5									25
			100 -> 80			5		5	5		5	5									25
WOT & PT		D	Slow	4/4	20 const -	5		5	5	5			5	5	5	5	5	5			50
				2/4		5		5	5	5								5			25
				1/4		5		5	5	5								5			25
			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
Rapid:		D	Slow	4/4	30 const -	5		5	5	5			5	5	5	5	5	5			50
Approx 0.5				2/4		5		5	5	5								5			25
sec				1/4		5		5	5	5								5			25
Full close			Rapid	4/4		5		5	5	5			5	5	5	5	5				45
to open			Slow	4/4	60 const -	5		5	5	5			5	5	5	5	5	5			50
			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
Slow		D	Slow	4/4	60 const -	5		5	5	5			5	5	5	5	5	5			50
Approx 1-2				2/4		5		5	5	5								5			25
sec				1/4		5		5	5	5								5			25
Full close			Rapid	2/4		5		5	5	5			5	5	5	5	5				45
to open			Slow	4/4	60 const -	5		5	5	5			5	5	5	5	5				45
Constant Vacuum		D	0.6		50 const -	5		5	5	5											20
			0.3			5		5	5	5											20
			0.15			5		5	5	5											20
Acceleration		1	20 const -> 15 -> 25		A/C on	5													5		10
& Deceleration					A/C off	5													5		10
1/4-2/4 PT		2	30 const->20->40->25		A/C on	5					5	5							5	5	25
Rapid Acceleration					A/C off	5					5	5							5	5	25
Engine Brake		3	40 const->30->50->35		A/C on	5					5	5							5	5	25
					A/C off	5					5	5							5	5	25
Secondary Shock		D	50 cons -> 120			5			5												10
Deceleration		D	120 cons -> 60			5				5				5						5	20
		2	100 cons -> 60			5				5				5						5	20
		2	cut 200 -> return 100			5				5		5									15
Run on		D	Top 80km/hr x 4km			5															5
Engine	Restart	D	Connect Clutch after 15 minutes			5	5														10
Soak	R-D surge	2	40			5				4											9
	max gearspeed					5				4											9
	WOT&PT	D	Slow	4/4	40 cons->	5	5	5	5	5			5	5	5	5	5	5			55
	Slow:	D		2/4		5	5	5	5	5								5			30
	approx1-2s			1/4		5	5	5	5	5								5			30
	rapid		Rapid	4/4		5	5	5	5	5			5	5	5	5	5				50
	approx 0.5s																				
						270	30	159	163	166	70	75	55	65	55	55	55	65	30	30	1343

FIGURE APPENDIX B:-15: CAMRY - E10 - HD TEST RESULTS

Hot Driveability Test Result - Lexcen Neat

															Knock						
Test Item		Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High speed	Accel	Rabbit hop	Decel	
Hot Idle		D	Idling Stop		A/C off	4.25	4.5														8.75
					A/C on	4.5															4.5
Constant		D	Creep Running			4.5				4											8.5
		2	40			4.5				4											8.5
		D	60			4.5				4											8.5
			80			4.5				4											8.5
			100			4.5				4											8.5
			120			4.5				4											8.5
Surge Max Gear		2	60																		0
Tip - in		D	20 const			4.5		4.5	5		5	5									24
			40 -> 20			4.5		4	5		5	4									22.5
			Cut 200 rp	Return 100 rpm																	0
1/8 - 1/4 PT		D	40 const			4.5		4.5	5		5	5									24
			60 -> 40			4.5		4.5	5		5	4									23
			Cut 200	Return 100																	0
Slow		D	60 const			4.5		4.25	5		5	5									23.75
Acceleration			80 -> 60			4.5		4	5		5	5									23.5
			80 const			4.5		4	5		5	5									23.5
			100 -> 80			4.5		4	5		5	5									23.5
WOT & PT		D	Slow	4/4	20 const -:	4.5		4	4.5	4.5			5	5	5	5	5	4			46.5
				2/4		4.5		4	4.5	4.5								4			21.5
				1/4		4.5		4	4.5	4.5								4			21.5
			Rapid	2/4		4.5		4	4.5	4.5			5	5	5	5	5				42.5
Rapid:		D	Slow	4/4	30 const -:	4.5		4	4.5	4.5			5	5	5	5	5	4			46.5
Approx 0.5				2/4		4.5		4	4.5	4.5								4			21.5
sec				1/4		4.5		4	4.5	4.5								4			21.5
Full close			Rapid	4/4		4.5		4	4.5	4.5			5	5	5	5	5				42.5
to open			Slow	4/4	60 const -:	4.5		4	4.5	4.5			5	5	5	5	5	4			46.5
			Rapid	2/4		4.5		4	4.5	4.5			5	5	5	5	5				42.5
Slow		D	Slow	4/4	60 const -:	4.5		4	4.5	4.5			5	5	5	5	5	4			46.5
Approx 1-2				2/4		4.5		4	4.5	4.5								4			21.5
sec				1/4		4.5		4	4.5	4.5								4			21.5
Full close			Rapid	2/4		4.5		4	4.5	4.5			5	5	5	5	5				42.5
to open			Slow	4/4	60 const -:	4.5		4	4.5	4.5			5	5	5	5	5				42.5
Constant Vacuum		D	0.6		50 const -:	4.5		4	4.5	4.5											17.5
			0.3			4.5		4	4.5	4.5											17.5
			0.15			4.5		4	4.5	4.5											17.5
Acceleration		1	20 const -> 15 -> 25		A/C on	4.5													5		9.5
& Deceleration					A/C off	4.5													5		9.5
1/4-2/4 PT		2	30 const->20->40->25		A/C on	4.5					5	5							5	2.5	22
Rapid Acceleration					A/C off	4.5					5	5							5	2.5	22
Engine Brake		3	40 const->30->50->35		A/C on	4.5					5	5							5	2.5	22
					A/C off	4.5					5	5							5	2.5	22
Secondary Shock		D	50 cons -> 120			4.5			4.5												9
Deceleration		D	120 cons -> 60			4.5				4.5				5						2.5	16.5
		2	100 cons -> 60			4.5				4.5				5						3.5	17.5
		2	cut 200 -> return 100																		0
Run on		D	Top 80km/hr x 4km			4.5															4.5
Engine	Restart	D	Connect Clutch after 15 minutes			4.5	4.5														9
Soak	R-D surge	2	40			4.5				4.5											9
	max gearspeed																				0
	WOT&PT	D	Slow	4/4	40 cons->8	4.5	4.5	4.5	4.5	4.5			5	5	5	4.5	5	4.5			51.5
	Slow:	D		2/4		4.5	4.5	4.5	4.5	4.5								4.5			27
	approx1-2s			1/4		4.5	4.5	4.5	4.5	4.5								4.5			27
	rapid		Rapid	4/4		4.5	4.5	4.5	4.5	4.5			5	5	5	5	5				47.5
	approx 0.5s																				0
						224.75	27	123.75	143.5	136.5	60	58	55	65	55	54.5	55	53.5	30	16	1157.5

FIGURE APPENDIX B:-16: LEXCEN - NEAT PETROL - HD TEST RESULTS

Hot Driveability Test Result - Lexcen E10

Test Item		Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Knock			Accel	Rabbit hop	Decel	
															Acel/Dece	Acceleratir	High speed				
Hot Idle		D	Idling Stop		A/C off	4.5	4.5														9
					A/C on	4.25															4.25
Constant		D	Creep Running			4.25				4											8.25
		2	40			4				4											8
		D	60			4				4											8
			80			4				4											8
			100			4				4											8
			120			4				4											8
Surge Max Gear		2	60																		0
Tip - in		D	20 const			4		4	4.5		4	4									20.5
			40 -> 20			4		4	4.5		4	4									20.5
			Cut 200 rp	Return 100 rpm																	0
1/8 - 1/4 PT		D	40 const			4		4	4.5		4	4									20.5
			60 -> 40			4		4	4.5		4	4									20.5
			Cut 200	Return 100																	0
Slow		D	60 const			4		4	4.5		4	4									20.5
Acceleration			80 -> 60			4		4	4.5		4	4									20.5
			80 const			4		4	4.5		4	4									20.5
			100 -> 80			4		4	4.5		4	4									20.5
WOT & PT		D	Slow	4/4	20 const -:	4		4	4.5	4.5			5	5	5	5	5	4			46
				2/4		4		4	4.5	4.5								4			21
				1/4		4		4	4.5	4.5								4			21
			Rapid	2/4		4		4	4.5	4.5			5	5	5	5	5				42
Rapid:		D	Slow	4/4	30 const -:	4		4	4.5	4.5			5	5	5	5	5	4			46
Approx 0.5				2/4		4		4	4.5	4.5								4			21
sec				1/4		4		4	4.5	4.5								4			21
Full close			Rapid	4/4		4		4	4.5	4.5			5	5	5	5	5				42
to open			Slow	4/4	60 const -:	4		4	4.5	4.5			5	5	5	5	5	4			46
			Rapid	2/4		4		4	4.5	4.5			5	5	5	5	5				42
Slow		D	Slow	4/4	60 const -:	4		4	4.5	4.5			5	5	5	5	5	4			46
Approx 1-2				2/4		4		4	4.5	4.5								4			21
sec				1/4		4		4	4.5	4.5								4			21
Full close			Rapid	2/4		4		4	4.5	4.5			5	5	5	5	5				42
to open			Slow	4/4	60 const -:	4		4	4.5	4.5			5	5	5	5	5				42
Constant Vacuum		D	0.6		50 const -:	4		4	4.5	4.5											17
			0.3			4		4	4.5	4.5											17
			0.15			4		4	4.5	4.5											17
Acceleration		1	20 const -> 15 -> 25		A/C on	4													5		9
& Deceleration					A/C off	4													5		9
1/4-2/4 PT		2	30 const->20->40->25		A/C on	4					4	4.5							5	2.5	20
Rapid Acceleration					A/C off	4					4	4.5							5	2.5	20
Engine Brake		3	40 const->30->50->35		A/C on	4					4	4.5							5	2.5	20
					A/C off	4					4	4.5							5	2.5	20
Secondary Shock		D	50 cons -> 120			4			4.5												8.5
Deceleration		D	120 cons -> 60			4				4.5				5						2.5	16
		2	100 cons -> 60			4				4.5				5						2.5	16
		2	cut 200 -> return 100																		0
Run on		D	Top 80km/hr x 4km			4															4
Engine	Restart	D	Connect Clutch after 15 minutes			4.5	5														9.5
Soak	R-D surge	2	40			4				4											8
	max gearspeed																				0
	WOT&PT	D	Slow	4/4	40 cons->8	4	4	4	4.5	4.5			5	5	5	5	5	4			50
	Slow:	D		2/4		4	4	4	4.5	4.5								4			25
	approx1-2s			1/4		4	4	4	4.5	4.5								4			25
	rapid		Rapid	4/4		4	4	4	4.5	4.5			5	5	5	5	5				46
	approx 0.5s																				
						201.5	25.5	120	139.5	136	48	50	55	65	55	55	55	52	30	15	1102.5

FIGURE APPENDIX B:-17: LEXCEN - E10 - HD TEST RESULTS

Hot Driveability Test Result - Magna Neat

															Knock						
Test Item		Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High speed	Accel	Rabbit hop	Decel	
Hot Idle		D	Idling Stop		A/C off	3.5	4														7.5
					A/C on	4															4
Constant		D	Creep Running			4				4											8
		2	40			3.5				3.5											7
		D	60			3.5				3.5											7
			80			4				4											8
			100			4				4											8
			120			4				4											8
Surge Max Gear		2	60																		0
Tip - in		D	20 const			4		4	4		4	4									20
			40 -> 20			4		4	4		4	4									20
			Cut 200 rp	Return 100 rpm																	0
1/8 - 1/4 PT		D	40 const			4		4	4		4	4									20
			60 -> 40			4		4	4		4	4									20
			Cut 200	Return 100																	0
Slow		D	60 const			4		4	4		4.5	4.5									21
Acceleration			80 -> 60			4		4	4		4.5	4.5									21
			80 const			4		4	4		4.5	4.5									21
			100 -> 80			4		4	4		4.5	4.5									21
WOT & PT		D	Slow	4/4	20 const ->	4		4	4	4			4.5	4.5	4.5	4.5	4.5	4			42.5
				2/4		4		4	4	4								4			20
				1/4		4		4	4	4								4			20
			Rapid	2/4		4		4	4	4			4.5	4.5	4.5	4.5	4.5				38.5
Rapid:		D	Slow	4/4	30 const ->	4		4	4	4			4.5	4.5	4.5	4.5	4.5	4			42.5
Approx 0.5				2/4		4		4	4	4								4			20
sec				1/4		4		4	4	4								4			20
Full close			Rapid	4/4		4		4	4	4			4.5	4.5	4.5	4.5	4.5				38.5
to open			Slow	4/4	60 const ->	4		4	4	4			4.5	4.5	4.5	4.5	4.5	4			42.5
			Rapid	2/4		4		4	4	4			4.5	4.5	4.5	4.5	4.5				38.5
Slow		D	Slow	4/4	60 const ->	4		4	4	4			4.5	4.5	4.5	4.5	4.5	4			42.5
Approx 1-2				2/4		4		4	4	4								4			20
sec				1/4		4		4	4	4								4			20
Full close			Rapid	2/4		4		4	4	4			4.5	4.5	4.5	4.5	4.5				38.5
to open			Slow	4/4	60 const ->	4		4	4	4			4.5	4.5	4.5	4.5	4.5				38.5
Constant Vacuum		D	0.6		50 const ->	4		4	4	4											16
			0.3			4		4	4	4											16
			0.15			4		4	4	4											16
Acceleration		1	20 const -> 15 -> 25		A/C on	4													5		9
& Deceleration					A/C off	4													5		9
1/4-2/4 PT		2	30 const->20->40->25		A/C on	4					4	4							5	4	21
Rapid Acceleration					A/C off	4					4	4							5	4	21
Engine Brake		3	40 const->30->50->35		A/C on	4					4	4							5	4	21
					A/C off	4					4	4							5	4	21
Secondary Shock		D	50 cons -> 120			4			4												8
Deceleration		D	120 cons -> 60			4				4				4.5						4	16.5
		2	100 cons -> 60			4				4				4.5						4	16.5
		2	cut 200 -> return 100																		0
Run on		D	Top 80km/hr x 4km			4															4
Engine	Restart	D	Connect Clutch after 15 minutes			4	4														8
Soak	R-D surge	2	40			4				4											8
	max gearspeed																				0
	WOT&PT	D	Slow	4/4	40 cons->8	4	4	4	4	4			4.5	4.5	4.5	4.5	4.5	4			46.5
	Slow:	D		2/4		4	4	4	4	4								4			24
	approx1-2s			1/4		4	4	4	4	4								4			24
	rapid		Rapid	4/4		4	4	4	4	4			4.5	4.5	4.5	4.5	4.5				42.5
	approx 0.5s																				0
						198.5	24	120	124	123	50	50	49.5	58.5	49.5	49.5	49.5	52	30	24	1052

FIGURE APPENDIX B:-18: MAGNA - NEAT PETROL - HD TEST RESULTS

Hot Driveability Test Result - Magna E10																					
															Knock						
Test Item		Gear	Condition			Good	Safety	Slow Res	Stumble	Surge	Jerk	Shock	Backfire	Afterfire	Acel/Dece	Acceleratir	High speed	Accel	Rabbit hop	Decel	
Hot Idle		D	Idling Stop		A/C off	4	4														8
					A/C on	4															4
Constant		D	Creep Running			4				4											8
		2	40			4				3.5											7.5
		D	60			4				4											8
			80			4				4											8
			100			4				4											8
			120			4				4											8
Surge Max Gear		2	60																		0
Tip - in		D	20 const			4		4	4		4	4									20
			40 -> 20			4		4	4		4	4									20
			Cut 200 rp	Return 100 rpm																	0
1/8 - 1/4 PT		D	40 const			4		4	4		4	4									20
			60 -> 40			4		4	4		4	4									20
			Cut 200	Return 100																	0
Slow		D	60 const			4		4	4		4	4									20
Acceleration			80 -> 60			4		4	4		4	4									20
			80 const			4		4	4		4	4									20
			100 -> 80			4		4	4		4	4									20
WOT & PT		D	Slow	4/4	20 const ->	4		4	4	4			4.5	4.5	4.5	4.5	4.5	4			42.5
				2/4		4		4	4	4								4			20
				1/4		4		4	4	4								4			20
			Rapid	2/4		4		4	4	4			4.5	4.5	4.5	4.5	4.5				38.5
Rapid:		D	Slow	4/4	30 const ->	4		4	4	4			4.5	4.5	4.5	4.5	4.5	4			42.5
Approx 0.5				2/4		4		4	4	4								4			20
sec				1/4		4		4	4	4								4			20
Full close			Rapid	4/4		4		4	4	4			4.5	4.5	4.5	4.5	4.5				38.5
to open			Slow	4/4	60 const ->	4		4	4	4			4.5	4.5	4.5	4.5	4.5	4			42.5
			Rapid	2/4		4		4	4	4			4.5	4.5	4.5	4.5	4.5				38.5
Slow		D	Slow	4/4	60 const ->	4		4	4	4			4.5	4.5	4.5	4.5	4.5	4			42.5
Approx 1-2				2/4		4		4	4	4								4			20
sec				1/4		4		4	4	4								4			20
Full close			Rapid	2/4		4		4	4	4			4.5	4.5	4.5	4.5	4.5				38.5
to open			Slow	4/4	60 const ->	4		4	4	4			4.5	4.5	4.5	4.5	4.5				38.5
Constant Vacuum		D	0.6		50 const ->	4		4	4	4											16
			0.3			4		4	4	4											16
			0.15			4		4	4	4											16
Acceleration		1	20 const -> 15 -> 25		A/C on	4													4.5		8.5
& Deceleration					A/C off	4													4.5		8.5
1/4-2/4 PT		2	30 const->20->40->25		A/C on	4					4	4							4.5	4	20.5
Rapid Acceleration					A/C off	4					4	4							4.5	4	20.5
Engine Brake		3	40 const->30->50->35		A/C on	4					4	4							4.5	4	20.5
					A/C off	4					4	4							4.5	4	20.5
Secondary Shock		D	50 cons -> 120			4			4												8
Deceleration		D	120 cons -> 60			4				4				4.5						4	16.5
		2	100 cons -> 60			4				3.5				4.5						4	16
		2	cut 200 -> return 100																		0
Run on		D	Top 80km/hr x 4km			4															4
Engine	Restart	D	Connect Clutch after 15 minutes			4	4														8
Soak	R-D surge	2	40			4				4											8
	max gearspeed																				0
	WOT&PT	D	Slow	4/4	40 cons->8	4	4	4	4	4			4.5	4.5	4.5	4.5	4.5	4			46.5
	Slow:	D		2/4		4	4	4	4	4								4			24
	approx1-2s			1/4		4	4	4	4	4								4			24
	rapid		Rapid	4/4		4	4	4	4	4			4.5	4.5	4.5	4.5	4.5				42.5
	approx 0.5s																				0
						200	24	120	124	123	48	48	49.5	58.5	49.5	49.5	49.5	52	27	24	1046.5

FIGURE APPENDIX B:-19: MAGNA - E10 - HD TEST RESULTS

APPENDIX C:FUEL CONSUMPTION

US experience

Since the introduction of the oxygenated petrol (CO) and RFG (ozone) programs, the US EPA has received questions from the public regarding various aspects of the programs.

Many of the questions were related to reduced vehicle performance and fuel economy. Some motorists indicated economy losses in excess of 20% but such complaints were not consistent with the experiences of most motorists in regions using similar ethanol/petrol formulations. The complaints were also inconsistent with the results of many automotive testing programs which indicate that oxygenated petrols do not negatively impact vehicle drivability and will not produce more than a slight reduction in fuel economy.

Studies Related to Fuel Economy Effects

Numerous fuel economy test programs have been carried out in the US, by the US EPA and other scientific organisations, in relation to E10 fuels. Listed below are summaries of some E10 related fuel economy programs, the list has been taken from {4}.

- *"On-Road Study of the Effects of Reformulated Gasoline on Motor Vehicle Fuel Economy in Southeastern Wisconsin "* US. Environmental Protection Agency and the Wisconsin Department of Natural Resources, March 31,1995.

  The Wisconsin Department of Natural Resources and the U.S. Environmental Protection Agency conducted an on-road study of the fuel economy effects of RFG in March, 1995. The intent of the study was to respond to consumer concerns that RFG was responsible for large reductions in motor vehicle fuel economy much larger than the 2% to 3% reduction predicted by previous studies or by the theoretical energy content of the fuel formulations. In this study, fuel economy was measured from a group of Milwaukee area vehicles representing various model years and fuel delivery systems, and using four types of petrols, one conventional petrol and three oxygenated RFGs (MTBE, ETBE, and ethanol). Eight vehicles were driven over a fixed, 100-mile route with urban, suburban and rural segments. Their fuel usage was determined by weighing the fuel at the beginning and end of the route. The study utilised vehicles with highly variable technologies and included carburetted vehicles, port fuel-injected vehicles, and throttle body fuel-injected vehicles. The study vehicles included older and newer technology vehicles as well as a pick-up truck in order to represent as large an array of on-road vehicles as possible.

  In general, the results of this practical on-the-road study were consistent with the predictions (based on both laboratory and on-road studies, as well as the energy content of the fuels tested) that were set out in the RFG regulations. The average change in fuel economy when RFG was compared to conventional petrol was a 2.8% reduction in miles per gallon when using RFG.

- *40 CFR Part 80 Regulation of Fuels and Fuel Additives.' Standards for Reformulated and Conventional Gasolines, February 16th, 1994.*

  US EPA combined the results of 19 studies with over 4000 vehicle/fuel tests. The analysis confirmed that fuel economy impacts are solely a function of fuel energy content. The analysis concluded that fuel economy is reduced by 2% to 3% during the winter season and 1% to 2% during the summer season.

- *"Fuel Composition Effects on Automotive Fuel Economy - Auto/Oil Air Quality Improvement Research Program." Albert M Hochhauser et al, AQIRP, SAE Paper #93013&*

  "The Auto/Oil Air Quality Improvement Research Program (AQIRP) is a co-operative research program initiated by three domestic automobile companies and 14 Petroleum Companies. This paper discusses the fuel economy measurements from two fleets of vehicles running on fuels whose composition varied in a number of parameters. The vehicle fleets used in this study are identified as the "Current Fleet" (20 vehicles, 1989 model year) and the "Older Fleet" (14 vehicles, model years 1983 to 1985)."

  Summary of findings on fuel economy:

  1. "Reducing aromatics from 45% to 20% lowered fuel economy by 2.8% in the Current Fleet and by 3.2% in the Older Fleet."

  1. "Adding 2.7 wt.% oxygen (equivalent to 7.7% v/v ethanol) lowered fuel economy by 2.3% in the Current Fleet and by 1.6% in the Older Fleet."

  1. "Reducing T90 from 360°F to 280°F lowered fuel economy by about 1.5% in both fleets."

  1. "Reducing olefins from 20% to 5% lowered fuel economy by 0.2% in the Current Fleet and by 0.6% in the Older Fleet."

- *"Are the Reductions in Vehicle Carbon Monoxide Exhaust Emissions Proportional to the Fuel Oxygen Content?" IA. Gething. et al., Chevron Research Company SAE Paper #890216.*

  An average 1.8% decrease in fuel economy was observed in an 18-vehicle test program testing a non-oxygenated fuel and comparing it to a 2.0 wt.% MTBE fuel and a 3.5 wt.% ethanol fuel.

- *"Fuel Economy Effects -- Controlled Fleet Study" Memo from Frank Gerry BP Oil Company to Jim Williams, American Petroleum Institute, February 24,1995."*

British Petroleum Company conducted an extensive on-road fuel economy test program testing eight 1992 model cars on non-oxygenated fuel and a 10% ethanol blended fuel. Each car accumulated 20,000 miles of test data. The results of this study show a fuel economy loss due to the use of the ethanol blend of 3.3% for the summer season, 2.4% for the winter season, and 2.8% overall.

- *"The Effect of Gasoline Composition and Characteristics on Fuel Economy" Downstream Alternatives, Inc. Information Document #930901, September 1993.*

  This paper is a summary of current studies and an overview of the many factors that may affect fuel economy. The factors discussed are engine design, consumer practices, climate, and fuel composition. The paper emphasises the effects of oxygenates on fuel economy. The paper cites theoretical calculations and observed fuel economy results from several sources. The conclusion is that a 2.7 wt.% oxygen level (7.7% v/v ethanol) fuel will cause, on average, a 1.6% to 2.3% decrease in fuel economy.

As can be seen from the works cited, research in this area indicates that fuel economy loss experienced as a result of ethanol use agrees closely with the theoretical prediction for fuel energy loss. Thus, although it may be reasonable to conclude that any fuel economy loss experienced with oxygenate use is solely a function of the change in fuel composition and the resulting slight decrease in energy content of the fuel other effects such as drivability may confound the issue in some instances.

APPENDIX D:MATERIAL COMPATIBILITY

FCAI Correspondence

TOYOTA

TOYOTA MOTOR CORPORATION AUSTRALIA LIMITED A.C.N. 004 384 338

Our Ref: RC512-AU297-MSM

Mr. Ernie Lom
Chief Engineer
Apace Research
21 Ventura Rd
NORTHMEAD, NSW 2152

RE: FCAI advice on Material Compatibility & Driveability for E10 vehicles.

This advice concerns appropriate evaluation points to be applied to vehicles in the Ethanol field trials programme being conducted by Apace Research.

The following represents a practical synthesis of manufacturer experience, from both overseas and available local sources and is of necessity simplified to make results comparable across each vehicle make/model. Both Material Compatibility and Hot/Cold Driveability are covered.

1) Material Compatibility

While overseas experience with up to 30% Ethanol blends (principally the U.S.) has led to specification revisions by all manufacturers in materials and engine calibrations to provide acceptable operation on (at least) E10 blends, the Australian market vehicle, especially going back more that 10 years, could not be assumed to be compatible.

Basic engine design compatibility in such areas as inlet valve deposits and deposits on fuel delivery systems can be assessed on the Long term durability fleet vehicles. However, the following steps & judgements can be applied to the customer base fleet vehicles;

Corrosion in Steel fuel tanks and fuel tubes

- Tanks are manufactured from Terne coated steel sheet. Local coatings can have microporosity, (where protection is missing at a pin prick site) and the coating is also burned away where spot welding occurs (eg. for baffles) and may be a corrosion site in the presence of water in the fuel. Bogas' advice that a corrosion inhibitor (DCI 11) is added to all E10 may make corrosion unlikely. Therefore a visual inspection (of an empty tank) should be performed on a sampling basis only, until either a problem (ie. visible red rust) or 'no problem' is established.

- Fuel tubes are generally Terne coated on the outside and often uncoated inside, although Nickel coating is becoming common. However, on early tubes (up to the late 80's in some models) the fuel tube was Copper coated inside. Copper catalysation of the fuel was a known problem, in conjunction with high aromatic levels, to form 'sour fuel'. As this coating is only approx 4µm thick when new, it is unlikely any will remain on vehicles in the survey.

  As for fuel tanks, the inspection could be concentrated on vehicles with the older copper coated inner surface and also confirm no problems on newer vehicles. Again the corrosion inhibitor should provide boosted protection.

Elastomers

- General opinion is that elastomers (rubbers etc) will swell in the presence of ethanol. A laboratory test is not appropriate for the purposes of this programme and so the following should be used.

- Measure I.D. of fuel hose (both delivery and return to tank). Cut across hose at centre and measure the I.D. using a vernier calliper or similar. A reduction below the nominal diam. indicates swelling of hose.

- Hardness of hose, diaphragm, gasket;
  Using a 'SHORE A' hardness tester, compare a new part to exposed part, A 10 point or greater decrease in hardness indicates swelling of the elastomer.

- Burst pressure of hoses;
  This may not be achievable in the workshop as it requires a Water pressure test at 1.2 MPa (175 psi). Clamp one end of a hose & pressurise the other end. An unexposed hose should hold 1.2 MPa. A swollen hose will have a reduced burst resistance.

- Fuel cap vent valve;
  The valve should be inspected for abnormal appearance and functionally checked for open/close operation. Note that some caps are vacuum opening only (ie. allow outside air in to tank under vacuum). Others can incorporate an excess pressure relief valve feature (such as required if an evap pipe is accidentally blocked) and will open under pressure (usually less than 1 bar but above the pressure required to open the evap valve at the charcoal canister.

Corrosion of aluminium, zinc alloy and other non-ferrous metals

- Documentation on corrosion of zinc alloy (Mazak used in fuel system as fuel pump and carburettor bodies) and non-ferrous metals (except Aluminium) is not available. If corrosion of these components can be ignored due to lack of evidence, Aluminium corrosion is the only non-ferrous item to be considered.

- It has been common practice to 'flash Nickel coat' the inside of cast Aluminium fuel rails for U.S. market vehicles (mandatory E_{10} compatibility) to provide protection from water in the fuel. The inclusion of DCI 11 inhibitor in Bogas E_{10} may adequately cover this concern.

- Some locally built vehicles use a brazed steel fuel rail with zinc plated & chromate passivated coating. These may show signs of corrosion after extended life exposure.

  Industry recommendation is to:

- Confirm condition of float chambers on some carburettor vehicles using zinc alloy bodies.
- Confirm inside of injector rail of cast Aluminium and brazed steel types. Aim for samples of both 'Nickel coated' and 'as-cast' to compare performance.

2) Hot/Cold Driveability

It is anticipated that differences in physical properties of Ethanol compared with petrol, such as oxygen content and vapour pressure, may effect driveability parameters due to their effects on A/F ratio (lean-off) and fuel vaporisation. In addition it has been suggested that the high latent heat of vaporisation of Ethanol may contribute to some quenching of inlet manifold porting with subsequent effect on mixture atomisation.

To address evaluation of these expected effects, a number of characteristics of driveability will be targeted in the attached test cycle, composed of elements from local manufacturer's procedures.

Test condition	Driveability Characteristic	E10 cause
A) Hot weather (Bourke)	Idling/Throttle response Warm-up driveability Acceleration Hot fuel handling (vapour lock resistance) Steady state surge	Lean-off of A/F " " " " Vapour pressure Inlet quenching &/or A/F ratio lean-off
B) Cold weather (Cooma)	Cold starting Cold transient driveability	Carburettor Icing Lean-off of A/F

I trust the information provided here is sufficient to permit evaluation of field performance of E_{10} blends and will be happy to discuss any queries arising from same.

Yours sincerely,

Mark S. Morarty
For FCAI fuels committee

CC: K. Marsh - MMAL
R. Scholar - FCAI

GUD Correspondence

GUD
MANUFACTURING COMPANY PTY LTD

June 11, 1997

Mr. Daniel Negus
Apace Research Ltd
PO Box 141
Baulkham Hills
NSW 2153

Dear Daniel,

With reference to your letter dated 20th May 1997 concerning fuel filters and ethanol resistance within filter components, please find details of GUD fuel filters listed below.

Chemical Resistance Testing of GUD Manufacturing Co Plastic Petrol Filter
Material : Du Pont Zytel 103 HS-L

Chemical	Concentration %	Exposure Conditions		Dimensional Change	
		Temp °C	Time (days)	Weight (%)	Length (%)
Acetone	100	23 50	365 365	<1 1 - 4	0 +0.3
Benzene	100	23	90	0	0
Ethanol	95 95	23 50	365 365	4-9 4-9	+2.4 +2.8
Methanol	100	23	365	4-9	+3.0
Mineral Oil	100	23	62	+0.5	+0.2
Unleaded Petrol	100	23	62	+0.8	+0.2

Conclusion : All tests conducted showed excellent chemical exposure resistance.

I hope this information is of assistance to you. If you require any further information, please do not hesitate to contact our Engineering Manager, Mr. David Daff.

Kind Regards,

Colin E. Tidball
National Marketing & Sales Manager

Document2 245 Sunshine Road, Sunshine, Victoria, 3020, Australia P.O. Box 62, Sunshine, Victoria, 3020, Australia
Telephone 61 3 9243 3333 Facsimile 61 3 9243 3344 ACN 004 237 727

E100 Compatible Materials

TABLE APPENDIX D:-1: E10 TOLERANT METALS

Uses in Vehicles - Metals	
Alloy	**Typical Use**
Aluminium alloy	Carburettor, fuel pump casing
Aluminium alloy (cast)	Carburettor, accelerator pump casing, fuel tank fill pipe intake manifolds
Magnesium ally	Fuel Pump casing, plate on steel, brass component speciality-purpose two cycle engine, transmission housings
Copper	Brass & Bronze
Zinc	Brass, air cleaner, carburettor
Carbon steel	Fuel line, fuel pump fittings and casing, fuel filter, fuel tank, carburettor fuel inlet, accelerator pump
Cartridge brass	Fuel line fittings, carburettor jets and inlet needle, fuel bowl float, power valve, valve seats
Iron (cast)	Carburettor body, iron plates, engine block, intake and exhaust manifolds
Zinc alloy (cast)	Carburettor body, plate on steel, carburettor diaphragm
Terne plate	Fuel tank, fuel line, air cleaner assemblies
Brass	Fuel line fittings, carburettor jets and inlet needle, fuel bowl float, power valve, valve seats

TABLE APPENDIX D:-2: E10 TOLERANT ELASTOMERS & PLASTICS

Uses in Vehicles - Elastomers/Plastics	
Materials	Typical Use
Nitrile	Carburettor gaskets, fuel cap gasket and seals, fuel filter tube grommet, gas hoses, fuel bowl float, accelerator pump diaphragms and plunger, fuel pump diaphragm
Viton®	EGR valves, fuel inlet needle tip
Neoprene® (Chloroprene)	Fuel cap vent to carburettor tube cover, fuel hose cover
Epichlorohydrin -Homopolymer -Coploymer	Diaphragm, carburettor choke control, fuel tube to filter, fuel vapour return tube, hoses
Nylon 6 6	Carburettor float bowl baffle, fuel vapour storage canister, carburettor components
Delrin® (Acetyl polymer)	Carburettor components
Teflon®	Shaft Coatings, venturi valve
Polyethlene (high density)	Hoses
Nitrophyl® (Nitrile rubber)	Floats, accelerator pump cups
Fluoroelastomers	Fuel line. hoses, carburettor needle tips, gaskets, "O" rings and fuel pump couplers, evaporative emissions line, fuel filler necks

Note:- Manufacturer data suggests that Viton & flourelastomers are preferred materials for use with alcohols, ethers, and higher concentrations of aromatics.

Catalytic Converter

Macquarie Research Ltd
ACN 003 849 198

Initial Report on

The Testing of a Catalytic Converter from a Vehicle which has Operated on Petrohol

Professor Noel W. Cant
School of Chemistry
Macquarie University

July 1997

MACQUARIE
UNIVERSITY – SYDNEY

COMMERCIAL-IN-CONFIDENCE

Summary

The converter supplied by APACE has been examined and tested in the following ways

1. The canister was cut open and four samples taken from the catalyst honeycomb.

2. Each sample has been tested to determine its ability to remove four pollutants from a simulated exhaust gas.

3. The surface area of each sample has been measured.

Results are as follows.

1. Initial Inspection and Testing

According to information given on delivery the converter had been taken from a 1991 Ford Falcon EB which had travelled between 200,000 and 250,000 km. The manufacturers codes on the converter (AFMO2, 91DA5E211BA) are consistent with that. It is our understanding that the vehicle had fuel injection in which case the catalyst honeycomb should be of the three-way type with platinum and rhodium, and possibly palladium, as the active elements. However we have no chemical analyses of our own to confirm that.

The appearance of the catalyst honeycomb (oval in section 15 cm wide by 8 cm high by 15 cm long) was normal for a unit which had seen extensive use but without gross overheating. It was light grey in colour, cracked across the middle and with a few white deposits on the front face. The retaining gasket had corroded to a considerable degree but there had been no bypassing.

Seven samples (each approximately 2 cm long by 1 cm diameter) were cut end-to-end in sequence along the centre axis. The tests described below were carried out on samples from the following positions 1 (front), 2 (next in line), 4 (centre) and 7 (adjoining rear face).

2. Performance Testing

Our standard procedure is to heat each sample in a continuous flow of simulated exhaust gas while raising the temperature from room temperature to 500 °C. The outlet stream is continually analysed to establish the % removal of each component of the test gas. The test gas contains

carbon monoxide (CO) - arises in an engine through incomplete combustion of fuel
propene (C_3H_6) - representative of easy to oxidise hydrocarbons in unburnt fuel
propane (C_3H_8) - representative of hard to oxidise hydrocarbons in unburnt fuel
nitric oxide (NO) - arises from heating of air during combustion
oxygen and hydrogen - in amounts similar to real exhaust
the balance is inert helium

When the catalyst is working properly it converts the CO, fuel components and NO to harmless carbon dioxide, water and nitrogen.

The test results for the four samples from the APACE converter are plotted in Figs 1 to 4. The performance of a sample taken from a vehicle which had travelled only 3,000 km is shown for comparison in Fig. 5. The samples from the APACE converter require higher temperatures to remove carbon monoxide and propene and their ability to remove NO and propane is very much worse. The standard way of comparing the performance of catalysts in the above type of test is in terms of the temperature required to remove 50% of the carbon monoxide (denoted $T_{50}CO$), the corresponding temperature for propene ($T_{50}C_3H_6$) and the mean conversion of nitric oxide averaged over the temperature range from 100°C to 500°C. The performance of the four samples from the APACE converter expressed in these terms is shown in Table 1.

TABLE 1 Performance of Samples from APACE Petrohol Converter

Vehicle and Converter Details	Location #	$T_{50}CO$ °C	$T_{50}C_3H_6$ °C	Mean conv. NO, %
Our test code MU97080 APACE 1991 Falcon EB 200,000 - 250,000 km	1	265	280	13
	2	284	295	6
converter codes 91DA5E211BA AFM02	4	288	318	13
	7	307	335	11

Figures 6, 7 and 8 show how the performance of the APACE samples compares against that of a set of samples taken from near the front faces of the 45 three-way converters studied in our project for the Environmental Research Trust of New South Wales. The $T_{50}CO$ values for the four APACE samples all sit well above the limit we used to designate satisfactory performance in that study. The best performing sample (position #1) has worse performance than 60% of the samples in the set while #7 is worse than 90%. The behaviour of the four APACE samples is similar in terms of $T_{50}C_3H_6$. All are above the limit with #1 worse than 55% and #7 worse than 75% of the reference set. Their performance is worse still in terms of the mean conversion of NO. None of the samples can achieve a mean conversion better than 13% and all perform worse than 95% of the samples in our set of 45.

The limits shown in Figs 6 to 8 should not be regarded as absolute ones above which failure of the vehicle on a driving cycle test is inevitable. Rather they indicate that the performance of the catalyst is well down on that of new and also that of many converters which have been used for quite long periods. Most of the converters in the best (ie left) half of the curves in each figure were from vehicles which had travelled much more than the 80,000 km statutory requirement placed on vehicle manufacturers by Australia Design Rule 37/00.

A more direct comparison for the APACE samples is against results for samples taken from two particular vehicles in our set which were similar in type to the APACE one. The results for them are shown in the following Table.

TABLE 2 Performance of Samples from Two Comparison Converters

Vehicle and Converter Details	Location #	$T_{50}CO$ °C	$T_{50}C_3H_6$ °C	Mean conv. NO, %
Our test code: MU94033 1990 Falcon EA 104,065 km converter codes 90DA58211AA AFA25	1	269	333	17
	2	253	275	22
	4	258	283	30
	7	253	279	21
Our test code: MU96073 1992 Falcon EB 283,234 km converter codes 90DA5E211BB AFB33	1	287	318	41
	2	-	-	-
	4	274	309	52
	7	253	274	57

It is apparent that the APACE samples perform, on average, slightly worse than the ones in Table 2 in terms of $T_{50}C0$ and $T_{50}C_3H_6$. In terms of mean NO conversion they are very much worse than the vehicle with test code MU96073 and significantly worse than that tested as MU94033. A further notable difference is that the performance of the APACE samples falls from front to back (positions 1 thru 7) along the converter. That is quite unusual. More than 90% of the converters we have tested have lowest activity at the front in the manner seen for MU94033 and MU96073 in Table 2.

The significant point here is that both vehicles referred to in Table 2 had been tested according to the ADR37 driving cycle test and both failed when fitted with the converter from which our test samples were taken but subsequently passed when a new converter was fitted. The results for MU96073 are not relevant since the vehicle was tested on LPG and there was a carburrettion problem when first tested. The ADR test results for MU94033 are shown in Table 3 below.

Table 3 Results for ADR37 Test on Vehicle With Designation MU94033

	CO (g/km)	HC (g/km)	NO (g/km)
ADR standard	9.30	0.93	1.93
Test result old converter	10.8	1.2	2.2
Test result new converter	6.1	0.3	0.4

The vehicle failed marginally on all three pollutants with the original converter but performed much better especially in terms of HC and NO with the new converter. Since the performance of the samples from the APACE converter on our tests was significantly worse than that of those from MU94033 it seems highly likely that the APACE vehicle would not pass ADR37 either. The only proviso here is that there were no large changes in engine systems between the two models.

3. Surface Area

Catalyst honeycombs lose activity through the following causes

(i) Deposition of large amounts of contaminants which. reduce access by the pollutant gases
(ii) Overheating which collapses the oxide structure which supports the active metals
(iii) Sintering of the particles of active metal which reduces the number of surface atoms responsible for the pollution control reactions
(iv) Poisoning of the activity of the metal particles by specific contaminants such as lead

Causes (i) and (ii) are accompanied by substantial reductions in the surface area of the honeycomb which can be measured by the adsorption of gases according to a standard procedure called the BET method. Table 4 shows the surface area of the four APACE samples in comparison with those from tests MU94033 and MU96073

TABLE 4 Surface Areas of Samples From APACE and Comparison Converters

	Surface area in square metres (m^2/g)		
Location #	APACE converter	MU94033	MU96073
1	10.4	2.5	1.8
2	11.9	10.4	-
4	13.9	14.3	6.5
7	14.9	16.4	10.8

The surface area of samples from unused converters is usually in the range 25 to 30 m^2/g. It falls to 18 to 20m^2/g after a few thousand kilometres of use on a vehicle and declines slowly from then on. In our previous study of the 45 converters, samples with surface areas below 7 m^2/g always showed activities below the limits in Figs 6 to 8. The front samples from MU94033 and MU96073 have very low areas which we know is due to contamination by deposits containing phosphorus, calcium, zinc etc derived largely from the combustion of engine oil. Either the front sample from the APACE converter has been less contaminated, which is possible although unlikely because of the high kilometres travelled by the vehicle, or the contaminants have been deposited somewhat differently. The surface areas of samples from positions #2 thru #7 are similar for all three converters. The only conclusion that can be drawn from Table 4 is that the loss of performance by the APACE samples was not solely due to blockage of the oxide structure through either collapse or filling by contaminants. In those cases the surface areas would have been lower than observed.

Tentative Diagnosis

Based on past experience we believe that the deterioration of the catalyst honeycomb on the APACE vehicle was most likely due to normal wear and tear attributable to the high number of kilometres travelled by the vehicle. The data for the comparison honeycomb, MU94033, shows that 100,000 km of use with this type of vehicle can be sufficient to bring catalyst performance below that required to meet ADR37. It should not be inferred from this that there is a design problem - the relevant ADR regulations only require conformity for 80,000 km and MU94033 could well have met the standard then. The poorer performance still of the APACE samples on our tests can then be attributed to the extra distance travelled - greater than 200,000 km. No significance should be attached to the APACE samples being worse than those from the second comparison converter, MU96073, which had travelled a higher distance still (287,000 km) since that converter came from a taxi which had operated on LPG since new. Oil consumption, one factor in causing deterioration, is expected to be less on vehicles which are in near continuous use.

There are three special features of the test results for the APACE samples which warrant some comment.

(i) The performance at the rear of the converter is worse than at the front which is the reverse of the normal pattern
(ii) The surface areas are relatively uniform throughout rather than showing a sharply lower area at the front as is usual.
(iii) The deterioration in performance for NO removal is considerably greater than for CO and C_3H_6.

One possible explanation is that the exhaust gas temperature was a little lower than normal and the rise in temperature along the converter, which accompanies the pollution control reactions, was more gradual than usual. This could have two effects. Firstly the rear of the converter could run hotter than the front third, the reverse of normal. Secondly, the chemical form taken by contaminants derived from oil and fuel could be changed leading to a somewhat different deposition mechanism on the honeycomb with consequences in terms of surface area and possible poisoning of the active metals. (The samples from MU94033 and MU96073 contained palladium as a major ingredient and this is more prone to poisoning than platinum). Temperature effects of the above types have been reported in more extreme forms in tests on vehicles powered by pure methanol. We do not know the % of ethanol in the Petrohol or if the APACE vehicle had operated on it exclusively. The effect of 10 or 15% ethanol on exhaust temperature and exhaust composition would be quite small but possibly sufficient to have some effect on the temperature gradient in the converter.

There is one other effect of methanol fuels which has been described in the literature. In one test it was found to dissolve lead out of "terne" plate which is used to protect the interior surfaces of steel petrol tanks against corrosion. The resultant mobilisation of lead into the fuel resulted in severe catalyst poisoning. We don't know if the APACE vehicle had a plastic or a steel fuel tank but even if it was the latter we think it is highly unlikely that the ethanol in Petrohol would leach out lead.

If the above explanations for observations (i) and (iii) are incorrect then the only alternative one that occurs to us is that that the active metals in this particular converter are distributed unevenly with much less at the rear than the front. Analyses on other converters in the past have sometimes shown quite substantial variations but probably insufficient to account for the extent of variation in activity in the samples taken from the APACE converter.

It would be possible to shed some additional light on the above points through

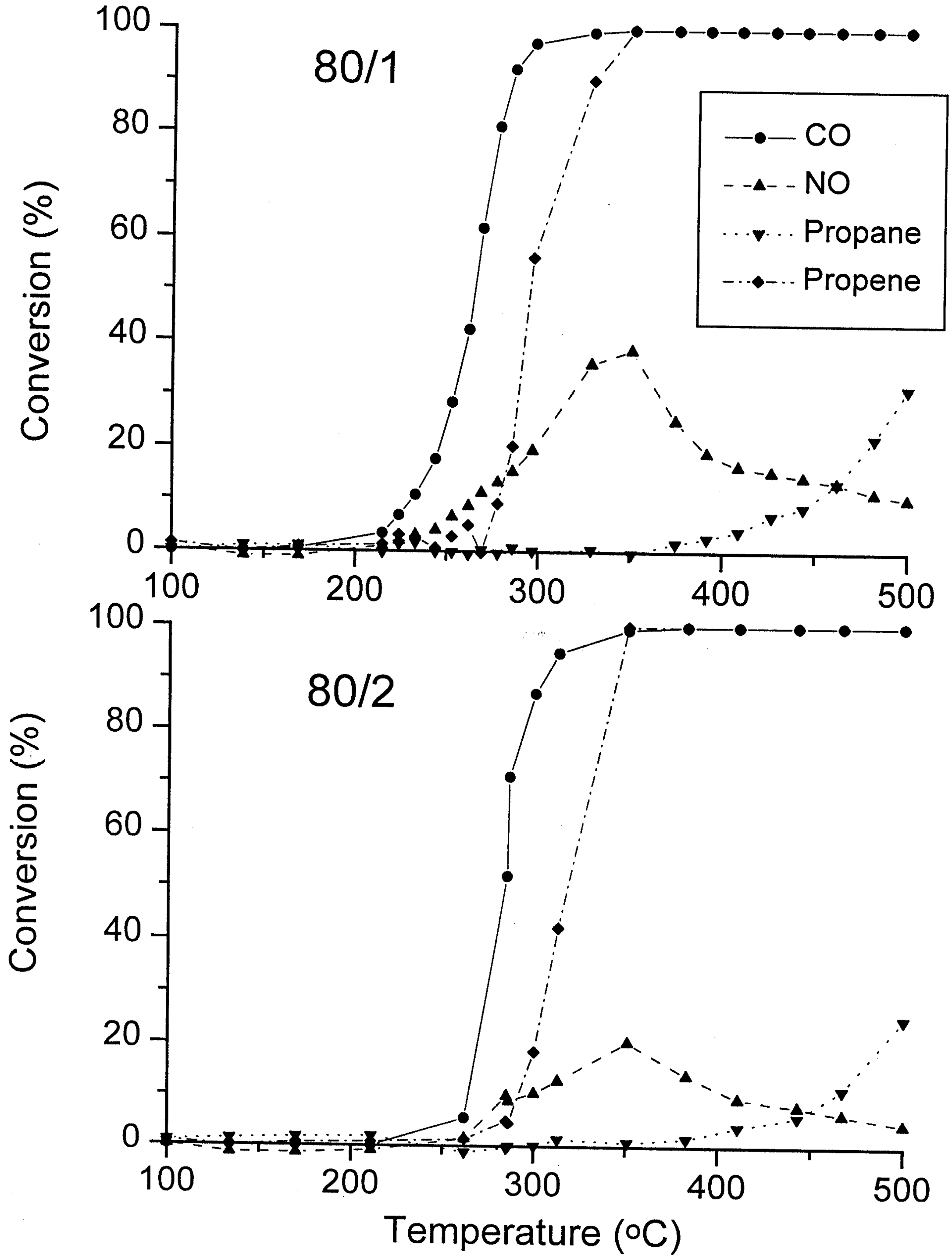
1. Analysis of the samples by the PIXE/PIGME method to determine if any contaminants are present in unusually high amounts and also to determine the amount of active metal at each sample location and whether palladium is present.
2. XRD measurements to see if any particular contaminant phases are present and to determine the size of ceria particles in the oxide support (from which the temperature experienced during use can sometimes be inferred).

Such additional work could provide extra assurance that nothing untoward had occurred in the APACE converter. However we think it is rather unlikely that the extra data would be of a form which would cause us to alter the tentative diagnosis expressed above (ie that deterioration is attributable to standard wear and tear on a vehicle which has travelled a long distance and hence not related to use of Petrohol itself).

Noel W. Cant

Dennys E. Angove 21 July 1997

Figures 1 and 2



Figures 3 and 4

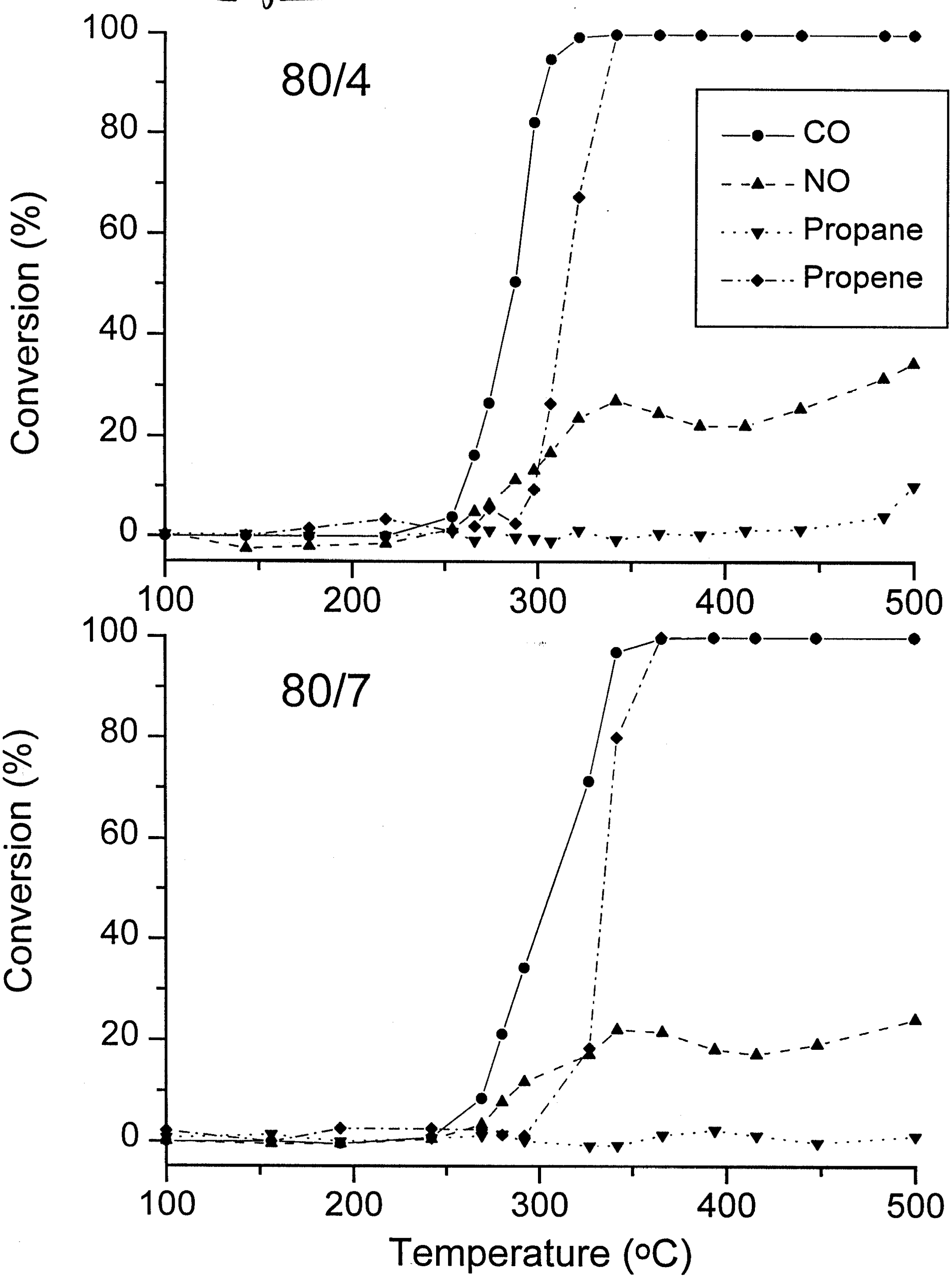


Figure 5

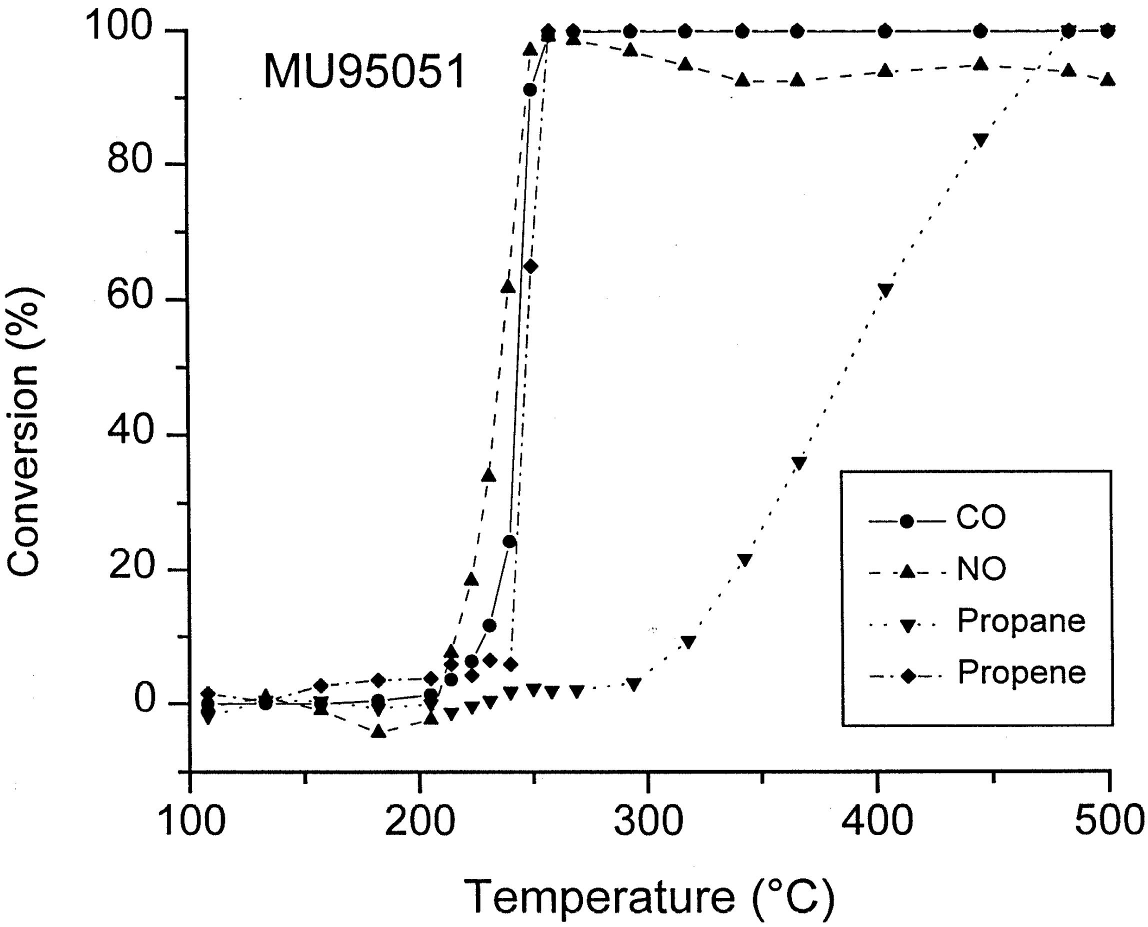
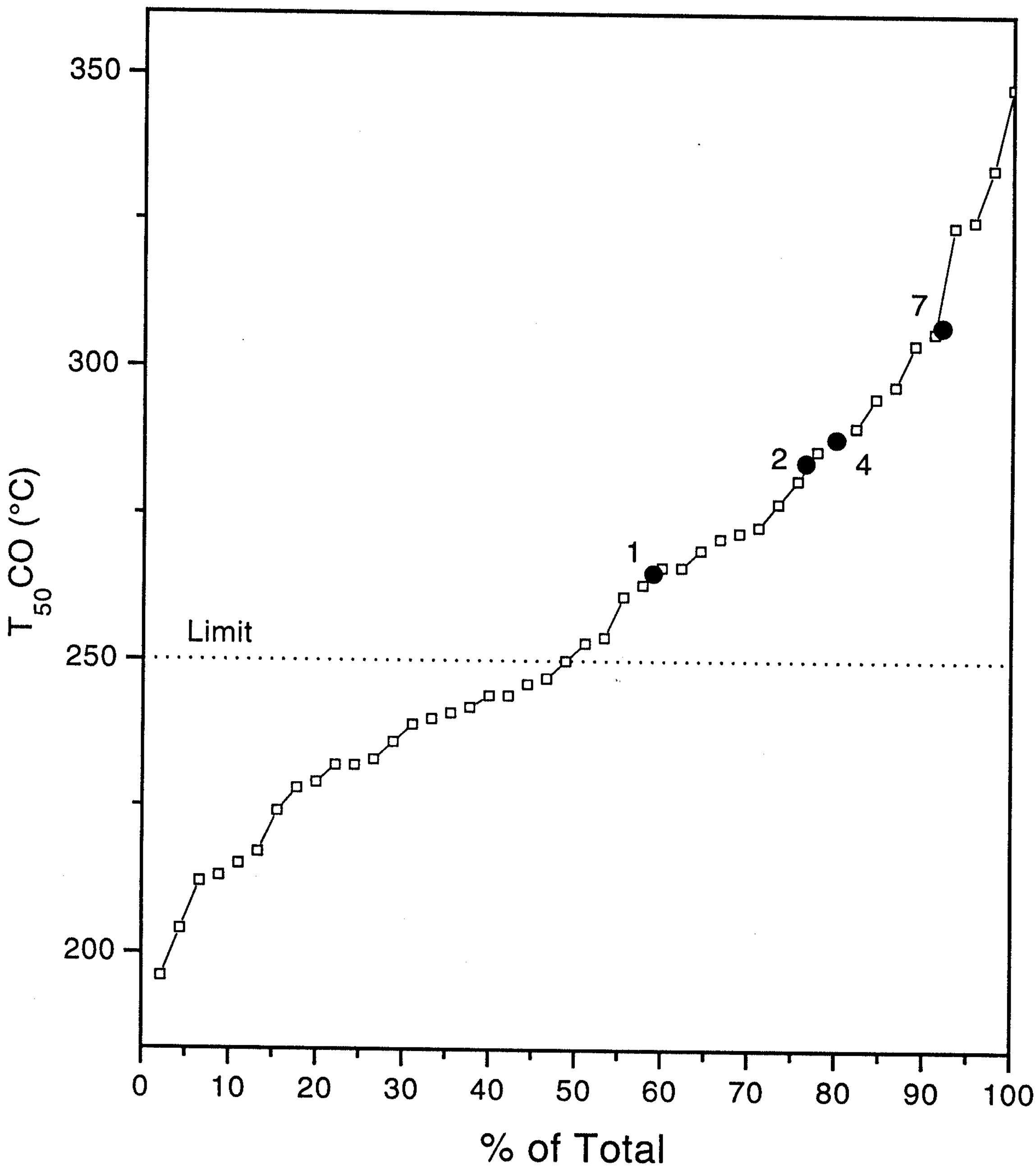

MU95051
Conversion (%)
100
80
60
40
20
0
100
200
300
400
500
Temperature (°C)
CO
NO
Propane
Propene

Figure 6



350
300
250
200
Limit
1
2
4
7
$T_{50}CO$ (°C)
0
10
20
30
40
50
60
70
80
90
100
% of Total

Figure 7

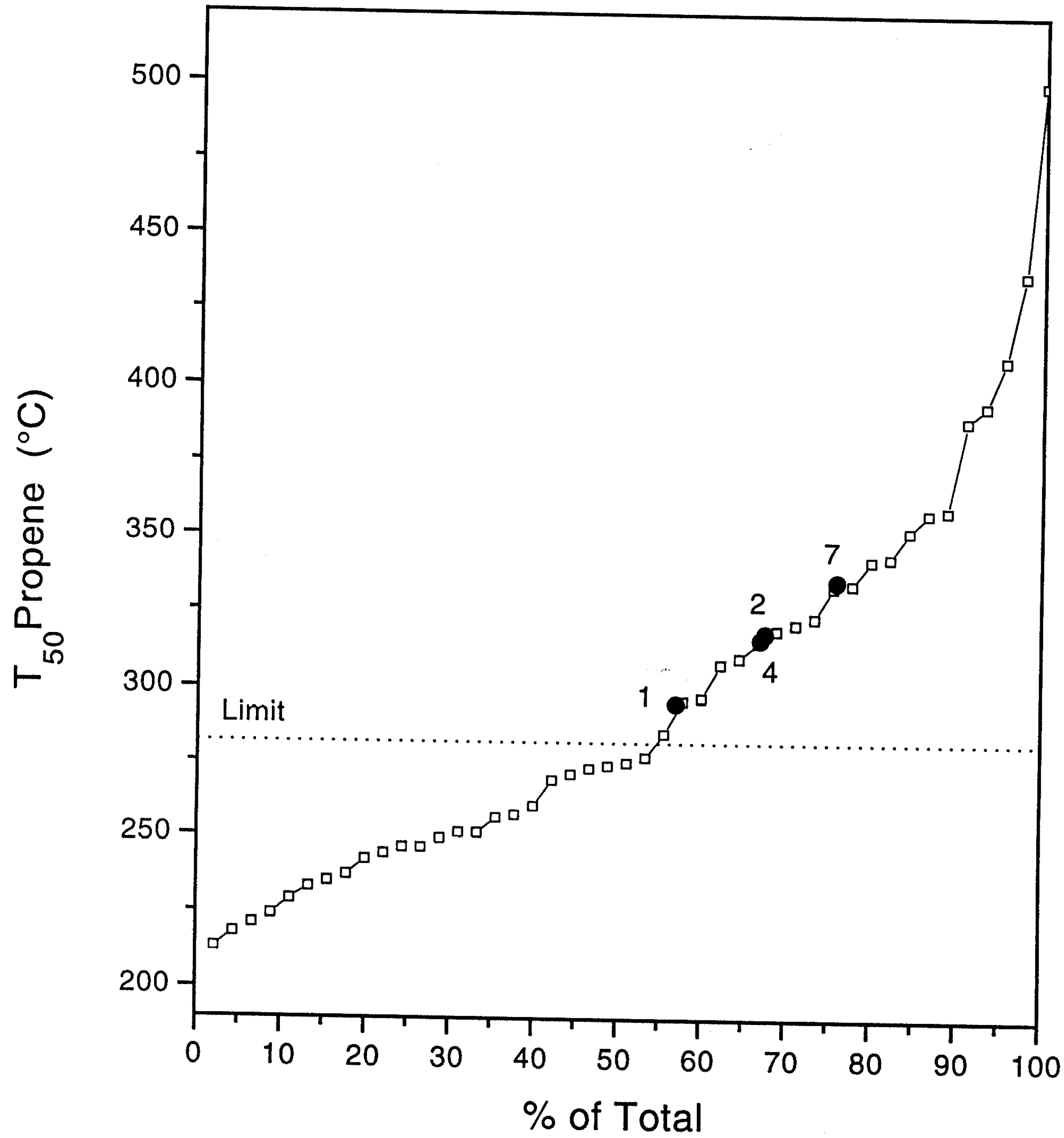
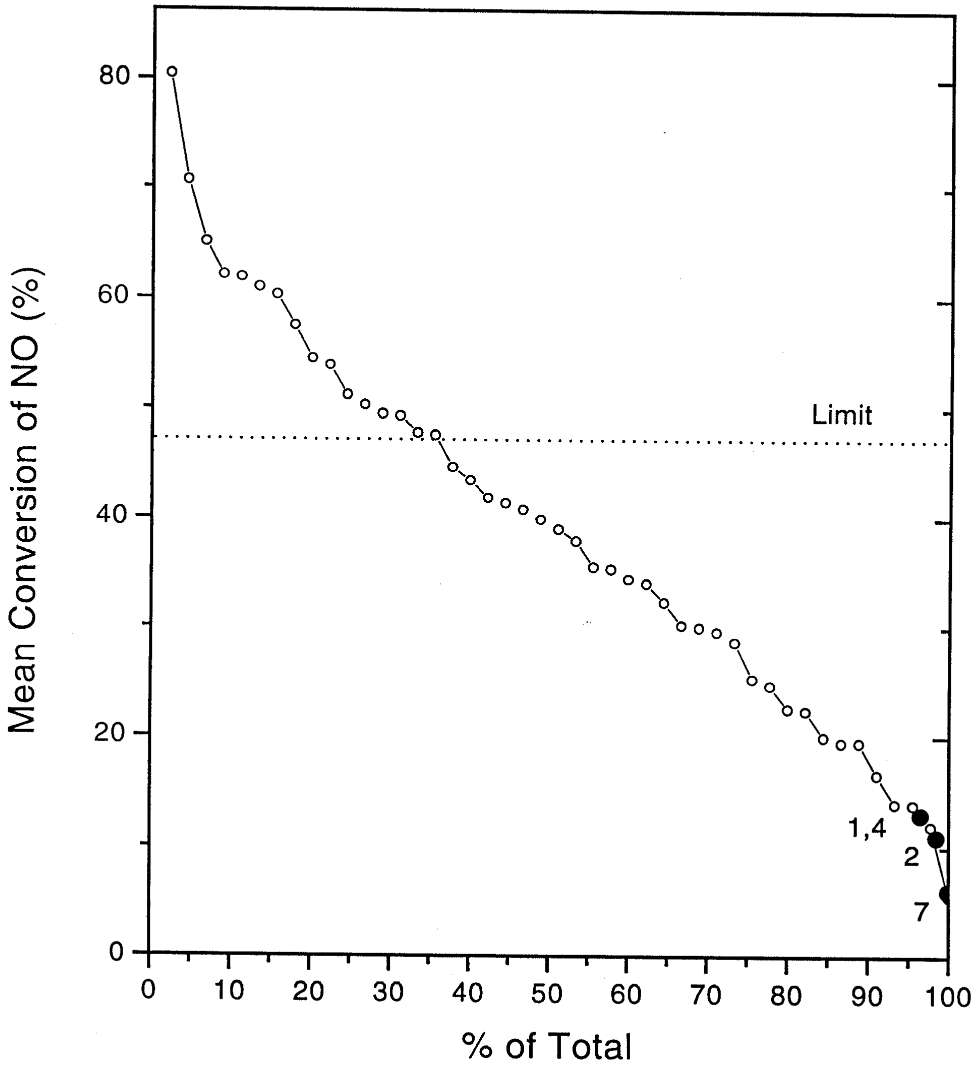

500
450
400
350
300
250
200
T_{50}Propene (°C)
Limit
1
2
4
7
0
10
20
30
40
50
60
70
80
90
100
% of Total

Figure 8



Mean Conversion of NO (%)
0
20
40
60
80
Limit
1,4
2
7
0
10
20
30
40
50
60
70
80
90
100
% of Total

Component Inspection Reports

NEVILLE WEBBER M.I.A.M.E. M.SAE.A
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LICENSED LOSS ASSESSOR & FORENSIC ENGINEER
33 DARLEY STREET, FORESTVILLE NSW 2087
Telephone: (02) 9451 6773 ❖ Mobile: 015 783 575

18th December, 1996

The Manager,
Apace Research,
21 Ventura Road,
NORTHMEAD NSW 2152

Dear Sir,

Further to the report carried out on the Ford Falcon NTL 353 fuel filters, fuel lines and in some cases EGR valves and filler caps were removed from the vehicles as detailed hereunder for analysis.

All fuel filters were dissected to inspect the bonding and condition of the paper elements being subjected to the ethanol blend.

In all instances, the filters, fuel lines, filler caps and EGR units were in serviceable condition.

VEHICLE	YEAR	REG.NO.	SPEEDO READING
Holden Commodore	1987	OTA 929	150,884 Klms.
Toyota Corona	1980	KTO 598	258,320 "
Ford Falcon EA	1988	PHF 441	244,562 "
Ford Falcon	1992	RG 235	248,012 "
Holden Camira	1985	NQS 898	229,957 "
Ford Falcon	1993	DJ 9970	49,057 "
Ford Falcon	1990	CP 268	87,995 "
Toyota Camry	1987	ABB 944	109,242 "
Mitsubishi Magna	1992	SYN 511	83,098 "
Ford Laser	1983	ABL 858	248,012 "

Yours faithfully,

NEVILLE WEBBER M.I.A.M.E. M.S.A.E.A.

Vehicle & Component Inspections * Independent Reporting * Specialising in Trade & Legal Requirements

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33 DARLEY STREET, FORESTVILLE NSW 2087
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10th June, 1997

The Manager,
Apace Research,
21 Ventura Road,
NORTHMEAD NSW 2152

Dear Sir,

Subsequent to the report on the Toyota Lexen TVM 115 a further analysis was carried out on the fuel delivery and ancilliary components of the following vehicles.

In most instances, the filters, fuel lines, spark plugs, filler caps, EGR units and seals were subjected to dissection where possible.

In all instances there was no apparent deterioration of the filter paper, seals, etc., as fitted to the intank pumps, gaskets.

In one instance only had the EGR valve been blocked off through apparent wear and tear. That vehicle being the Toyota Corona 1984, Q761ABJ at 175,000 kilometers.

VEHICLE	YEAR	REG.NO.	SPEEDO
Toyota Corolla	1984	77 281	128,000 KLMS
(Operational period on Ethanol fluid - 6 months)			
Mitsubishi Magna	1989	OYK 579	57,000 "
Holden Commodore	1986	GG 881	N/a
Holden Commodore	1988	ADW 84K	154,000 "
Toyota Corona	1984	Q761ABJ	175,000 "
Mitsubishi Sigma	1985	NHP 619	170,000 "
Mitsubishi Magna	1995	77F 843	45,000 "
Mitsubishi Magna	1992	SFP 585	N/a
Mitsubishi Magna	1992	SMX 261	120,000 "
Ford Falcon	N/a	N/a	N/a

Yours faithfully,

NEVILLE WEBBER M.I.A.M.E. M.S.A.E.A.

Vehicle & Component Inspections * Independent Reporting * Specialising in Trade & Legal Requirements

NEIL GILLIES & ASSOCIATES PTY LIMITED

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*****

REPORT ON ENGINE COMPONENTS IN ETHANOL TRIALS

*****

for
APACE RESEARCH LIMITED
20 MARCH 1997

INTRODUCTION

This report is a summary of relatively basic inspection of a number of components reportedly from some engines that had travelled some distance using a mix of 10 percent ethanol with petrol, after a request from Apace Research Limited. The components were seen at the NRMA service depot at Villawood on 19 February 1997.

The previous operating and servicing details of the vehicle were not known, so that the conclusions are only relevant for significant use with the petrol and ethanol mix.

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NGA20C97-ETHANOL-Page 2

The following components, marked as being from the vehicles with the noted identification and type, were inspected visually, to see if there had been some deterioration from their expected condition.

Vehicle: Holden Commodore VL 1987 OTA929 150884 km
Chassis: AVL049121M Engine: 17411A

Air filter - Ryco A326A	No unusual condition noted.
Petrol filter - Ryco Z200	No unusual condition noted.
Two fuel hoses	No unusual condition noted.
Fuel cap - Ford - Unleaded	No unusual condition noted.
Spark plugs - Champion RN13LYC	No unusual condition noted.

Vehicle: Toyota Corona 1980 KTO598 258320 km
Chassis: XT130-E-011486 Engine: UN20771

Air filter	No unusual condition noted.
Petrol filter - Ryco Plastic 90 deg	No unusual condition noted.
Two fuel hoses	Hardened somewhat
Vacuum hose - Normal at booster end, heat affected at engine end	
Carburettor float chamber gasket	No unusual condition noted.
Seal for carburettor fuel pump	No unusual condition noted.

Vehicle: Ford Falcon 1992

Petrol filter - Ryco GUD metal can - cut open - bonding and paper filter	No unusual condition noted.
Fuel hose - Red rubber	No unusual condition noted.
Air filter - Rectangular	No unusual condition noted.

Vehicle: Holden Camira JD 1985 NQS898 229957 km
Chassis: AJD020721M Engine: 18JUX25018601

Fuel hose	No unusual condition noted.
Air filter - Rectangular	No unusual condition noted.
Petrol filter - Holden 9541 metal can - cut open - No unusual condition noted.	

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NGA20C97-ETHANOL-Page 3

Vehicle: Toyota Camry Ultima 1987 ABB944 109242 km

Fuel filler cap	No unusual condition noted.
Spark plugs - ND Q16R-U	No unusual condition noted.
Rubber hose	No unusual condition noted.

Vehicle: Ford Falcon ED 1993 DJ9970 49057 km
Chassis: 6FPAAATGSWPD56445 Engine: 865183

Air filter - Rectangular Rydo A491	No unusual condition noted.
Fuel filler cap - Unleaded	No unusual condition noted.
Fuel hose - black	No unusual condition noted.
Spark plugs - NGK BPR5FS15	No unusual condition noted.

Vehicle: Mitsubishi Magna TR 1992 SYN511 83098 km
Chassis: 6MMTR4D41NT036254 Engine: W531B29245

Air filter - Square Ryco A489	No unusual condition noted.
Head cover gasket - rubber	Quite hard.
Fuel filler cap - Unleaded CPC	No unusual condition noted.
Spark plugs - NGK BP6ES	No unusual condition noted.
Fuel filter - metal can - cut open	No unusual condition noted.

Vehicle: Holden Camira 1985 NQB898

Fuel pressure regulator	Diaphragm reasonably flexible.
Fabric covered hose	No unusual condition noted.
Spark plugs - NGK BP5ES	No unusual condition noted.
Pump seal - 5 hole rubber	Slight expansion noted.
Fuel filler cap - locking GM	No unusual condition noted.

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NGA20C97-ETHANOL-Page 4

CONCLUSIONS

The following conclusions are thus given for the components of the vehicles using the petrol and ethanol mix:-

a) The condition of the components seen was not worse than than that expected from several years of use under normal conditions with petrol.

b) It was not possible to determine if the condition of the components from the vehicles from use with ethanol was any different from that expected with normal use, because details of the actual time and distance run of the items was not available.

NEIL GILLIES

BE, Grad Dip, ME, FIEAust, MIMechE, FSAEA

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*****

REPORT ON ENGINE COMPONENTS IN ETHANOL TRIALS

*****

for
APACE RESEARCH LIMITED
6 JUNE 1997

NGA06F97-ETHANOL-Page 1 of 5

INTRODUCTION

This report is a summary of relatively basic inspection of a number of components reportedly from some engines that had travelled some distance using a mix of 10 percent ethanol with petrol, after a request from Apace Research Limited. The components were seen at the NRMA service depot at Villawood on 5 June 1997.

The previous operating and servicing details of the vehicle were not known, so that the conclusions are only relevant for significant use with the petrol and ethanol mix.

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NGA06F97-ETHANOL-Page 2

The following components, marked as being from the vehicles with the noted identification and type, were inspected visually, to see if there had been some deterioration from their expected condition.

Vehicle: Toyota Corolla 1984 TT281

Air filter	Moderate amount of dirt No other unusual condition noted
Petrol filter - Ryco Z91 Plastic 90 deg	No unusual condition noted
Fuel hose	No unusual condition noted
Fuel cap	Steel screws somewhat rusty

Vehicle: Holden Commodore VH 1982 ABC556

Air filter - Round Blue Rubber - Ryco A24	Large amount of dirt No unusual condition noted
Spark plugs - Champion S9YC6	No unusual condition noted

Vehicle: Holden Commodore 1986 GG881

Fuel filler cap - Unleaded CPC/GM plastic	Rubber seal moderately hard
Spark plugs - Champion RC9YC4	No unusual condition noted

Vehicle: Mitsubishi Sigma GK 1985 NHP619

Air filter - Round Green Rubber	Moderate amount of dirt No unusual condition noted
Spark plugs - ND W20EP-U	Marking as if slightly lean/hot

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NGA06F97-ETHANOL-Page 3

Vehicle: Mitsubishi Magna 1989 OYK577

Fuel filler cap - Unleaded CPC/Tristar plastic
Rubber seal slightly soft
Fuel Hose — No unusual condition noted
Rubber head cover sealing ring
No unusual condition noted
Spark plugs - ND W20EP-U — Marking as if slightly lean/hot

Vehicle: Toyota Corona 761ABJ

Air filter - Round Metal Ends - Ryco A242Y
Moderate amount of dirt present
No unusual condition noted
Petrol filter - Plastic Straight
No unusual condition noted
Fuel hose — No unusual condition noted
EGR Valve Assy - Largely blocked
Valve jammed but diaphragm still flexible
Rubber head cover sealing ring
No unusual condition noted
Spark plugs - NGK BP5EY — Marking as if slightly lean/hot

Vehicle: Mitsubishi Magna 1995 TTF843

Air filter - plastic support frame - Square Yellow paper filter
Moderate amount of dirt present
No unusual condition noted
Fuel filler cap - Unleaded CPC/Tristar plastic
Rubber seal moderately hard
Fuel filter - metal can - cut open - Quite full - still wet
No unusual condition noted
Spark plugs - Champion N9YC — Marking as if slightly lean/hot

Vehicle: Mitsubishi Magna 1992 SFP585

Air filter - plastic support frame - Square yellow paper filter
- Ryco A489 — Minimal amount of dirt
No unusual condition noted
Fuel filter - metal can - cut open - Moderate amount of dirt present
No unusual condition noted
Spark plugs - NGK BP6ES — No unusual condition noted

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NGA06F97-ETHANOL-Page 4

Vehicle: Mitsubishi Magna 1992 SMX261

Fuel filler cap - Unleaded CPC/Tristar plastic	
	Rubber seal moderately hard
Fuel Hose with metal end fittings	
	Slightly soft
Spark plugs - ND W16EP-U	No unusual condition noted

Vehicle: Ford Falcon

Petrol filter - Metal can - cut open	
	Moderate amount of dirt present
	No unusual condition noted
Spark plugs - Champion RN13LYC	
	Marking as if slightly lean/hot

Vehicle: Holden Commodore 1988 ADW84K

Air filter - Rectangular EFI filter type	
	Medium amount of dirt present
	No unusual condition note
Fuel filler cap - Unleaded CPC/GM plastic	
	Rubber seal moderately hard
Fuel Hose	No unusual condition noted.
Tank electrical fuel pump rubber surround	
	Some hardening and shrinking but possibly partly after removal
Tank access cork gaskey	Some shrinking but possibly partly after and drying
Tank pickup strainer	Normal hardening
Fuel filter - metal can GUD NZ - cut open	
	Moderate amount of dirt
	No unusual condition noted
Spark plugs - Champion RS12YC6	
	Marking as if slightly rich

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NGA06F97-ETHANOL-Page 5

CONCLUSIONS

The following conclusions are thus given for the components of the vehicles using the petrol and ethanol mix:-

a) The condition of the components seen was not worse than than that expected from several years of use under normal conditions with petrol.

b) It was not possible to determine if the condition of the components from the vehicles from use with ethanol was any different from that expected with normal use, because details of the actual time and distance run of the items was not available.

NEIL GILLIES

BE, Grad Dip, ME, FIEAust, MIMechE, FSAEA

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SUMMARY OF REPORTS ON ENGINE AND COMPONENTS IN ETHANOL TRIALS

* * * * *

for
APACE RESEARCH LIMITED
7 JUNE 1997

INTRODUCTION

This report is a summary of assessments of some engines that reportedly were from vehicles that had travelled some distance to various extents using a mix of 10 percent ethanol with petrol, and similarly some components from some other various vehicles, after a request from Apace Research Limited.

The vehicles were seen at the NRMA service depot at Villawood on the dates shown, with their engines already removed and partly disassembled. The vehicle details are shown in the separate reports for reference purposes but brief details are shown here:-

DATE	VEHICLE	REG.	ODOMETER	YRS	CYL	REPORT
26-11-96	Ford Falcon	SKR946	205,504	4	6	NGA26K96
18-12-96	Ford Falcon	NTL353	102,117	11	6	NGA18L96
19-02-97	Holden Commodore	DP710	128,465	15	6	NGA19B97
5-06-97	Toyota Lexcen	TVM115	45,179	2	6	NGA05F97
19-02-97	Components	various	various	various		NGA20C97
5-06-97	Components	various	various	various		NGA06F97

The operating conditions of the vehicle were not known, and two of the vehicles would probably have spent less than half of their life on the petrol and ethanol mix.

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NGA07F97-ETHANOL-Page 2

SUMMARY

The main impression from the inspection of the mechanical components of the engines was the considerable difference in their previous use, which outweighed any effect of the use of ethanol. Any such effect and particularly on rubber and plastic components needs to be judged under closely controlled test conditions.

CONCLUSIONS

The following conclusions are thus given for the vehicles run on the petrol and ethanol mix:-

a) Although possibly different from that expected with those of petrol only, there were no problems found with the engine condition which would be attributed to the ethanol.

b) It was not possible to distinguish any extra or reduced wear of the engines from normal use due to the ethanol, particularly in two cases where the vehicle spent only a fraction of their life on the ethanol mix and where their previous lubrication was inadequate.

c) There was not believed to be sufficient control of comparative testing of vehicles for wear of the mechanical components to be resolved as a function of the use of ethanol, rather than a function of the particular use of each vehicle.

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APPENDIX E: ENGINE & FUEL SYSTEM WEAR

Engine Inspection Reports
1985 Ford Falcon XF

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* * * * *

REPORT ON ENGINE IN ETHANOL TRIALS 18 DECEMBER 1996

* * * * *

for
APACE RESEARCH LIMITED
18 DECEMBER 1996

NGA18L96-ETHANOL-Page 1 of 4

INTRODUCTION

This report is directed at an assessment of an engine that was from a vehicle that reportedly had travelled about 100,000 km with only about the last half of that distance using a mix of 10 percent ethanol with petrol, after a request from Apace Research Limited. The Ford Falcon sedan was seen at the NRMA service depot at Villawood on 18 December 1996, with the engine removed and partly disassembled. The vehicle details are shown in the Appendix for reference.

The purpose of the limited inspection was to determine if there were significant effects from the presence of the ethanol, given that the precise nature of the previous use of the vehicle was not known, and the nature of any previous parts replacement was also not known.

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INSPECTION

A skin had formed at some time of the oil deposits on the inner side of the sump and a section of about 100 x 150 mm was missing, and only a little of this was evident on the pump pick-up strainer and in the sump. There was oily caked material build-up in the cylinder head cover and the upper side of the cylinder head.

The main bearing shells showed largely copper and the big-end bearings showed copper in the centre third of the upper half shells. Both the main and big-end journals of the crankshaft were generally stained grey, and there were copper-coloured markings around the oil feed holes of the crankshaft.

There was evidence of an amount of block distortion around the bottom of some of the bores and there was a ridge at the top of the bores from a moderate amount of wear. There was some minor metal pick-up on three of the pistons. The camshaft drive link belt was quite loose.

The exhaust and inlet valve stems and guides only had moderate wear. There were corrosion marks on the inlet valve seat and a moderate build-up of carbon on the back of the inlet valve head. There was some corrosion build-up on the exhaust valve seats and valve face. There was normal carbon build-up in the combustion chambers.

The first and second piston rings had moderate wear, with the upper rings worn on the lower surface from normal type wear. All the oil control rings were moderately stuck in place in their piston grooves.

The carburettor float area was quite clean, but there was some minor expansion in the rubber float chamber seal. The carburettor was quite clean internally.

No unusual condition of any of the fuel hoses or seals on the vehicle were noted.

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NGA18L96-ETHANOL-Page 3

SPECIAL COMMENT

The previous operating and servicing details of the vehicle were not known, so that the conclusions are only relevant if the general conditions of use were normal, the engine had not been previously reconditioned, and the vehicle was substantially used with the petrol and ethanol mix.

SUMMARY

From the inspection shown above, and given the age and distance travelled of the vehicle, the main impression was that the engine had been generally subjected to poor lubrication schedules and/or oil types. It had been significantly overheated at least once.

CONCLUSIONS

The following conclusions are assumed to be, but not guaranteed, for a vehicle which had travelled 100,000 km:-

a) Although possibly different from that expected with petrol only, there were some problems found with the engine condition but these are regarded as attributed to the inadequate lubrication and overheating and not to the ethanol.

b) Although with some moderately deteriorated compression and performance, the engine would probably have been expected to be able to be used for about another 50,000 km (to 150,000 km) but with poor performance if it had not been dismantled, provided that the recommended lubrication schedule was used for that distance.

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NGA18L96-ETHANOL-Page 4

c) Reassembly of the engine with replacement rings and bearing shells after proper cleaning would result in reasonable compression and performance, and the capability of running perhaps another 100,000 km, provided that the recommended lubrication schedule was used for that distance.

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APPENDIX

VEHICLE DETAILS

FORD FALCON XF Sedan Registration NTL-353 102,117 km odometer
6 Cylinder OHV engine 4-speed manual Transmission

ADR PLATE Seats 5 12 85 JG23FE 72973 C

VIN PLATE	Prefix	Serial		SIDO
	JG23FE	72973 C		556176
	MODEL 18433	ENGINE L	TRANS L	
	TRIM W2	PAINT A	BUILT DEC 85	

ENGINE NUMBER JG23FE
72973 C

NRMA

ENGINE INSPECTION

A Ford Falcon XF Sedan bearing the below identification was inspected at the workshop of NRMA Fairfield Street, Villawood on the 18th December 1996, for the purpose of inspecting engine components for adverse wear, following usage over a period of time of an Ethanol blend fuel.

Vehicle Identification:	Ford Falcon Sedan
Series Type:	XF
Compliance Plate Date:	December 1985
Registration:	NTC 353
Speedometer Reading:	102 117 kilometres
Vehicle Identification No:	JG23FE72973C

The engine had been removed from the vehicle and dismantled having the cylinder head removed and dismantled, sump pan removed, all pistons removed and the carburettor removed from the manifold and dismantled.

Observations

1. Moderate to heavy oil sludge residue about the sump pan interior areas. The centre lower areas of the sump pan were devoid of sludge consistent with major oil flow washing. The oil pump pick up screen was free of any major sludge residue.

2. Heavy oil sludge residue build up about the interior of the rocker cover, cylinder head upper surface, valve springs and rocker arms. Timing chain displayed excess wear and oil sludge build up on chain.

3. Oil residue in air filter areas adjacent to engine breather pipe inlet.

4. Evidence of coolant leakage at water pump gasket area and the hose fitting spigot displayed moderate corrosion damage.

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NRMA

5. The back of the inlet valve heads displayed varying degrees of carbon residue and the carbon was of an oil wet nature.
The valve stems displayed minimal wear at their guide contact areas, some general wear in keeping with the distance travelled was evident in the valve guides. All the valve seats and valve seat contact surfaces of the valves displayed some general wear again consistent with the distance travelled. The valve stem seals had hardened due to age and excess heat, their sealing on the valve stems was of a limited nature due to their condition.

6. The cylinder bores displayed heavy load polished wear markings at the piston skirt thrust areas. The lower areas of the cylinder bores displayed an abnormal uneven ring wear contact markings and were oil varnish discoloured. Some minor cross hatch hone markings were still visible in the cylinder bores. The cylinder bores recorded varying degrees of wear ranging from 0.01mm to 0.07mm, ovality was recorded at 0.04mm and taper at 0.04mm to 0.07mm. The lower areas of the cylinder bores recorded varying degrees of out of round with a maximum of 0.04mm being noted.

7. Numbers one (1), three (3) and five (5) pistons displayed progressive early stages of seizure to the skirt areas, the number five (5) piston being the most affected. The pistons recorded wear ranging from 0.02mm to 0.03mm. The carbon residue on the piston crowns displayed no major oil wetting.

8. All the pistons oil control rings were held solid in their respective grooves due to oil sludge/oil carbon residue build up about the ring lands. The circumferential expander of the oil control rings had contacted the cylinder bores, this was most pronounced at the expander end sections. Limited service life remaining to the oil control rails.

9. The top compression rings displayed heavy wear to their underside surfaces, wear was recorded at 0.10mm. The second compression rings displayed wear to the under surfaces also, however to a lesser degree. Compression rings recorded end gaps ranging from 2.50mm to 3.57mm, the greater end gaps being present to the top rings.

10. The crankshaft displayed an oil varnish discolouration of the crankpins and main journals. The crankpins recorded a maximum of 0.01mm wear and ovality. The number six (6) crankpin displayed a noticeable branding mark of the precision inserts joint across the journal surface. All the crankshaft journals displayed fine scoring of the surfaces. The number four (4) main journal displayed a noticeable score mark about its centre area consistent with an oil borne foreign object being present in the early stages of engine service. The corresponding precision inserts lower section displayed a corresponding score markings.

Australian Quality Awards Winner 1992

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NRMA

11. All the crankpin and main bearing precision inserts displayed general wear of their load contact areas. The crankpin precision inserts displayed abrasive wear/score marks to the lower sections. Oil clearance of the crankpin precision inserts was found to average 0.10mm.

12. The oil residue about the main journal precision inserts evidenced a putrid burnt odour.

13. No evidence of major deterioration of carburettor gaskets, fuel bowl or fuel hose or emission component hoses. The fuel tank sender unit and associated fuel lines displayed no abnormal deterioration or corrosion damage.

CONCLUSIONS

As a result of my inspection of the said engine, it is my opinion that the engine displays lack of regular oil change maintenance and as a result of this, oil borne contamination wear has taken place.

The piston partial seizure and distortioning of the lower cylinder bores would indicate that the engine had, had a major overheat due to the lack of coolant. The putrid oil smell would indicate that the overheating would have been of a recent nature.

None of the wear present as listed in this report can be attributed to the Ethanol fuel blend used by the vehicle.

E Wardell, Inspecting Engineer
Automotive Technical Services, Pyrmont

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NEVILLE WEBBER M.I.A.M.E. M.SAE.A

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INSTITUTE OF AUTOMOTIVE MECHANICAL ENGINEERS iame

18th December, 1996

The Manager,
Apace Research,
21 Ventura Road,
NORTHMEAD NSW 2152

Dear Sir,

Re: FORD FALCON - REGISTERED NUMBER NTL 353
ENGINE NUMBER: JG23FF72973C
SPEEDO READING: 102,117 KILOMETERS

The following report has been carried out in order to assess the mechanical condition of the motor as fitted to the above mentioned vehicle and a number of its ancilliary components.

This particular unit has been operating on a blended fuel mixture of 10% ethanol for a period of three years.

At the time of the inspection the motor had been removed from its chassis and dismantled with the exception of the crankshaft and timing chest.

The examination revealed the following:

Cylinder bore dimensions were as detailed hereunder:

Lower unworn area: 3.682" or 93.5mm
Maximum wear and ovality being .004 or 0.10mm

All cylinder bores displayed substantial carbon layer at the lower area and some discolouration indicative of high operational temperatures.

Piston skirt measurements being 3.680".

Total skirt clearance at the maximum cylinder bore wear area being .006" or 0.15mm.

Pistons three and five displayed slight vertical scoring. Again indicative of extremes in temperature.

Piston rings were complete, however there was substantial side wear evident on the compression rings of .004" or 0.10mm.

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The butt ends of a number of the oil scraper expanders were in contact with the cylinder bores.

Rod alignment and gudgeon pins were in satisfactory condition.

Conrod journal measurements being 2.123" or 57mm standard.

Bearing to journal clearance being .004" or 0.10mm.

A number of main bearing caps were removed. Slipper bearings were slightly scored but serviceable.

The connecting rod slipper bearings, whilst still serviceable, had lost a significant amount of the lead overlay.

Cylinder head and valves were in satisfactory condition with no indication of poor seating or combustion loss.

Valve stem diameter being .342" or 0.87mm revealed a maximum clearance of .003" or 0.08mm.

The interior of the engine block and sump and valve cover were covered with a substantial residue of carbon.

Fuel lines, carburettor and ancilliary items did not reveal any significant deterioration or chemical reaction.

The fuel tank, sender unit and ancilliary fuel lines were also found to be in serviceable condition.

CONCLUSION

The examination of components submitted did not reveal excessive wear on the internal reciprocating units such as valves, pistons, crankshaft and rings considering the age of the vehicle and the distance travelled nor was there any evidence of impending failure.

However the motor appears to have suffered from a lack of regular oil changes and short operational periods resulting in the already mentioned build up of carbon residue.

As previously mentioned there was no apparent chemical reaction to the fuel components as a consequence of the ethanol blend.

..3/.

Apace Research -3- 18.12.96

Trusting this report will be of assistance to you.

Yours faithfully,

NEVILLE WEBBER M.I.A.M.E. M.S.A.E.A.

1995 Toyota Lexcen

NEIL GILLIES & ASSOCIATES PTY LIMITED

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REPORT ON ENGINE IN ETHANOL TRIALS 5 JUNE 1997

*****

for
APACE RESEARCH LIMITED
5 JUNE 1997

NGA05F97-ETHANOL-Page 1 of 4

INTRODUCTION

This report is directed at an assessment of an engine that was from a vehicle that reportedly had travelled about 45,000 km largely using a mix of 10 percent ethanol with petrol, after a request from Apace Research Limited. The Toyota Lexcen sedan was seen at the NRMA service depot at Villawood on 5 June 1997, with the engine removed and partly disassembled. The vehicle details are shown in the Appendix for reference.

The purpose of the limited inspection was to determine if there were significant effects from the presence of the ethanol, given that the precise nature of the previous use of the vehicle was not known, and the nature of parts replacement was also not known, except that it was understood that the major mechanical parts of the engine were replaced at some time due to an engine internal problem from original assembly.

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NGA05F97-ETHANOL-Page 2

INSPECTION

The crankcase and oilways and sump interior were quite clean, with no blocking of the oil pick-up screen. There was insufficient wear to form a ridge at the top of the bores, and there was almost no signs of wear in the lower portion of the bore. However there was some bore distortion evident at the siamesed areas. There was fatigue evident in the upper bigend shells.

The more recent combustion deposits on the tops of the pistons were white over the general blac deposits. All the piston rings were free with minimal signs of wear.

There was some build-up in the inlet port of the cylinder head at the throat behind the valve head, and with the inlet valves showed heavy build-up on the back face, so that there was some contact between the deposits and resultant shrouding of the inlet area. The inlet valves showed some spot build-up on the seating face. The exhaust valves showed some pitting of the seating face, but all the seats in the heads were in quite good condition.

The fuel sender sealing gasket was acceptable, with some minimal shrinkage of the cork seal, and minimal effect on the black rubber surround.

There was no noticable corrosion inside the fuel tank.

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NGA05F97-ETHANOL-Page 3

SUMMARY

From the inspection shown above, and given the age and distance travelled of the vehicle, the main impression was that the engine had been subjected to mild overheating and mild over-revving.

SPECIAL COMMENT

The previous operating and servicing details of the vehicle were not known, so that the conclusions are only relevant if the general conditions of use were normal, the engine had not been previously reconditioned, and the vehicle was substantially used with the petrol and ethanol mix.

CONCLUSIONS

The following conclusions are assumed to be, but not guaranteed, for a vehicle which had travelled 45,000 km:-

a) Although possibly different from that expected with petrol only, there were some problems found with the engine condition but these are regarded as attributed to the conditions of use and not to the ethanol.

b) The engine would probably have been expected to be able to be used for about another 50,000 km (to 100,000 km) if it had not been dismantled, provided that the recommended lubrication schedule was used for that distance.

NEIL GILLIES & ASSOCIATES PTY LIMITED

NGA05F97-ETHANOL-Page 4

c) Reassembly of the engine with replacement rings and bearing shells after proper cleaning would result in reasonable compression and performance, and the capability of running perhaps another 80,000 km (to 125,000 km), provided that the recommended lubrication schedule was used for that distance.

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APPENDIX

VEHICLE DETAILS

TOYOTA LEXCEN CSi Sedan	Registration TVM-115	Odometer 045,179 km
Engine LG2	V6 Cylinder OHV engine	Built JULY 95
Transmission M30	Automatic Transmission	Power Steering
Model VS8VK19-U4A	Body T839193	VIN 6H8T4K19HST839193

ENGINE INSPECTION

NRMA

A Toyota Lexen Sedan bearing the below identification was inspected at the workshop of NRMA Fairfield Street, Villawood on the 5th June 1997, for the purpose of inspecting engine components for adverse wear following usage over a period of time on an Ethanol blend of unleaded fuel.

Vehicle Inspection:	Toyota Lexen CSi Sedan
Engine Type/Size:	V6 3.8 Litre
Compliance Plate Date:	11th July 1995
Registration Number:	TVM-115
Speedometer Reading:	45179 Kilometres
Vehicle Identification No.:	6H8T4K19HST839193

The engine had been partially dismantled prior to arrival for inspection, having the left hand cylinder head removed, engine sump pan, all the fuel injectors and the number one (1) piston removed.

Observations

1. No major oil sludge residue build up about internal areas of the engine sump, valve cover or oil pump pick up strainer.

2. Moderate to heavy dirt/road dust contamination of the air filter element.

3. Light carbon residue build up on the cylinder head combustion chamber surfaces. A slightly heavier carbon residue present on the piston crown surfaces.

4. The number five (5) exhaust valve head carbon residue displayed a noticeable difference in colour to the numbers one (1) and three (3) exhaust valves, consistent with higher combustion chamber temperatures.

5. All the valves were removed from the cylinder head during the course of the inspection, the inlet valves displayed heavy carbon build up about the lower stem area and back of the valve heads. The extent of the carbon build up on the back of the valve heads was such that it evidenced polishing due to contact of the valve seat undercut areas.

6. All the inlet and exhaust valve seating surfaces were of a wide nature, displaying variance in width and extending in some instances to the valve head margin edge.

7. The exhaust valve seats displayed evidence of combustion reside between the seat mating surfaces, consistent with incorrect sealing of the valves.

8. The inlet valves, valve stem seals displayed limited sealing pressures on the valve stems when the valve stems were drawn through the seals.

9. The number one (1) piston displayed no abnormal ring land wear. The top compression ring displayed having fully seating against the cylinder bore surface. The second compression ring displayed only being partially bedded in to the cylinder bore surface. The oil control ring displayed having been fully seated against the cylinder bore.

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NRMA

10. The cross hatch hone markings were still evident in the cylinder bores, however an abnormal heat transfer pattern was evident in the upper rear centre area of the number one (1) cylinder bore. The said marking diminished down the cylinder bore surface.

11. The number one (1) connecting rod precision inserts displayed some oil borne contamination scoring. The upper insert displayed fatigue of the inlay material in two (2) areas at the major load bearing surface.

12. Slight carbon residue about all the injector pintel cover areas, the pintel point areas were of a clean carbon free appearance.

13. The injectors were flow tested and found to be flowing at an even rate. The injector spray patterns were also of an even nature.

14. The interior of the fuel tank as viewed via fuel pump/sendor unit with the tank insitu displayed no evidence of corrosion activity.

Conclusions

From the items inspected from the dismantled engine it is my opinion that no detrimental wear has taken place due to the usage of an "Ethanol" blend fuel.

It was however apparent that due to insufficient sealing of the inlet valve stem seals, that an engine oil usage problem had been evident.

The abnormal valve seat, seating width should also be given corrective attention to ensure future serviceability of the valves and seats.

At the time of the inspection numerous fuel hoses, spark plugs, fuel filters and sections of fuel hoses were offered for inspection.

The said parts were reported to have been removed from various other vehicles that had been operating on "Ethanol" blend fuels over varying periods of time.

No detrimental defects or deterioration of the components was evident.

One (1) fuel filter said to be removed from a Magna vehicle did however display some moderate build up in the filter media of a brown grit type substance consistent with a dirty fuel contamination.

E Wardell.

E Wardell, Inspecting Engineer
Automotive Technical Services

D951602 12/96

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10th June, 1997

The Manager,
Apace Research,
21 Ventura Road,
NORTHMEAD NSW 2152

Dear Sir,

RE: TOYOTA LEXEN - REGISTERED NUMBER TVM 115
SPEEDO READING 45,179 KILOMETERS
VIN 6H874K19HS7839193

The inspection and subsequent report deals with a number of operational components associated with fuel delivery and combustion as fitted to the above mentioned vehicle.

The unit had operated for a period of around 45,000 kilometers using a blend of 10% Ethanol within the fuel system.

A piston and rod were removed from the left bank of the motor in an endeavour to check the condition of the cylinder bore, pistons, rings and gudgeons, crank journal, cylinder head and valves.

The examination revealed the following:

Cylinder bore measurements being 3.779" or 96.5mm. Maximum wear being .0015" or 0.04mm. Satisfactory.

Piston to bore clearance .004" or 0.10mm. Satisfactory.

Piston skirt did not display evidence of overheating or misalignment.

Piston rings were complete and serviceable.

Gudgeon pin bush was within manufacturer's tolerances. Satisfactory.

A section of the cylinder bore cross hatch hone pattern had been removed in an area opposite to the thrust indicative of heat transfer.

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Apace Research -2- 10.6.97

Connecting rod slipper bearings revealed some scuffing an minor detachment of a small section of the bearing surface at the top bearing shell.

Connecting rod bearing to journal clearance being .0025" or 0.06mm. Satisfactory.

Cylinder head combustion area and head gasket did not display any irregularities, however there was an exhaust leak between the manifold gasket and cylinder head.

Inlet and exhaust valve guides were within manufacturer's specifications.

There was a variation in the valve face to seat contact on both inlet and exhaust valves.

Exhaust valve face surface revealed minute discolouration indicative of the use of unleaded fuel.

Engine sump, oil pump pick up were clean with no evidence of metallic infiltration or breakdown of the lubrication system.

Fuel pump, fuel tank and filler cap were free from corrosion or seal deterioration.

The six injectors were checked. Delivery and spray pattern were found to be satisfactory in both facets of the operation.

CONCLUSION

The examination of component parts available did not reveal any major operational problems.

The only deterioration observed was of the top half of the connecting rod slipper bearing most probably due to a manufacturing fault and the leakage of the exhaust manifold gasket.

Trusting this report will be of assistance to you.

Yours faithfully,

NEVILLE WEBBER M.I.A.M.E. M.S.A.E.A.

1995 Mitsubishi Magna

NRMA

ENGINE INSPECTION

NRMA Limited
ACN 000 010 506
151 Clarence Street
Sydney NSW 2000
Australia
Telephone (02) 9292 9222
Web site www.nrma.com.au

A Mitsubishi Magna Sedan bearing the below identification was inspected at the workshop of NRMA Fairfield Street, Villawood on the 1st July 1997, for the purpose of inspecting the engine components for adverse wear following usage over a period of time on an Ethanol blend of unleaded fuel.

Vehicle Type:	Mitsubishi Magna Executive Sedan
Engine Type Size:	4 Cylinder Overhead Cam 2.6 Litres
Compliance Plate Date:	May 1995
Registration Number:	TTF-843
Speedometer Reading	42082 Kilometres
Vehicle Identification No.:	6MMTS4D41ST047158
Engine Number:	HW531E85485

The engine had been partially dismantled prior to arrival for inspection, having the cylinder head removed and all the valves removed. All the fuel injectors had been removed for testing and set up on the fuel injection test bench.

OBSERVATIONS

1. No evidence of major oil sludge residue about the internal areas of the valve cover or oil washed areas of the cylinder head and valve train components.

2. The piston crowns carbon residue was of a soft nature, due to contamination of engine coolant at the time of removal of the cylinder head. The number (2) two piston crown displayed a lesser degree of carbon residue, this was discoloured consistent with higher operational temperatures than the other (3) three.

3. All the cylinder bores displayed uneven polished wear marks and longitudinal markings consistent with the piston rings not rotating in their ring grooves. The original cross hatch hone marks were still evident in the cylinder bore surfaces. The number (2) two cylinder evidenced an abnormal hone markings over and across the original hone marks, this being consistent with the hone stones having been drawn across the surface after the honing process had been completed.

4. No abnormal heat discolouration of the cylinder head gasket fire ring seals.

5. The exhaust valves displayed minimal carbon residue about the valve head surfaces. The valve seating/sealing surface displayed having had some fine particles of carbon between the seat resting surfaces. All the valve seating/sealing surfaces were central on the valve face.

6. The numbers one (1) and four (4) exhaust valve stem end sections displayed fatiguing of the contact area of the rocker/lifter. The number (1) one exhaust valve stem end had fatigued to the extent that the surface displayed pitting in an area.

D957801 7/96

NRMA

7. The inlet valves displayed moderate to heavy carbon build up on the undersides of the valve heads. The carbon build up was to the extent that the carbon on the number (2) two inlet valve was polished due to contact of the valve seat undercut area.

8. The number (3) three inlet valve stem seal displayed limited tension on the valve stem. The extent of loss of tension was such that at times under its own weight the valve would slide through the stem seal.

9. Slight score marks on the camshaft journals and associated bearing caps/tunnels were consistent with some oil borne foreign particle damage.

10. The engine oil displayed some moderate discolouration consistent with requiring changing.

11. Flow test of the fuel injectors was satisfactory at 70.5 to 71 mls over the test period and spray patterns were satisfactory.

12. All fuel and emission control unit vacuum hoses displayed no abnormal softening and hardening.

CONCLUSIONS

From the items inspected it is my opinion that no abnormal wear was detected that could be associated with usage of an "Ethanol" blend fuel.

It would be suggested that prior to reassembly of the components that two (2) new exhaust valves be fitted, also a new set of valve stem seals to ensure further serviceability to the engine.

E Wardell

E Wardell, Inspecting Engineer
Automotive Technical Services

D951602 12/96

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30th June, 1997

The Manager,
Apace Research,
21 Ventura Road,
NORTHMEAD NSW 2152

Dear Sir,

Re: MITSUBISHI MAGNA - ENGINE NUMBER HW 531E85485
COMPLIANCE PLATE - MAY 1995
SPEEDO READING 42,082 KILOMETERS

The following report relates to the operational condition of the valve mechanism, camshaft journals and lobes, valve stem seals, valve springs, cylinder bore and injectors.

It is understood the vehicle had used a fuel blend of 10% Ethanol for the total period of kilometers travelled.

At the time of the inspection, the cylinder head had been removed and all valve mechanism had been dismantled.

The examination revealed the following:

Cylinder bore cross hatch hone pattern had been removed in a number of areas.

Maximum wear and ovality being .00075" or 0.02mm. Satisfactory.

There was relatively soft carbon buildup on the piston crown. Satisfactory.

Camshaft journals and lobes displayed only minor scuffing through normal operational service. Satisfactory.

All exhaust valves had been positively seated.

Valve stem diameter being .312" or 0.79mm.

Inlet velve stem diameter was increased by .001" or 0.79mm.

Wear factor being .00075" or 0.02mm.

Maximum stem to guide clearance .003" or 0.08mm. Satisfactory.

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Vehicle & Component Inspections * Independent Reporting * Specialising in Trade & Legal Requirements

NEVILLE WEBBER M.I.A.M.E. M.SAE.A
AUTOMOBILE ENGINEERING CONSULTANT
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33 DARLEY STREET, FORESTVILLE NSW 2087
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30th June, 1997

The Manager,
Apace Research,
21 Ventura Road,
NORTHMEAD NSW 2152

Dear Sir,

Re: MITSUBISHI MAGNA - ENGINE NUMBER HW 531E85485
COMPLIANCE PLATE - MAY 1995
SPEEDO READING: 48,082 KILOMETERS

The following report relates to the operational condition of the valve mechanism, camshaft journals and lobes, valve stem seals, valve springs, cylinder bore and injectors.

At the time of the inspection, the cylinder head had been removed and all valve mechanism had been dismantled.

The examination revealed the following:

Cylinder bore cross hatch hone pattern had been removed in a number of areas.

Maximum wear and ovality being .00075" or 0.02mm. Satisfactory.

There was relatively soft carbon buildup on the piston crown. Satisfactory.

Camshaft journals and lobes displayed only minor scuffing through normal operational service. Satisfactory.

All exhaust valves had been positively seated.

Valve stem diameter being .312" or 0.79mm.

Inlet valve stem diameter was increased by .001 or 0.79mm.

Wear factor being .00075" or 0.02mm.

Maximum stem to guide clearance .003" or 0.08mm. Satisfactory.

..2/.

Vehicle & Component Inspections * Independent Reporting * Specialising in Trade & Legal Requirements

1992 Ford Falcon EB

NEIL GILLIES & ASSOCIATES PTY LIMITED

A.C.N. 052 531 021

7 March Place
Earlwood 2206
AUSTRALIA

Tel (61 2) 9558 4430
Fax (61 2) 9558 2790

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REPORT ON ENGINE IN ETHANOL TRIALS 26 NOVEMBER 1996

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for
APACE RESEARCH LIMITED
26 NOVEMBER 1996

NGA26K96-ETHANOL-Page 1 of 4

INTRODUCTION

This report is directed at an assessment of an engine that was from a vehicle that reportedly had travelled about 200,000 km, largely using a mix of 10 percent ethanol with petrol, after a request from Apace Research Limited. The Ford Falcon station wagon was seen at the NRMA service depot at Villawood on 26 November 1996, with the engine removed and partly disassembled. The vehicle details are shown in the Appendix for reference.

The purpose of the limited inspection was to determine if there were significant effects from the presence of the ethanol, given that the precise nature of the previous use of the vehicle was not known, and the nature of any previous parts replacement was also not known.

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NGA26K96-ETHANOL-Page 2

INSPECTION

The inside of the sump area was free of sludge. The top of the cylinder bores had lips left from a small amount of wear. The cylinder bores were glazed somewhat in the lightly loaded areas, but minimally worn on the thrust side with the hone marks still generally visible. One cylinder bore had a minor vertical score mark. The big-end bearing upper shells were worn through the overlay significantly.

The piston tops were generally minimally coated with carbon, except for some areas toward the edge where it had built up somewhat. There was minimal carbon build-up in the combustion chamber. The upper rings were worn considerably on their upper face, leaving an outer ridge projecting vertically. The second rings were worn only a little radially, and not significantly on their upper and lower faces. The oil control rings were worn somewhat.

The camshaft journals in the cylinder head had all scored significantly in the upper halves and the lower bearings were reasonable. The cam followers were not significantly worn, but there was minor ridging on the cam surfaces.

The exhaust and inlet valve stems and guides only had moderate wear. There was minimal build-up in the exhaust ports and on the back of the exhaust valves and the seat of the valves and the face of the seat had minor product build-up rather than wear or sinking. There was minimal build-up in the inlet port but moderate build-up on the back of the valve head, and the inlet face on the valve was recessed, and the seat in the head had some minor corrosion and pitting.

No significant swelling of the front and rear main bearing cap seals were noted, nor of the cylinder head to front timing cover seal.

The head coolant areas showed a limited amount of the corrosion of the aluminium, and there was moderate corrosion on the outside of the water outlet elbow (in the narrow gap under the hose down as far as the hose clamp).

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NGA26K96-ETHANOL-Page 3

Initial testing of the six fuel injectors showed excessive flow and leakage from one, but this generally settled down on repeating the test, and was possibly as a result of grit acquired from disassembly, since reportedly there were no recent engine difficulties. The fuel filter was quite clean and unaffected.

The v-belt and poly-v-belt idler pulley bearings were somewhat worn.

No unusual condition of any of the fuel hoses or seals on the vehicle were noted.

SPECIAL COMMENT

The previous operating and servicing details of the vehicle were not known, so that the conclusions are only relevant if the general conditions of use were normal, the engine had not been previously reconditioned, and the vehicle was largely used with the petrol and ethanol mix.

SUMMARY

From the inspection shown above, and given the age and distance travelled of the vehicle, the main impression was that the engine had been generally lightly loaded, not generally over-revved, and had received proper lubrication.

CONCLUSIONS

The following conclusions are made for the Ford Falcon Station Wagon which had presumably travelled a significant part of 200,000 km use on an ethanol mix:-

a) Although possibly different from that expected with petrol only, there were no significant problems found with the engine condition and thus none which could be attributed to the ethanol.

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NGA26K96-ETHANOL-Page 4

b) Although with some moderately deteriorated compression and performance, the engine would probably have been expected to be able to be used satisfactorily for about another 100,000 km (to 300,000 km) or more if it had not been dismantled and was used under similar conditions to its earlier use.

c) Reassembly of the engine with replacement rings and bearing shells after proper cleaning would result in reasonable compression and performance, and the capability of running perhaps another 200,000 km under similar conditions to its earlier use.

NEIL GILLIES

BE, Grad Dip, ME, FIEAust, MIMechE, FSAEA

APPENDIX

VEHICLE DETAILS

FORD FALCON EB Station Wagon Reg SKR-946 205,504 km odometer
6 Cylinder OHC engine Automatic Transmission

ADR PLATE	Approval Number 8664 Seats 5 10/92 VIN 6FPAAAJGWANY51385
VIN PLATE	6FPAAAJGWANY51385 SIDO 716472 MODEL 18263 ENGINE H TRANS W TRIM 61 PAINT L7 BUILT OCT 92
ENGINE NUMBER	JGWANY 51385

NRMA

ENGINE INSPECTION

A Ford Falcon Station Wagon bearing the below identification was inspection at the workshop of NRMA, Fairfield Street, Villawood for the purpose of inspecting engine components for adverse wear, following extended usage on an Ethanol blend fuel.

Vehicle Identification: Ford Falcon Station Wagon

Series Type: EB

Compliance Plate Date: October, 1992

Registration: SKR-946

Speedometer Reading: 205 504 kilometres

Vehicle Identification No: 6FPAAAJGWANY51385

The engine had been removed from the vehicle and partially dismantled, having the cylinder head, sump pan, numbers four (4) and five (5) pistons removed and the inlet and exhaust valves of the number four (4) cylinder removed from the cylinder head.

Observations

1. Interior areas of the engine block, sump pan, rocker cover and all internal components of the engine displayed minimal oil sludge residue. For the indicated distance travelled the interior areas of the engine would be considered to be remarkably clean.

2. Evidence of oil leakage at the rear of the sump pan rear seal area.

3. Cross hatch hone marks still evident in the cylinder bores. The cylinder bores also displayed a noticeable oil varnish glazing of the surfaces. Minimal wear lip on the upper and lower cylinder bore areas, cylinder bore size recorded at 92.28mm with .02mm ovality. No measurable taper evident. Standard cylinder bore size 92.25 - 92.31mm. The cylinder bore size is still within standard specifications.

4. Minimal carbon build up about piston crowns and cylinder head combustion chamber areas.

5. The top compression rings of the numbers four (4) and five (5) pistons displayed heavy side wear, this was most pronounced on the upper surfaces. The said wear was recorded at 0.17mm.

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9/12/96
EWDOC221:LW:B

NRMA

The cylinder bore contact surfaces of the top rings in question displayed some fine score markings consistent with abrasive type wear, which may have been caused by dustings or dry fuel.

6. The second compression rings displayed no abnormal wear patterns or abrasive wear markings.

7. The oil control rings of the said pistons displayed limited service life remaining.

8. The numbers four (4) and five (5) pistons recorded a size of 92.21mm to 92.22mm. Standard piston size is 92.23mm to 92.29mm. No abnormal wear patterns present on the piston skirt areas. The undersides of the piston crowns displayed no abnormal combustion chamber temperature discolourations.

   The underside of the piston crowns however did display some oil varnish discolouration and a noticeable cleaned area of the surface due to the oil cooling spray.

9. The piston skirts displayed a moderate to heavy oil varnish residue about the pin boss and associated areas.

10. The connecting rod precision inserts of the numbers four (4) and five (5) connecting rods displayed moderate load wear of the upper inserts inlay material. This wear was to the extent that a noticeable step had formed at the edge of the worn inlay material, some oil borne foreign particles scoring was also present. The condition of the bearings is considered to be consistent with general wear for the indicated distance travelled.

11. The crankpins displayed no abnormal wear or scoring and recorded a size of 53.93 with .01 ovality. Standard size of journal 53.93mm to 53.95mm.

12. The camshaft displayed some general wear and scoring of the lobes and journals, this wear was a direct result of oil borne contaminants. The cylinder head camshaft tunnels displayed no major wear, however impregnation of fine abrasive particles could be felt in the tunnel surfaces.

13. No abnormal wear in valve guides or on valve stems of the number four (4) cylinder inlet and exhaust valves.

    The exhaust valve seat and insert seat surfaces were lightly carbon coated and small pitting of the carbon residue was evident in areas. The inlet valve displayed a moderate degree of recession of the seat surface. This would be considered consistent with indicated distance travelled.

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14. No evidence of deterioration of the fuel pressure regulator diaphragm or seat seal.

15. No abnormal residue about the injector pintel areas.

16. Fuel injector flow test was undertaken which resulted in number six (6) injector full flowing, consistent with some form of foreign body being present in the internal areas. Following a further series of flow tests the full flowing of number six (6) injector ceased, the subsequent flow test of the injectors then revealed and even flow of all injectors of between 58 to 59 millilitres over the test sequence period. Open flowing of the number six (6) was possibly due to debris from the fuel rail as there was no indication of the engine running with the injector in the full flow condition.

17. The fuel pump/sendor unit tank seal displayed advanced deterioration of its fuel contact areas. The fuel pump hose section and rubber insulators displayed no abnormal deterioration.

18. Limited inspection of the fuel tank interior via the fuel pump/sender unit aperture revealed no evidence of corrosion activity.

CONCLUSIONS

From the inspection of the components sighted, it is considered that the engine displays no evidence of abnormal wear, other than the top compression rings which is of some concern.

Until further engines running on the same fuel type are inspected, a reserved judgement as to the prime cause of the top ring wear is held.

E Wardell.

E Wardell, Inspecting Engineer
Automotive Technical Services, Pyrmont

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9/12/96
EWDOC221:LW:B

NEVILLE WEBBER M.I.A.M.E. M.SAE.A
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28th November, 1996

The Manager,
Apace Research,
21 Ventura Road,
NORTHMEAD NSW 2152

Dear Sir,

Re: FORD FALCON - REGISTERED NUMBER SKR 546
ENGINE NUMBER: JGWANY51385
SPEEDO READING: 205,504 KILOMETERS

The inspection and subsequent report deals with the operational condition of the above mentioned motor.

At the time of the examination the unit had been removed from its chassis and partially dismantled.

Components available were as follows: Pistons, rings, conrods and slipper bearings from cylinders four and five. Cylinder head valves at number four were also removed.

A number of fuel ancilliary items, such as injectors, sender units and pressure regulator seals were also submitted.

It is understood that this particular motor had operated in excess of 200,000 kilometers using a blend of unleaded fuel and ethanol.

The reason for the examination was to ascertain as to whether or not the motor had suffered from excessive wear because of the fuel additive.

The inspection revealed the following:

Piston skirt taper and thrust surfaces of numbers four and five measured .001" or approximately 0.02mm.

Top compression rings at number four piston displayed excessive side wear of up to .007" or 0.18mm. Second compression ring side wear being .002" or 0.05mm. Oil ring tension adequate.

Number five top compression ring side wear being .003" or 0.08mm. Second compression side wear being .002" or 0.05mm. Oil ring tension again adequate.

..2/.

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There was no evidence of piston crown oil wash which would be indicative of excessive use of lubrication oil.

All cylinder bores displayed some minor glazing, however the cross hatch pattern was in evidence.

Cylinder wear and ovality at numbers four and five being approximately .003" or 0.08mm.

Cylinder bore standard size being 92.3mm or 3.632".

Crankshaft journal dimensions at numbers four and five being 2.1235". Standard size being 54mm or 2.125".

Maximum journal to slipper bearing clearance being .004" or 0.10mm.

There was evidence that the sacrificial surface of the slipper bearings had been penetrated at the maximum load contact area.

Inlet and exhaust stem diameter being .340" or maximum wear .0005".

Valve stem to guide clearance .003 or 0.08mm.

There was no evidence of valve seat pocketing or valve face distortion.

Positive head gasket seat at all combustion areas.

Oil residue in engine sump revealed no significant contamination.

Rocker mechanism appeared serviceable, however there was some rotational minor scoring on all cam journals with variation of up to .0015" or 0.03mm at number four cam journal.

Ancilliary components such as the fuel tank and pressure regulator seals were operational though there was some minor deterioration of the tank sender unit seal in an area which was in constant contact with the fuel level.

Injector flows being approximately 60 mls. per 30 second flow time.

Spray pattern was within manufacturer's specifications.

CONCLUSION

The examination of components available for inspection did not reveal any significent deterioration within the motor.

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Apace Research -3- 28.11.96

The side wear factor of the number four top compression ring appears to have been brought about by loss of side wall tension due to fair wear and tear exacerbated by piston ring rotation.

Cylinder bore wear was not excessive.

Piston skirt did not display signs of lack of lubrication or over heating.

Slipper bearings at number four and five journals displayed high load factor indicative of ignition advance and/or consistent full throttle operation.

Valve mechanism revealed an extremely low rate of wear, though cam journals were lightly scored.

Cam journal bearings displayed only slight scoring.

There was no evidence of serious seal deterioration at injectors, sender unit or pressure regulator.

Taking into account the 200,000 kilometers travelled, the motor, although displaying some general wear would in the main still be considered operational.

There was no indication that any of the major components or its ancillaries had reached the stage of impending failure.

Trusting this report will be of assistance to you.

Yours faithfully,

NEVILLE WEBBER M.I.A.M.E. M.S.A.E.A.

1981 Holden Commodore VH

NEIL GILLIES & ASSOCIATES PTY LIMITED

A.C.N. 052 531 021

7 March Place
Earlwood 2206
AUSTRALIA

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Fax (61 2) 9558 2790

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REPORT ON ENGINE IN ETHANOL TRIALS 19 FEBRUARY 1997

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for
APACE RESEARCH LIMITED
19 FEBRUARY 1997

NGA19B97-ETHANOL-Page 1 of 4

INTRODUCTION

This report is directed at an assessment of an engine that was from a vehicle that reportedly had travelled about 140,000 km with only about the last third of that distance using a mix of 10 percent ethanol with petrol, after a request from Apace Research Limited. The Holden Commodore sedan was seen at the NRMA service depot at Villawood on 19 February 1997, with the engine removed and partly disassembled. The vehicle details are shown in the Appendix for reference.

The purpose of the limited inspection was to determine if there were significant effects from the presence of the ethanol, given that the precise nature of the previous use of the vehicle was not known, and the nature of any previous parts replacement was also not known.

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NGA19B97-ETHANOL-Page 2

INSPECTION

The crankcase and sump interior was quite clean, with no blocking of the oil pick-up screen. There was moderate scaling on the inside of the rocker cover.

The ridge at the top of the bores was moderate, but there was almost no signs of wear in the lower portion of the bore with almost no wear on the thrust side of the pistons themselves. The big-end journals and the bigend shells were somewhat worn towards the edges indicating some cocking, in both directions. There was a small circumferential ridge formed on one big-end journal.

The inlet manifold was quite clean internally, but the exhaust deposits were quite white, and to a large extent so were the more recent deposits on the combustion chambers and the tops of the pistons. There was some build-up in the inlet port and at the outlet of the manifold.

The exhaust and inlet valve stems and guides only had moderate wear. The exhaust valves had some light grey build-up and the seats were sunk to a significant extent. The inlet valves showed heavy black build-up, with some of the deposits having previously broken off. The valves showed a moderate amount of settling.

The pistons had some brown discolouration on their sides. All the piston rings were free with minimal wear except for significant wear at the top surface of the top ring.

The crankshaft front seal had been replaced at some time. The petrol pump was semingly new.

No unusual condition of any of the fuel hoses or seals on the vehicle were noted.

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NGA19B97-ETHANOL-Page 3

SUMMARY

From the inspection shown above, and given the age and distance travelled of the vehicle, the main impression was that the engine had been generally subjected to poor lubrication schedules and/or oil types.

SPECIAL COMMENT

The previous operating and servicing details of the vehicle were not known, so that the conclusions are only relevant if the general conditions of use were normal, the engine had not been previously reconditioned, and the vehicle was substantially used with the petrol and ethanol mix.

CONCLUSIONS

The following conclusions are assumed to be, but not guaranteed, for a vehicle which had travelled 140,000 km:-

a) Although possibly different from that expected with petrol only, there were some problems found with the engine condition but these are regarded as attributed to the inadequate lubrication and conditions of use and not to the ethanol.

b) Although with some moderately deteriorated compression and performance, the engine would probably have been expected to be able to be used for about another 40,000 km (to 180,000 km) but with poor performance if it had not been dismantled, provided that the recommended lubrication schedule was used for that distance.

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NGA19B97-ETHANOL-Page 4

c) Reassembly of the engine with replacement rings and bearing shells after proper cleaning would result in reasonable compression and performance, and the capability of running perhaps another 100,000 km, provided that the recommended lubrication schedule was used for that distance.

NEIL GILLIES

BE, Grad Dip, ME, FIEAust, MIMechE, FSAEA

APPENDIX

VEHICLE DETAILS

HOLDEN COMMODORE VH Sedan Registration DP-710 128,465 km odometer
6 Cylinder OHV engine Automatic Transmission

ADR PLATE Seats 5 09-81 AVH000896A

VIN PLATE 8K 69LB L532074H

ENGINE NUMBER VL253804

NEVILLE WEBBER M.I.A.M.E. M.SAE.A
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19th February, 1997

The Manager,
Apace Research,
21 Ventura Road,
NORTHMEAD NSW 2152

Dear Sir,

Re: HOLDEN COMMODORE - REGISTERED NUMBER: DP 710
SPEEDO READING: 128,466 KILOMETERS
ENGINE NUMBER: VL253804

The following report relates to the condition of the above mentioned motor which is understood to have operated for a very considerable period using a fuel blend of 10% Ethanol.

At the time of the inspection the motor had been removed from its chassis and dismantled with the exception of the timing chest and crankshaft.

The examination revealed the following:-

Cylinder bore measurements in the unworn area being 3.625" or 92mm standard. Maximum wear being .004" or 0.10mm.

Pistons, rings and gudgeons were in serviceable condition.

Rod alignment was satisfactory.

Piston skirt measurements being 3.623",overall skirt variation being .001" or 0.03mm.

Crankshaft connecting rod journals were serviceable however journal numbers one and six had been ground approximately .010" undersize to 48mm or 1.890".

Journals two, three, four and five measurements being 1.998".

All slippers displayed some minor rotational scoring.

The back of slippers numbers one and six were stamped .010" whilst two, three, four and five were stamped .001".

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Inlet exhaust valves displayed adequate seat contact.

There was no evidence of excessive valve train wear.

Fuel tank seals and filters were serviceable.

Fuel pump displayed a faulty diaphragm.

There was no evidence of corrosion having formed within the fuel tank.

CONCLUSION

Examination of components available did not reveal abnormal wear or deterioration of the motor.

As previously mentioned, connecting rod journal variation appears to have been brought about possibly at the time of the initial factory assembly.

Fuel pump diaphragm deterioration could be considered fair wear and tear.

With regards to the condition of the pistons, rings, bearings, etc., it is reasonable to assume that the motor was fully operational prior to dismantling there being no evidence of high oil consumption or ring scuffing.

The wear factor acknowledged is what one would reasonably expect from normal operation considering the age of the vehicle and the kilometers travelled.

Trusting this report will be of assistance to you.

Yours faithfully,

NEVILLE WEBBER M.I.A.M.E. M.S.A.E A.

NRMA

ENGINE INSPECTION

A Holden VH Commodore bearing the below identification was inspected at the workshop of NRMA Fairfield Street, Villawood on the 19th February `997, for the purpose of inspecting the engine components for adverse wear following usage over a period of time on an Ethanol blend of leaded fuel.

Vehicle Identification:	Holden Commodore Sedan S/L
Series Type:	VH 3.3 litre
Compliance Plate Date:	September 1981
Registration Number:	DP-710
Speedometer Reading:	128,465 kilometres
Vehicle Identification No.	AVH000896A

The engine had been removed from the vehicle and dismantled, having the cylinder head fully disassembled, sump pan removed all pistons removed.

It was reported at the time of the inspection that the fuel pump had been replaced approximately one (1) week prior, due to fuel leakage at same.

OBSERVATIONS

1. Moderate to heavy oil sludge residue about the interior areas of the valve cover, cylinder head oil washed areas, valve springs and valve rocker arm components.
2. Evidence of prior oil leakage form valve cover gasket areas.
3. No evidence of major corrosion activity to cylinder head or cylinder block coolant passages.
4. Moderate carbon build up about the cylinder head combustion chamber surfaces, consistent with leaded fuel usage.
5. Heavy carbon residue build up on the back of the inlet valve heads and lower valve stem areas. This is consistent with oil induction from the valve guide areas.

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The exhaust valves displayed moderate build up of carbon residue on the combustion chamber head surface and under head areas.

All the valve seats and valve heads seat contact surfaces displayed varying degrees of wear consistent with the indicated kilometre of service life.

6. No major wear evident on the valve stems or in the valve guides.

   The valve stem seals that were sighted were of a hardened brittel nature, numerous small sections of valve stem material also sighted were brittle and hardened and were broken on dismantling of the valves from the cylinder head.

7. Oil varnish staining residue was present on all connecting rods and piston skirt areas. The undersides of the piston crowns displayed above normal heat discolouration consistent with higher than normal combustion temperatures, as a result of an engine overheating condition.

8. No major wear evident to the piston ring lands or piston rings upper or lower surfaces. The oil control rings displayed limited service life remaining to the rail sections.

9. The pistons recorded a size ranging from 92.03mm to 92.04mm with no major wear/damage to the skirt areas.

10. The cylinder bores recorded sizes ranging from 92.15mm to 92.28mm under the top wear lip of the cylinder bore which would indicate some 0.09mm to 0.12mm wear. Taper of the cylinder bores ranged from 0.10mm to 0.13mm.

11. The connecting rod precision inserts displayed varying degrees of load wear about their centre areas. One (1) set of inserts displayed heavy scoring by oil borne foreign particle.

12. The crankpin journals recorded a size of 48.24mm to 28.22mm on the numbers two (2), three (3), four (4) and five (5) journals. The numbers one(1) and six (6) crankpins recorded a size of 48.00mm. The precision inserts were of mixed sizes ranging from STD, .025mm and 0.25mm oversize.

13. All the engine emission control vacuum hoses were heat hardened at their engine component fitting end sections, the remainder of the hose sections were still in a serviceable condition although having lost some pliability due to engine bay temperature.

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14. The leaking fuel pump when dismantled displayed a small split in the rubber diaphragm. The said split was on the edge of the metal diaphragm support at tis maximum flex position. The diaphragm rubber material displayed no evidence of abnormal deterioration or hardening.

15. The interior areas of the fuel tank sighted via the sendor unit aperture displayed no evidence of corrosion activity.

CONCLUSIONS

As a result of the inspection of the dismantled engine components it is my opinion that the engine displays general wear consistent with the indicated distance travelled.

No evidence of abnormal wear could be attributable to the use of an Ethanol fuel blend.

The sizes recorded on the crank pins and displayed on the rear of the precision inserts would indicate that from original assembly the engine had been fitted with a crankshaft having two (2) undersized journals.

Failure of the fuel pump diaphragm is resultant from general age/flexing of the material.

E Wardell
Inspection Engineer

D951602 2/89

Australian Quality Awards Winner 1992

APPENDIX F: IMPACTS OF TEST PROCEDURES

Impacts Of Conventional And Future Emissions Test Procedures On The Assessment Of E10 Ethanol/Petrol Blends

Conventional Evaporative and Exhaust Emissions Test Procedures

Vehicle evaporative and exhaust emissions are measured in a sequence of laboratory tests that attempt to simulate typical vehicle use in a metropolitan area during the summer months. The conventional test sequence consists of:

- Vehicle preconditioning.

  Preconditioning of a vehicle is critical to achieving accurate and repeatable measurements of the vehicle's evaporative and exhaust emissions.

- In the "SHED" evaporative emissions determination test procedure, after preconditioning the vehicle is placed in a sealed enclosure. A measurement of hydrocarbon (HC) evaporative emissions is then made during a "Diurnal Heat-Build" in which the vehicle fuel tank is heated with a resistance heater (heat blanket) to cause the temperature of the fuel at the geometric centre of the fuel to rise from 16 to 29.3°C (an increase of 13.3°C) in 60 minutes.
- A 17.9 km drive cycle on a chassis dynamometer incorporating cold transient, cold stabilised and hot transient cycles, during which exhaust emissions are measured, is then completed.
- Immediately following the 17.9 km drive cycle the vehicle is again placed in the sealed enclosure and the change in the HC concentration of the enclosure over a 60 minute "Hot Soak" period is measured.

The actual methods used to carry out each step in the above test sequence exert a significant effect on the emissions results obtained. Some of the more critical aspects for each of the steps are now discussed.

Vehicle Preconditioning

Adequate vehicle preconditioning is critical to achieving accurate and repeatable measurements of evaporative and exhaust emissions. The attached figures (1-3) show the preconditioning procedures either recommended or adopted by various organisations. Fig. 4 shows the procedure adopted by NSW EPA/Apace study.

SAE J171 APR91 Recommended Practice (Fig 1) - describes a preconditioning procedure which will result in adequate preconditioning but which is time consuming due to repeating diurnal soak phases.

ADR37 Certification Procedure (Fig 1) - is very similar SAE J171 but does not provide any guidelines as to the determination of number of simulated trips.

Auto/Oil AQIRP/NIPER Procedure (Fig 1) - has been developed specifically for the determination of evaporative emissions to eliminate carryover where different fuels are being evaluated. It is tedious but is reported to enable repeatable evaporative and exhaust emissions measurements to be achieved.

FORS Study Procedure (Fig 2) - was used for the FORS in-service study. The procedure was initially used for the Apace project but was found to be unsuitable as the results did not accord with the traditional results for petrol and E10 petrol/ethanol blend. The NSW EPA conjectured that the apparent high evaporative emission results achieved with petrol was as a result of E10 blend being present in the car at time of delivery and undergoing at least one and possibly two natural diurnal cycles while parked in the EPA compound at Lidcombe.

NSW EPA/Apace Study Procedure (Fig 2) - was adopted by NSW EPA to establish the minimum number of highway purge cycles required to achieve stable vehicle preconditioning as a result of the unsuitability of the NSW-FORS study preconditioning procedure. It should be noted that the NSW EPA/Apace procedure bears some relationship to both the SAE Recommended Practice and ADR37. Table 1 relates the step numbers to those shown on Graphs 1(a) to 7(a).

Table 1 - Step identification

Step No	Description	
	Petrol	E10
1	As received condition Refuel with petrol	Follows Step 10 of petrol Refuel with E10
2	Highway cycle-Precon #1	
3	Highway cycle-Precon #2	
4	ADR27-Precon	
5	Drain and refuel with petrol	Drain and refuel with E10
6	Temperature stabilisation	
7	Diurnal phase	
8	ADR37 & Hot soak	
9	Highway cycle-Precon	
10	Highway cycle fuel consumption	

Graphs 1 (a) through to 4(b) and Graphs 6(a) to 7(b) show that there is a reduced purge of the canister for the "as received" condition thus generally biasing the results to the second part of the test. This is evidenced by the lower canister weight at Step 4 in the (a) series of graphs for the E10 preconditioning compared with the weight of the canister for neat petrol at the same point.

Graph series (b) were derived from Graph series (a) in order to estimate the minimum number of drive cycles required to fully purge the canister. This appears to range from 3 for a Ford Laser (Graph 6(b)) to 15 for a Toyota Lexcen (Graph 1(b)).

The exception to the above is the result for a Commodore VB shown in Graphs 5(a) and 5(b). The reduction in canister weight during a highway drive cycle is very small requiring almost 21 drive cycles (predicted) to achieve minimum canister weight. The preconditioning for this vehicle involved delivery to and from NRMA at Villawood for additional repairs and therefore its previous history for Step 1 for petrol operation is somewhat unclear.

Page 2

The major difference in the preconditioning procedure for the two fuels is the inclusion of the 2 highway drive cycles (Step 10) following the hot soak period (Step 8) resulting in additional preconditioning for the second part of the test.

The SAE Recommended Practice states that purging may be considered adequate when repeated test cycles consisting of diurnal soak, drive cycle and hot soak result in canister weights repeatable to within 5 g. This 5 g limit has been applied by EPA using the more limited preconditioning procedure. In order to remove the current bias to the second part of the test Apace believes that an additional limit of 2.5 g should be set for the canister weights at Step 4 for the two fuels.

The "as received" (Step 1, Refuel petrol) condition can be considered as being equivalent to Step 7, i.e. the vehicle has been driven for considerable distance (HWY #1, HWY #2, ADR27) then followed by a natural diurnal soak, however no fuel change as per Step 5 had been carried out. In every instance the "as received" canister weight (Step 1, Refuel petrol) is lower than that measured following a diurnal soak shown at Step 7.

It is evident that the procedure adopted for the FORS program would result in a heavy bias in favour of the second test. Originally it was proposed that the Apace project was to draw a comparison with the much larger FORS database however this is no longer possible for the diurnal phase as the preconditioning procedure necessary to obtain comparative data for petrol and E10 blend is incompatible with that adopted for the FORS study.

The preconditioning procedure shown in Fig. 4 was finally adopted for the remainder of the tests. The major changes are:

- 2 Highway drive cycles were added at the start of test procedure and prior to initial test fuel charge;
- preconditioning fuel charge was at room temperature rather than 10°C; and
- the difference in canister weights at Step 4 was limited to 2.5 g for the two fuels.

Evaporative Emissions Measurement

A fundamental deficiency in the current "SHED" test procedure is that the "Diurnal Heat-Build" phase does not correspond to an ambient equilibrium condition. The procedure of heating the fuel to a predetermined temperature does not model an ambient equilibrium condition in which the specific heat and heat of vapourisation of the fuel are able to exert their effect. In particular the current test procedure does not permit a valid comparison of different fuels having different physico-chemical properties. The U.S. EPA has adopted a new evaporative emissions test procedure due, in part, to deficiencies in the current "SHED" test procedure.

New Test Procedure

In the new "Multiday Diurnal" test procedure the preconditioned vehicle is placed in the enclosure and the ambient temperature of the sealed enclosure is varied from 22°C to 36°C (an increase of 14°C) in 12 hours and then back to 22°C in 12 hours. This cycle is repeated for a total of 3 days.

Using this procedure fuel temperature equilibrium conditions are achieved. The actual temperature, and hence vapour pressure, of a particular fuel at a given ambient temperature is dependent on the physico-chemical properties of the particular fuel.

In the U.S. the "Multiday Diurnal" test procedure replaced the current test procedure for the emissions certification of 1996 model-year vehicles. Vehicle manufacturers must use the multiday test for 20% of the 1996 MY, 40% of the 1997 MY, 90% of the 1998 MY and 100% of the ensuing model-year vehicles.

Results from "Multiday Diurnal" tests, using a stand alone fuel tank installation instead of a complete vehicle, conducted at NIPER show that the evaporative losses from E10 blend are approximately the same as those from the base petrol. That is, although the ethanol causes increased volatility (ca. 7kPa RVP), there is no corresponding increase in evaporative emissions. This is thought to be due to the relatively high heat capacity and latent heat of vaporisation of ethanol. These factors limit the peak fuel temperature and, therefore, peak vapour pressure, which is the driving force for the transfer of fuel vapour to (and through) the charcoal canister. Peak fuel temperatures in the tests conducted at NIPER were a minimum of 1°C lower for E10 blend. Although this might appear small, the effect on the quantity of vapour transferred to (and through) the carbon canister is significant (see discussion below and SAE paper 892089).

Current "SHED" Test

ADR37 specifies that the fuel temperature rise over the one hour period shall be 13.3±0.5°C measured at the geometric centre of the fuel (the fuel tank being filled to 40% of its volume).

Because of possible difficulties in installing the temperature measuring device within the fuel tank and the perception that tank integrity may not be re-established following the installation of such temperature measuring device, methods have been devised to measure the fuel temperature by sensing the fuel tank skin temperature.

In 1979 NSW EPA carried out a number of tests to determine the measurement relationship between 2 J-type thermocouples, one installed within the fuel tank and the other mounted externally to one side of the tank at the 20% fuel tank volume thus approximating the 40% geometric centre of the fuel.

Graph 8(a) depicts the average temperature rise over 5 tests as measured with the temperature rise controlled by the internal thermocouple. It can be seen that for an internal fuel temperature rise of 13.3°C the skin temperature rise is only 12.12°C. Using the values from Graph 8(a), for a skin temperature rise of 13.3°C the internal temperature rise is calculated to be 14.7°C. This is shown in Graph 8(b).

Graph 8(c) shows the measured internal temperature rise of 16°C when the skin temperature rise is controlled to 13.7°C. This graph shows the only result presented by any party which actually used the skin temperature to control the temperature rise. The temperature rise should have been only 15.1°C if based on Graphs 8(a) and 8(b).

The calculated 14.7°C and the measured 16.0°C fuel temperature rises are both outside the specified 13.3±0.5°C ADR37 specification.

The effect on the mass of evaporative emissions of this increased fuel temperature rise is significant compared with the 13.3°C target. Graph 9(a) (Toyota Lexcen, TVM115, ULP) shows the measured HC concentration (dimensionless) within the sealed enclosure and the fuel tank skin temperature having a rise of only 12.8°C. It is estimated that the temperature rise at the geometric centre of the fuel using a correction factor derived from Graph 8(c) is approximately 14.95°C.

Graph 9(b) is rescaled to give a temperature rise of 14.95°C at the end of the 1hr soak period and the HC concentration at 13.3°C temperature rise is taken as 100%. The graph clearly shows that a 31% increase in evaporative emissions can be expected for the additional 1.65°C increase in fuel temperature.

NSW EPA did not evaluate the effect of temperature rise from 13.3°C to 16.0°C on evaporative emissions and therefore a comment was sought from NIPER, USA. Their comment was that the increase in the mass of fuel vapour transferred to the canister for fuels with a vapour pressure in the range of 80-86 kPa is 35-40% depending on which model is used. Reddy's model (reference SAE paper 892089) gives a 35% increase while the NIPER model (reference Bill Marshall, priv. com.) gives a 40% increase. This is in reasonable accord with the result presented in Graph 9(b).

Note: FCAI have indicated that motor vehicle manufacturers will generally only provide the minimum evaporative system capacity to comply strictly with any regulations. Thus any in-use testing procedure which results in test conditions exceeding ADR37 requirement are unrealistic and should not be implemented.

The relationship between fuel temperature at its geometric centre and fuel tank skin temperature is also fully described in a report prepared for the U.S. EPA in 1978 by Saip Ereren, Olson Laboratories, Inc, titled "Evaluation of Thermosensing Devices to Measure Diurnal Fuel Tank Temperature for In-Use Vehicle Testing" under contract No. 68-03-2411 and now published by U.S. EPA reference No EPA 460/3-78-003.

The analysis of the US study will not be presented here as there is little difference between the average results from the US (1.1°C) and NSW EPA (1.2°C) results.

However the U.S. EPA report draws the following conclusions and recommendations:

- External sensors mounted on fuel tanks can be used to monitor the diurnal heat build when testing in-use vehicles for evaporative emissions. The readings from these sensors are closer to actual fuel temperature at midpoint of the 40% volume fill than readings from thermocouples routed through the fuel cap.
- Resistance temperature detectors (RTDs) and grid thermocouples gave the most satisfactory results among the external sensors.
- Bead thermocouples mounted on tank surfaces are not reliable indicators of internal fuel temperature.

Large thermal masses created by soldering and using adhesive might have caused the sluggish temperature response. Also, inherent danger in soldering to a fuel tank, long curing time for the adhesive, and questionable quality of the thermal contact achieved with the adhesive made bead thermocouples less desirable than RTDs and grid thermocouples.

- If the diurnal heat build procedure is modified so that the fuel temperature measured by an external RTD is monitored to rise from 61°F to 82.5°F (16.1 - 28.0°C) within a 1-hr period then the actual fuel temperature will follow the desired 60.0°F to 84.0°F (15.6-28.9°C) heat build.

  (Note: In the FORS study the temperature controller was not modified to account for the temperature rise for use with tank skin temperature measurement as opposed to internal fuel temperature measurement.)

In the U.S. tests the fuel temperature was always raised the required 13.3°C controlled by the internal thermocouple and the skin temperature measured. At no time was the result reversed with the temperature controlled by an external temperature measuring device and the fuel temperature measured. The only result available where this was carried out is by NSW EPA during their 1979 series of tests and this shows that the difference between the internal and external temperatures is significantly greater (Graph 8(c)).

Fuel Characteristics

The mass of evaporative emissions is dependent on the vapour pressure and temperature of the fuel. Graphs 10(a) and 10(b) show the relationship between temperature and vapour pressure for the various fuels together with the limits imposed by the temperatures used for evaluating evaporative emissions. The effect of extending the temperature range used for evaluating evaporative emissions results in increasing the evaporative emission from the E10 blends at a greater rate than those from neat petrol.

Petrol and ethanol possess different specific and latent heats. The sensible and latent heat have not been established for E10 petrol/ethanol blends however estimates based on information contained in Chemical Engineer's Handbook, Perry and Chilton, and SAE Fuels and Standards Manual are shown in Table 2.

Table 2- Estimated fuel characteristics

Fuel	Specific heat kJ/kg.K	Latent heat kJ/kg @ 20°C
Petrol	2.01	302
Ethanol	2.40	896
E10	2.05	366

Note: The above values are calculated to indicate the possible differences in heat build up conditions during an evaporative test.

If it is assumed that a typical fill consists of 25 L and its temperature is raised by 13.3°C then the specific heat requirement will be 490 kJ for petrol and 503 kJ for E10. If it is also assumed that 0.035 kg (sum of typical gain in canister mass and mass of evaporative emissions at Step 5) of petrol and 0.042 kg of E10 are evaporated then the latent heat required will be 10.6 kJ for petrol and 15.4 for E10. Thus the total heat requirements are 500.6 kJ for petrol and 518.4 kJ for E10, an increase of almost 4%. Measurement of the heating blanket power consumption during this project shows an increase of 6% for E10.

This calculation and observation is consistent with the lower fuel temperatures achieved during the new U.S. "Multiday Diurnal" procedure as noted on Page 3.

The effects of this increased heat requirement and the higher surface cooling effect of E10 on fuel tank thermal flows are not known but it is considered that they would affect the relationship of the fuel temperature at its geometric centre to the fuel tank skin mounted temperature control device.

Exhaust Emissions Measurement

The U.S. EPA has adopted an additional "aggressive" drive cycle for the determination of exhaust emissions due to deficiencies with the current drive cycles. The fundamental deficiency with the current drive cycles is that the exhaust emissions obtained do not accurately model the emissions measured in real life urban air samples.
The oxygenated fuel program in Colorado, USA has shown much greater carbon monoxide benefit than would be predicted from FTP (ADR37) tests. This could indicate that:

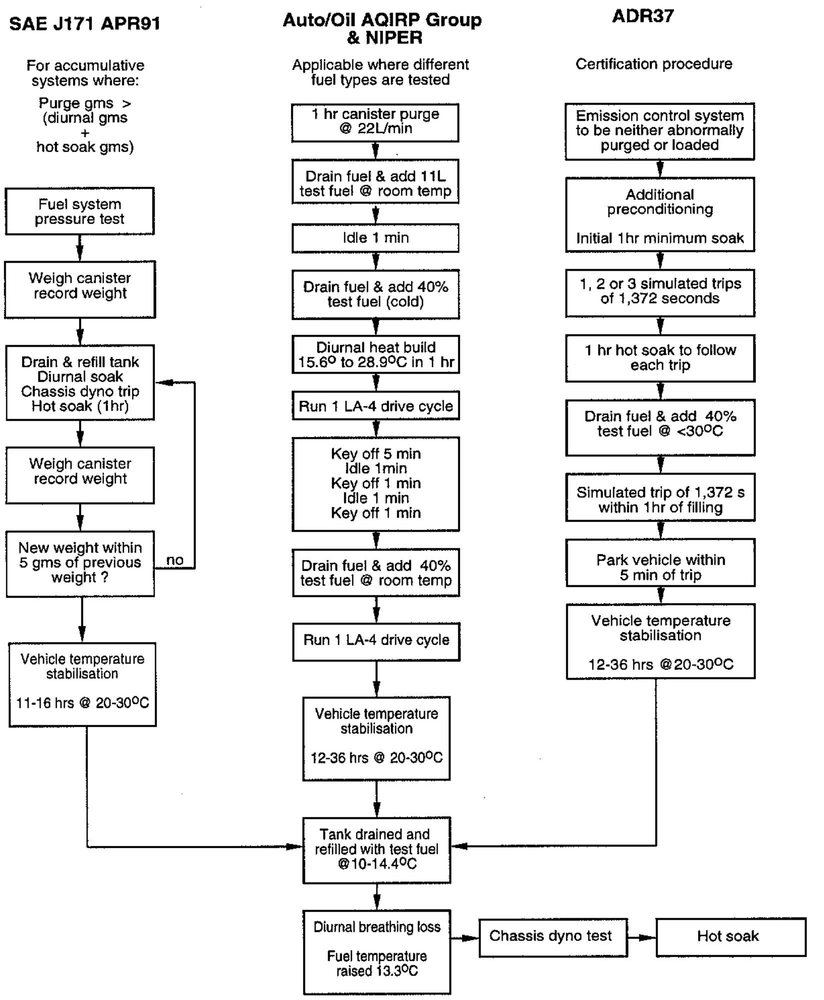
1. Severe driving, not represented in the FTP, constitutes a significant portion of in-use driving.

2. In the FTP emissions from modern vehicles are much lower than from older vehicles. However during periods of high engine load (accelerations) even modern vehicles go into excessive enrichment which results in high emissions of CO and unburned fuel. The effect of oxygenate blending is to reduce the excessiveness of enrichment, thereby reducing emissions. The reduction works for both older and modern vehicles.

References

"Impacts of Current and Future U.S. Emissions Test Procedures on the Assessment of Ethanol-Gasoline Blends", W. F. Marshall, Science Adviser Fuels/Engines Research, IIT Research Institute/National Institute for Petroleum and Energy Research (NIPER), USA. Private communication.

Fig. 1 - Measurement of Fuel Evaporative Emissions Preconditioning



Revised 25/04/97

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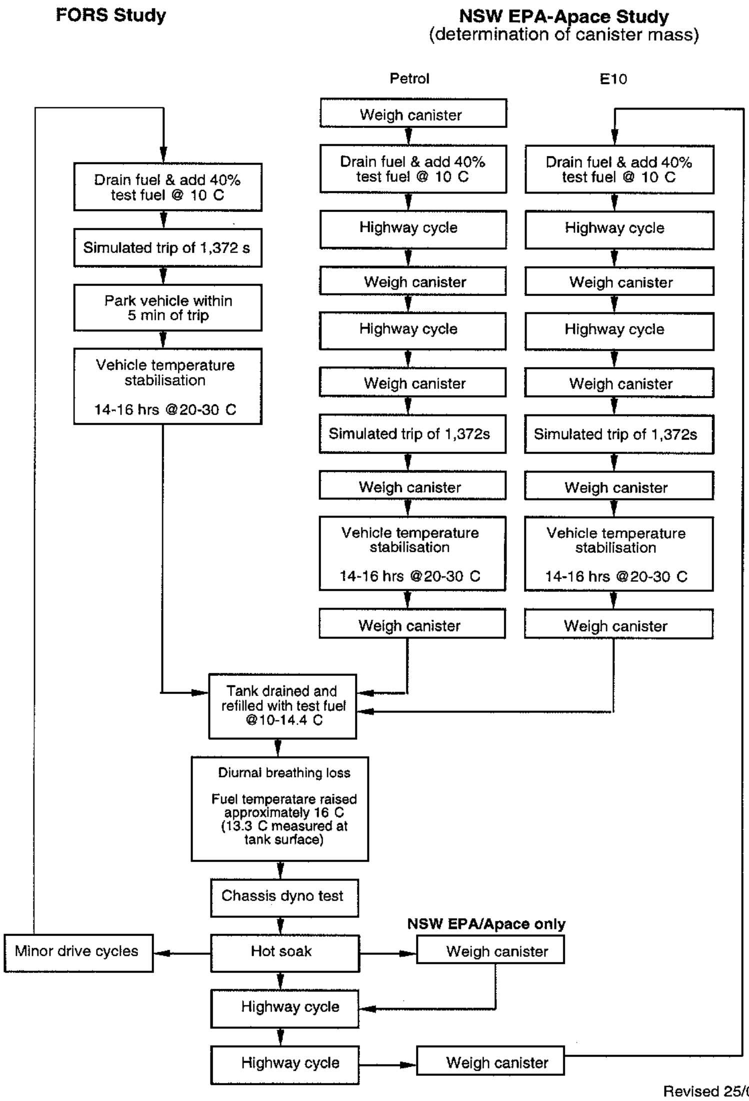
Fig 2 - Measurement of Fuel Evaporative Emissions Preconditioning



Revised 25/04/97

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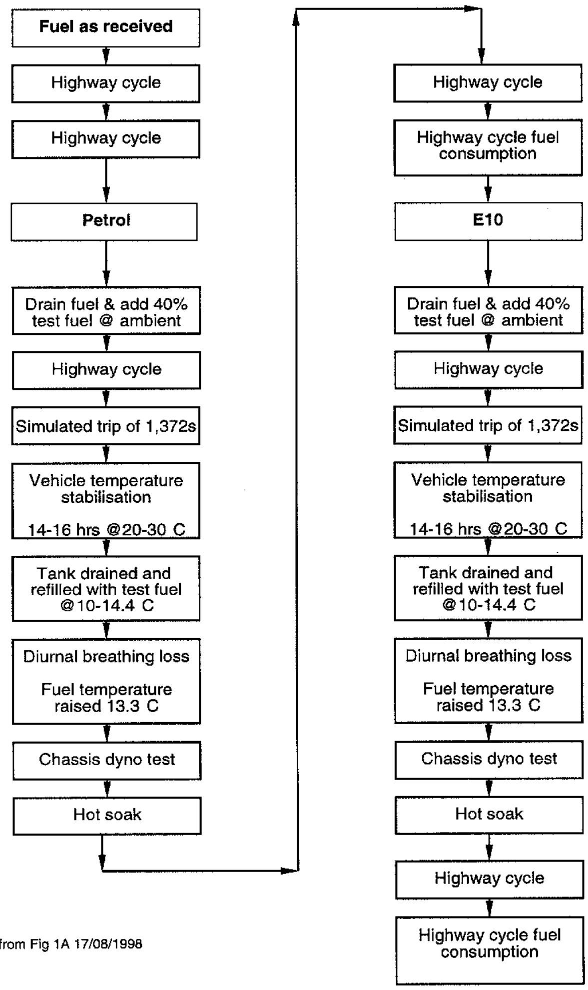
Fig 3 - Measurement of Fuel Evaporative Emissions
Preconditioning & Test Procedure
(based on ADR37)

Petrohol Project



Revised from Fig 1A 17/08/1998

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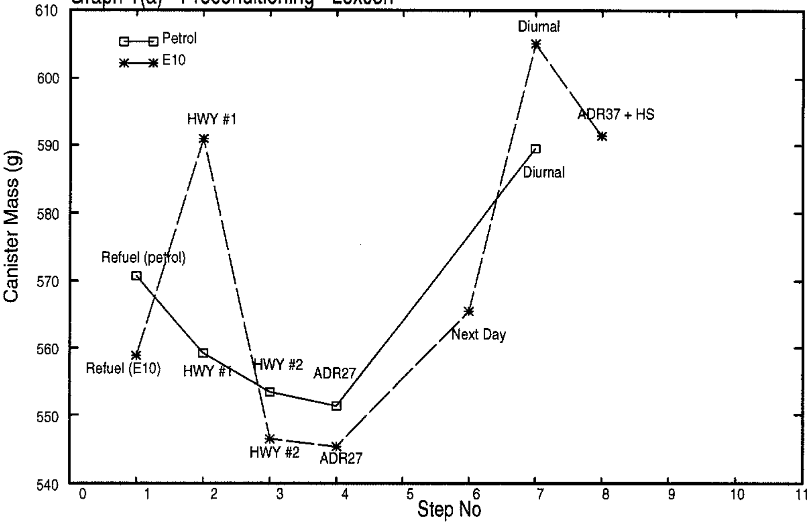
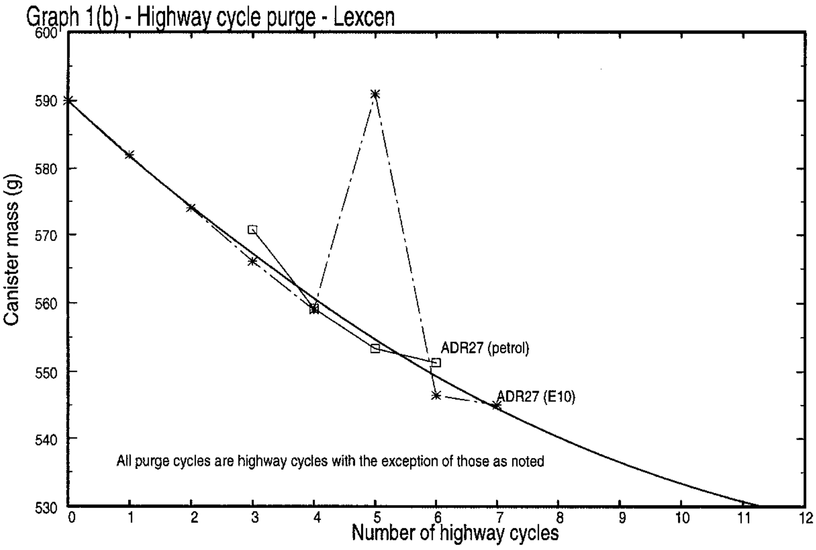
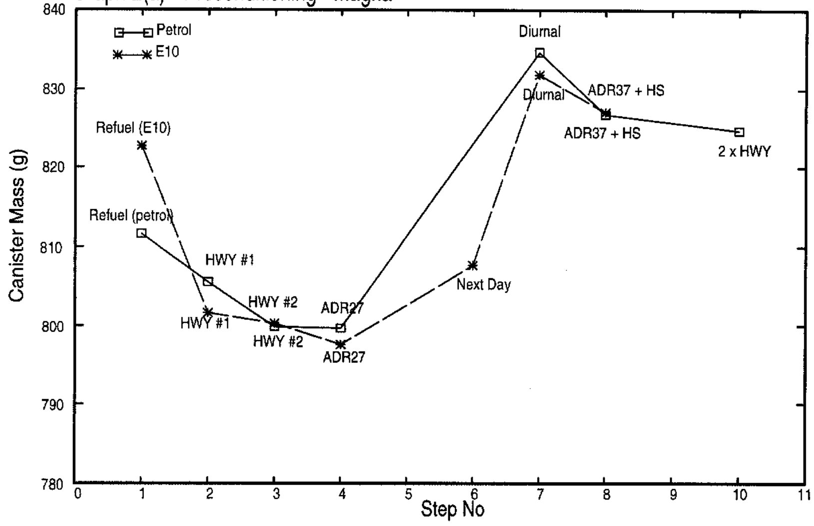
Graph 1(a) - Preconditioning - Lexcen



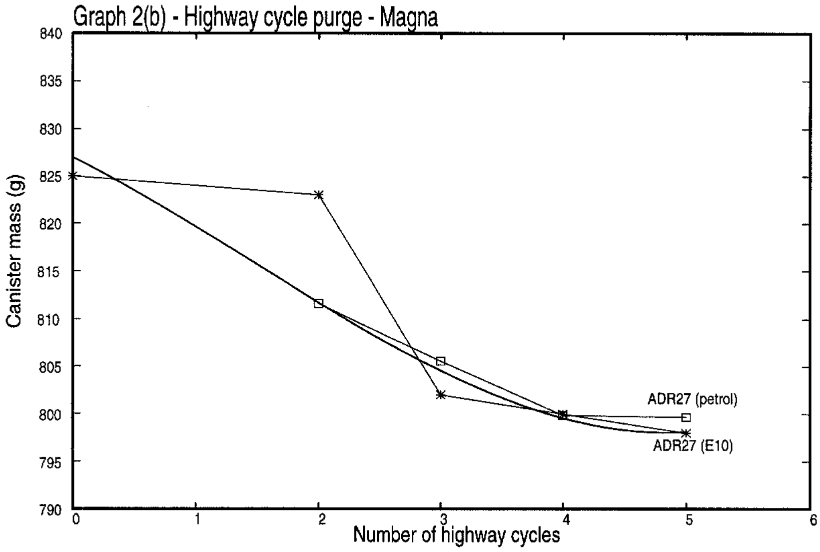
Graph 1(b) - Highway cycle purge - Lexcen



Graph 2(a) - Preconditioning - Magna



Graph 2(b) - Highway cycle purge - Magna



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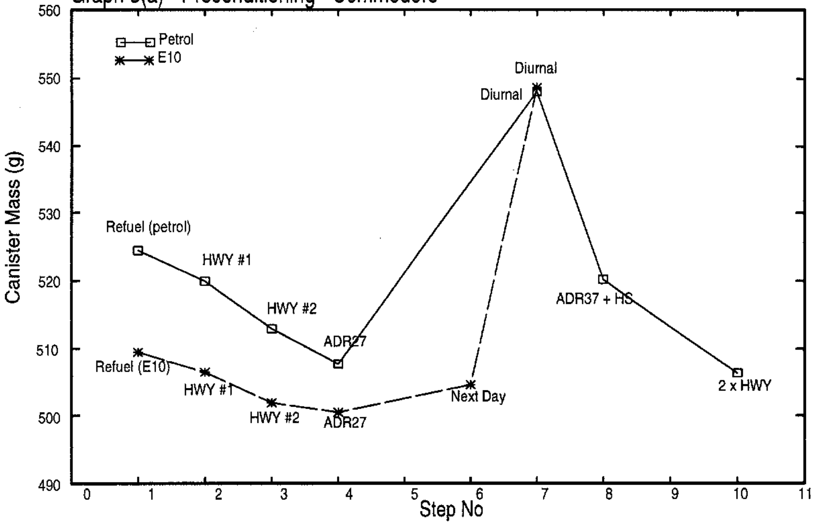
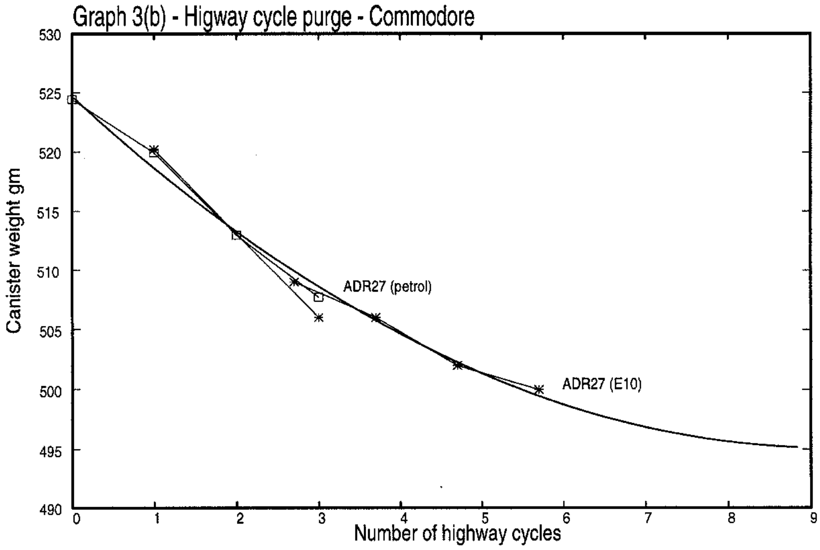
Graph 3(a) - Preconditioning - Commodore



Graph 3(b) - Higway cycle purge - Commodore



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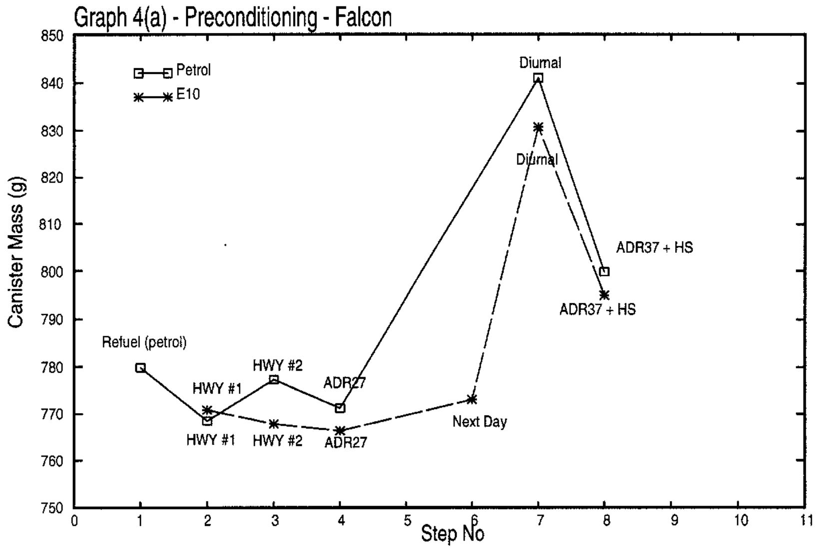
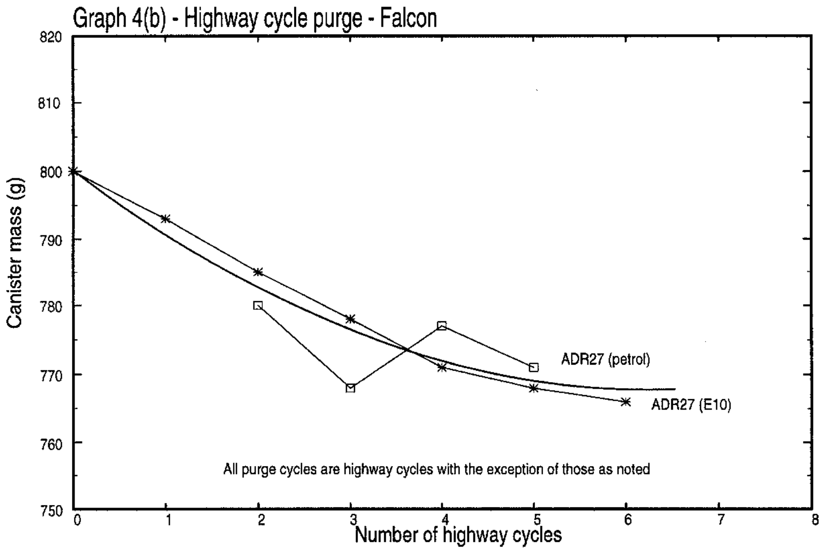

Graph 4(a) - Preconditioning - Falcon
Canister Mass (g)
Step No
Petrol
E10
Refuel (petrol)
HWY #1
HWY #2
ADR27
Diurnal
ADR37 + HS
Next Day
850
840
830
820
810
800
790
780
770
760
750
0
1
2
3
4
5
6
7
8
9
10
11


Graph 4(b) - Highway cycle purge - Falcon
Canister mass (g)
Number of highway cycles
ADR27 (petrol)
ADR27 (E10)
All purge cycles are highway cycles with the exception of those as noted
820
810
800
790
780
770
760
750
0
1
2
3
4
5
6
7
8

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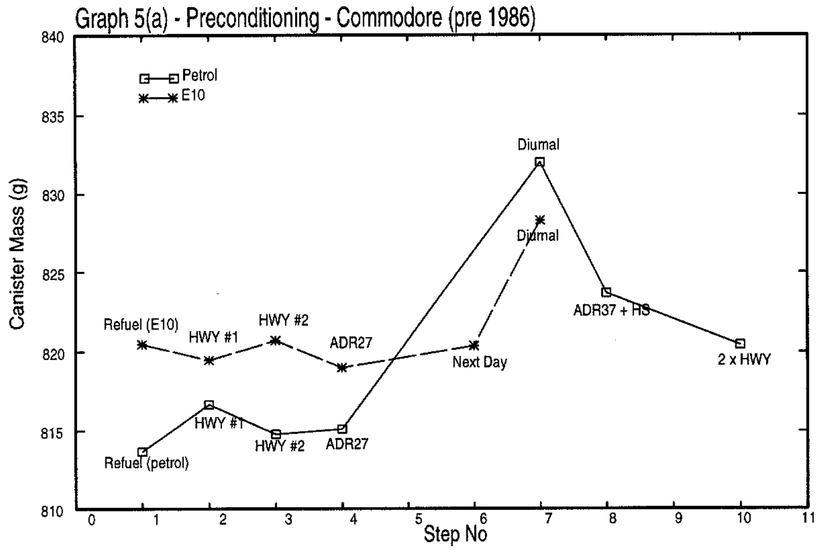
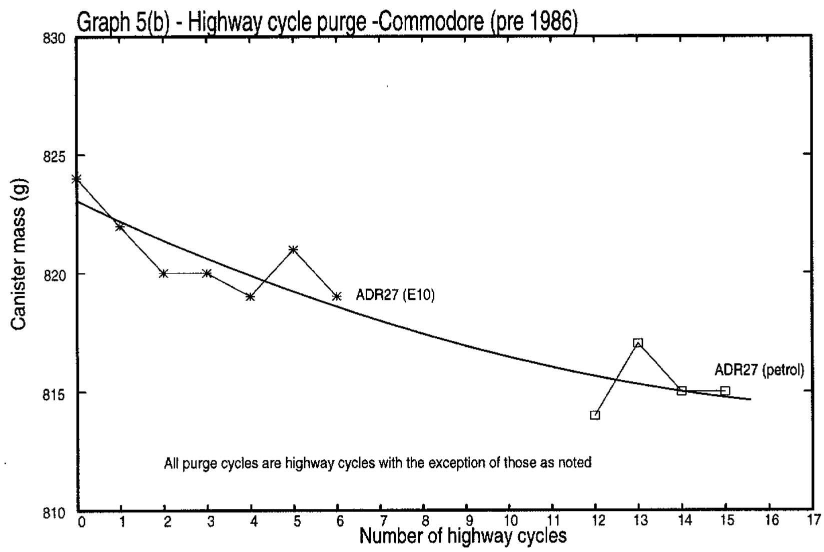

Graph 5(a) - Preconditioning - Commodore (pre 1986)
Petrol
E10
Diurnal
Refuel (E10)
HWY #1
HWY #2
ADR27
Next Day
ADR37 + HS
2 x HWY
Refuel (petrol)
Canister Mass (g)
Step No
840
835
830
825
820
815
810
0
1
2
3
4
5
6
7
8
9
10
11


Graph 5(b) - Highway cycle purge -Commodore (pre 1986)
ADR27 (E10)
ADR27 (petrol)
All purge cycles are highway cycles with the exception of those as noted
Canister mass (g)
Number of highway cycles
830
825
820
815
810
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

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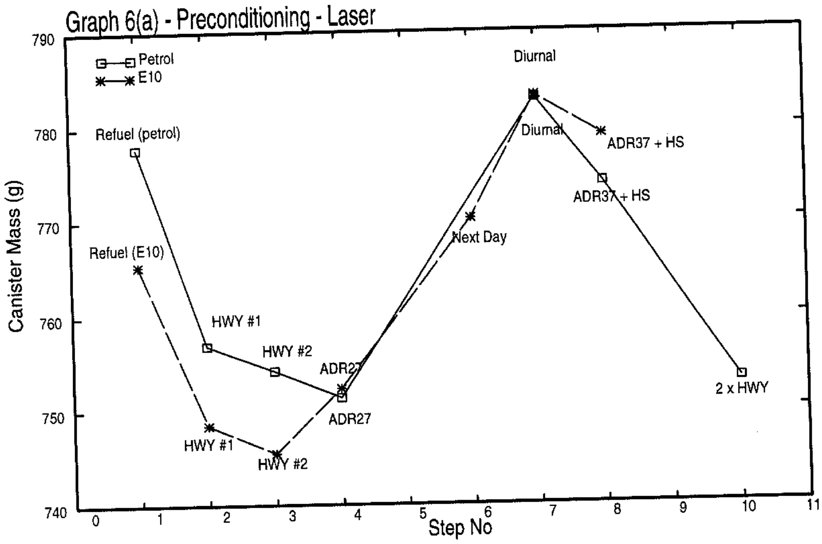
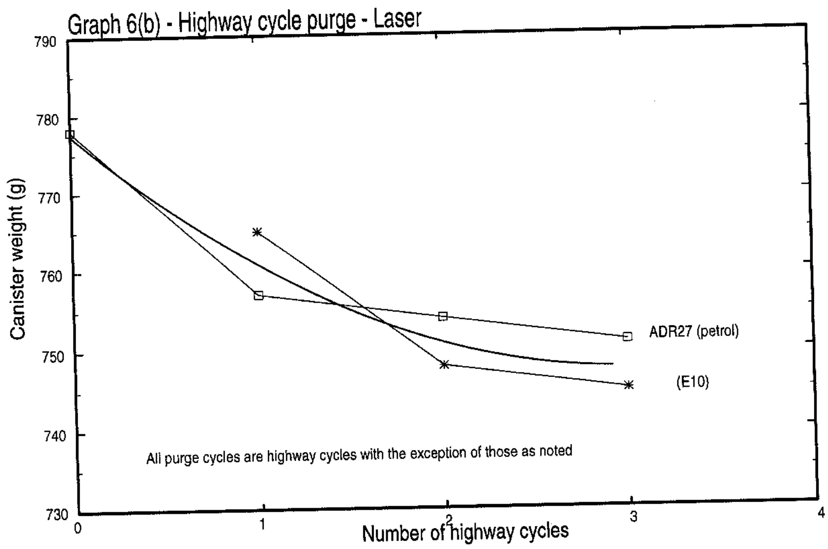

Graph 6(a) - Preconditioning - Laser
Petrol
E10
Refuel (petrol)
Refuel (E10)
HWY #1
HWY #2
ADR27
Next Day
Diurnal
ADR37 + HS
2 x HWY
Canister Mass (g)
Step No


Graph 6(b) - Highway cycle purge - Laser
ADR27 (petrol)
(E10)
All purge cycles are highway cycles with the exception of those as noted
Canister weight (g)
Number of highway cycles

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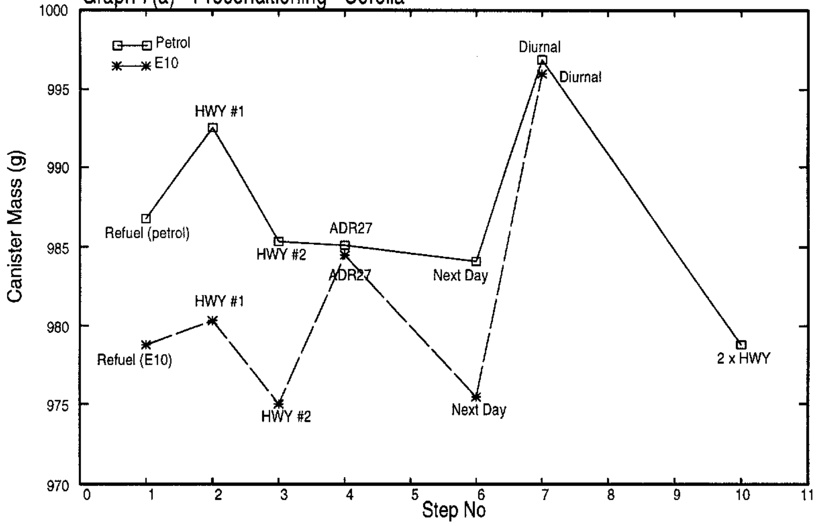
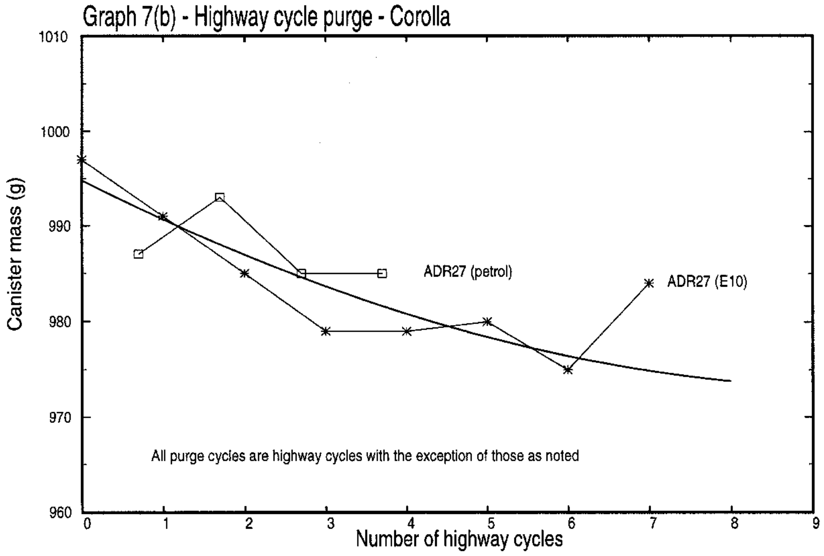
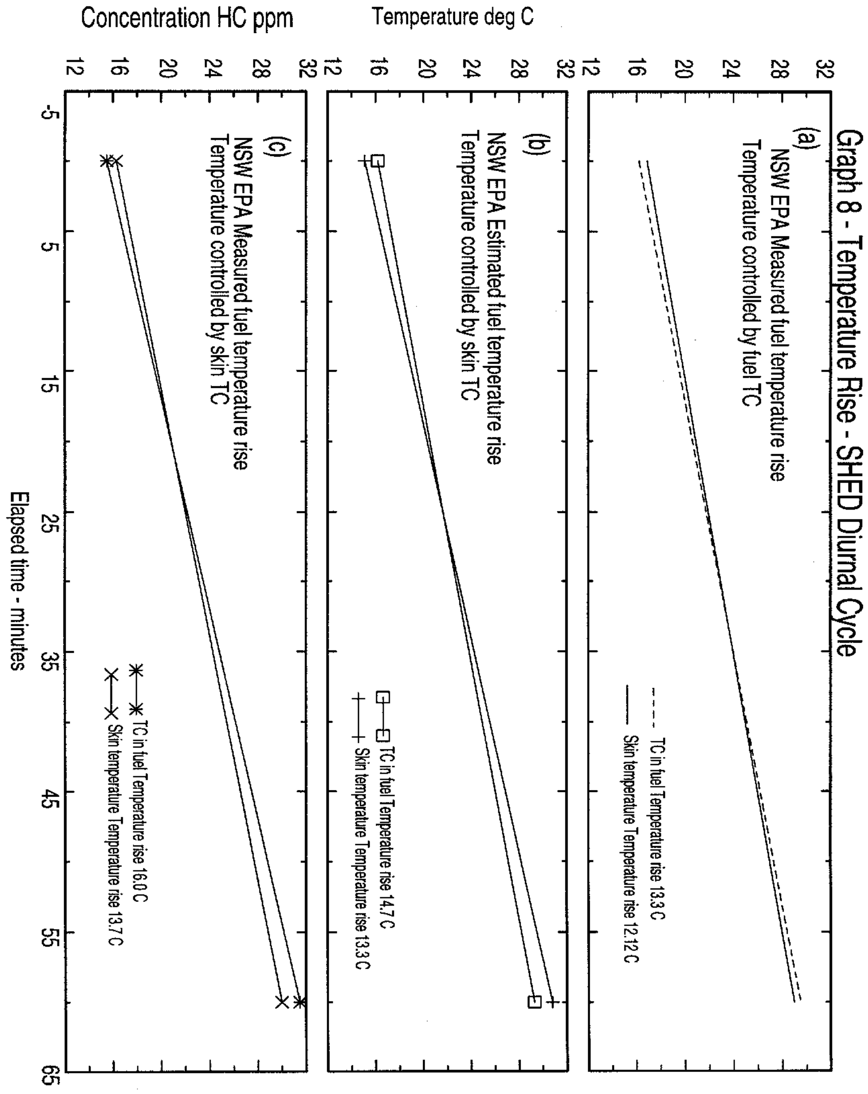
Graph 7(a) - Preconditioning - Corolla



Graph 7(b) - Highway cycle purge - Corolla




Graph 8 - Temperature Rise - SHED Diurnal Cycle
(a)
NSW EPA Measured fuel temperature rise
Temperature controlled by fuel TC
TC in fuel Temperature rise 13.3 C
Skin temperature Temperature rise 12.12 C
(b)
NSW EPA Estimated fuel temperature rise
Temperature controlled by skin TC
TC in fuel Temperature rise 14.7 C
Skin temperature Temperature rise 13.3 C
(c)
NSW EPA Measured fuel temperature rise
Temperature controlled by skin TC
TC in fuel Temperature rise 16.0 C
Skin temperature Temperature rise 13.7 C
Temperature deg C
Concentration HC ppm
12
16
20
24
28
32
-5
5
15
25
35
45
55
65
Elapsed time - minutes

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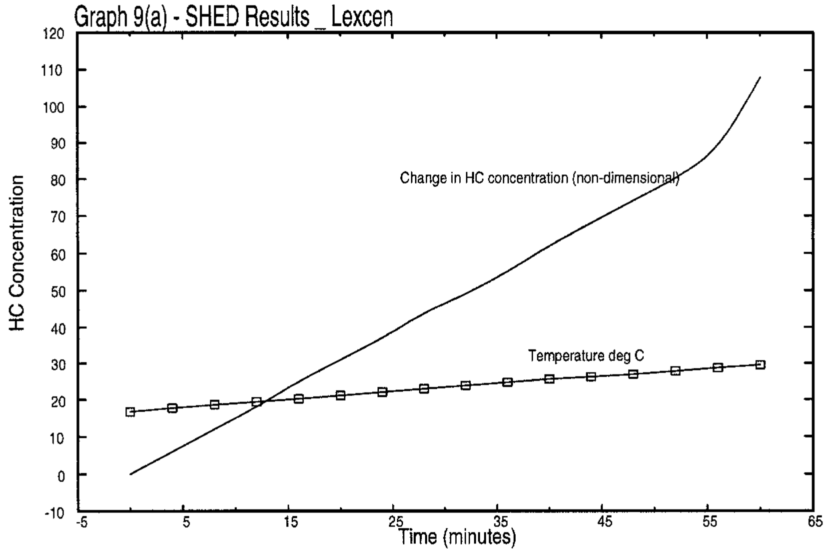
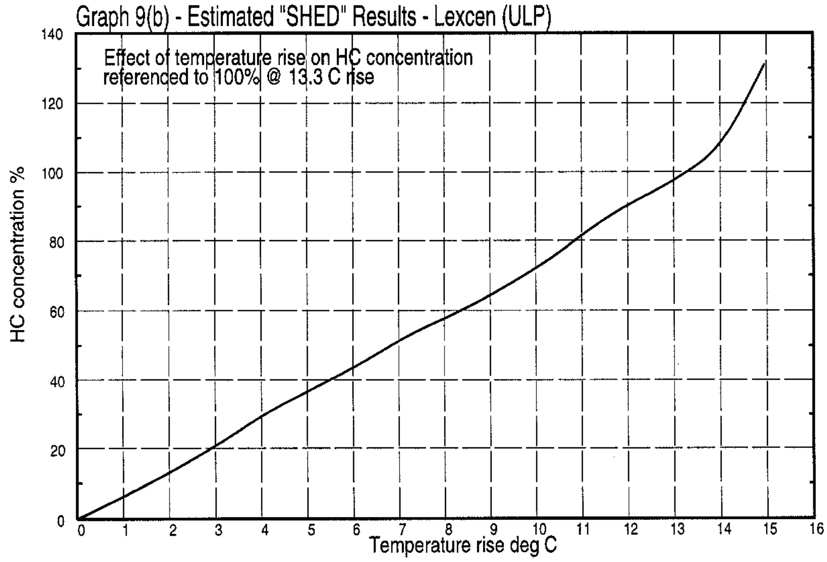
Graph 9(a) - SHED Results _ Lexcen



Graph 9(b) - Estimated "SHED" Results - Lexcen (ULP)



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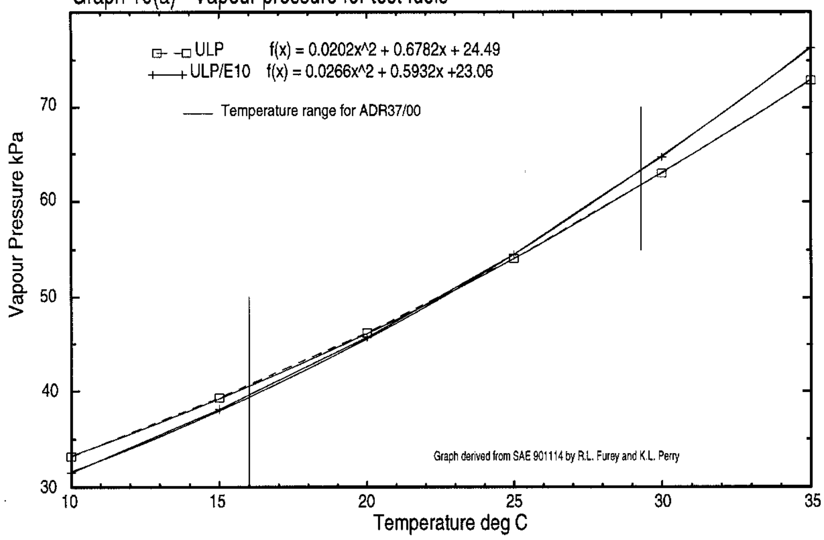
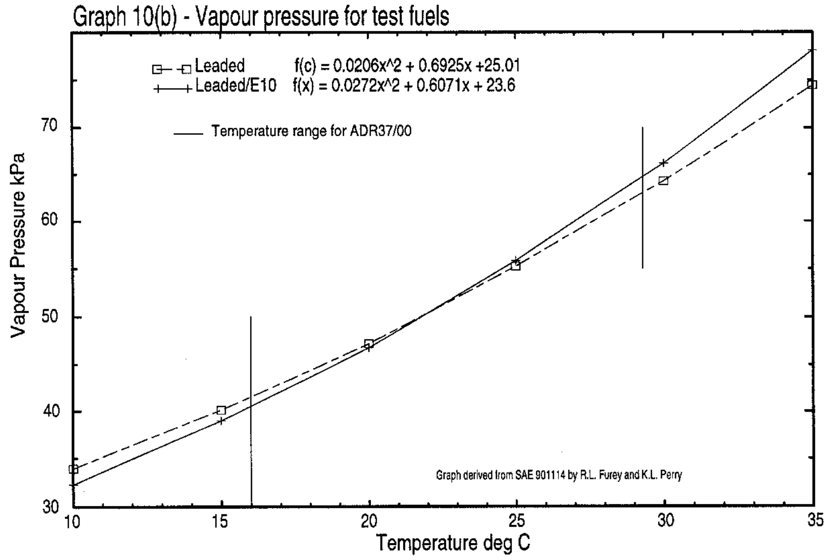
Graph 10(a) - Vapour pressure for test fuels



Graph 10(b) - Vapour pressure for test fuels



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APPENDIX G: VEHICLE SELECTION QUESTIONAIRE

Part B

Details of vehicle offered for participation in the trial

Make ____________ Model __________ Year ____

Engine No ____________ Engine capacity ________

Registration No__________ Registered until ________

Speedo/odometer reading _________ km/miles

Annual distance covered by the vehicle (in km) ?

Less than 10,000	10,000 to 20,000	More than 20,000

For how long have you been using ethanol blend ?

Less than 3 months	3 to 6 months	More than 6 months

Of your vehicle's total fuel consumption, what proportion do you estimate is ethanol blend

Less than a third	about half	well over half

Is your vehicle modified to use LPG or CNG ? YES | NO

Of your vehicle's total fuel consumption, what proportion do you estimate is LPG or CNG

Less than a third	about half	well over half

Which of the following best describes your use of the vehicle ?

- Local domestic/short distance commuting (1hr/day) ☐
- Local domestic/long distance commuting (2-3 hrs/day) ☐
- Intensive use/short trips (more than 3 hrs/day total) ☐
- Intensive use/long trips (more than 3hrs/day total) ☐

Is the above vehicle offered for testing insured ? YES | NO

Is the insurance cover Comprehensive ☐ Third party property damage ☐

Your vehicle may be required for up to a week for EPA to complete the testing. Please indicate the week when your vehicle **is not** available.

My vehicle will not be available from ______________

to ______________

Part B cont'd

If your offer is accepted and, in return, you require Apace to lend you a courtesy car while your vehicle is tested, would you agree to provide Apace with the confidential information set out at Part C ?.

YES ☐ NO ☐

If "YES", would you also be prepared to borrow the courtesy car on the conditions of assignment set out in Part D ?.

YES ☐ NO ☐

If you did not answer "YES" to both questions above, Apace would not be permitted to lend you a courtesy car. Are you willing to offer your vehicle for testing even though the Apace courtesy car could not be lent to you ?

YES ☐ NO ☐

You do not need to complete Part C at this time. However completing Part C now will enable Apace to ensure that a loan vehicle can be made available for your use.

To enable Apace to contact you in response to this questionnaire, please provide the following details -

Name ______________

Postal address ______________

Phone/Fax No ______________

Signature ______________ Date ________

Thank you for completing this questionnaire. Please mail it to

Apace will advise you within one month whether your vehicle is suitable for testing.

Part C

Vehicle details

The following information is required for insurance purposes only. The information will be kept strictly confidential and not divulged to any other party.

Insurance company ______________

Policy No ______________ NCB % ________

Driver details

Name ______________

Date of birth (optional) ______________ or aged over 25 | 35 | 45

Address ______________

Phone (home) __________ (work) __________

Driving licence number ______________

Any motoring offences leading to loss of points since 1991 ?

NO ☐ YES ☐ Please specify

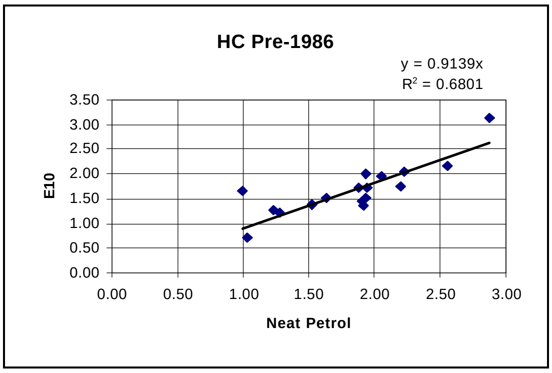
Will there be any other drivers of the courtesy car ?

NO ☐ YES ☐ Please give details separately

Driver's signature ______________ Date ________

APPENDIX H:LINEAR REGRESSION ANALYSIS

Regulated Exhaust Emissions



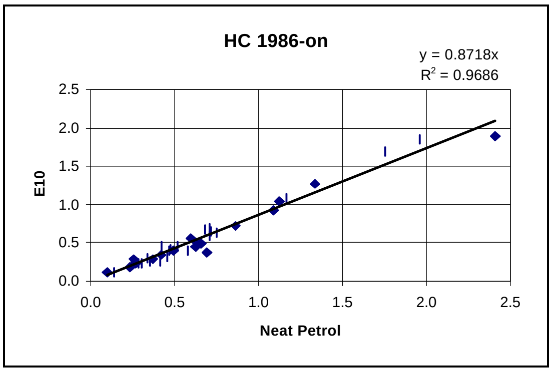


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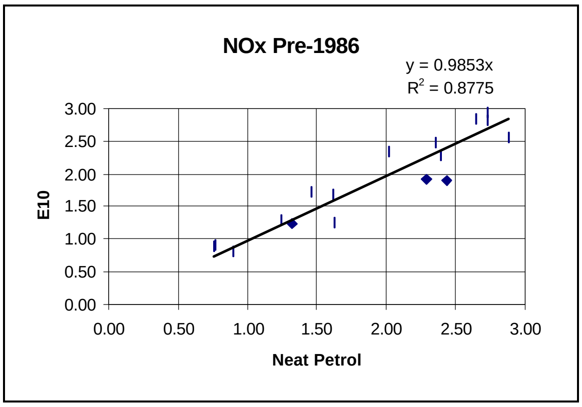
FIGURE APPENDIX H:-1: SCATTER GRAPHS - EXHAUST - POST-TUNE HC EMISSIONS



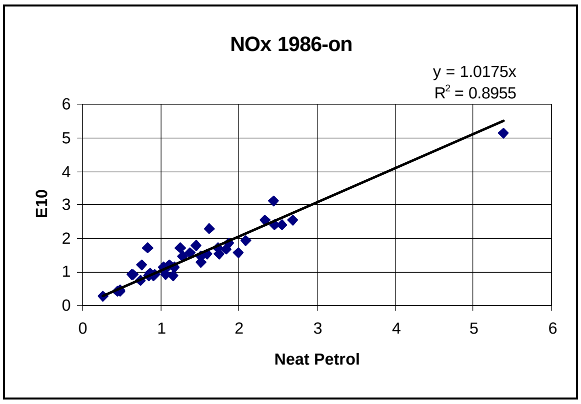


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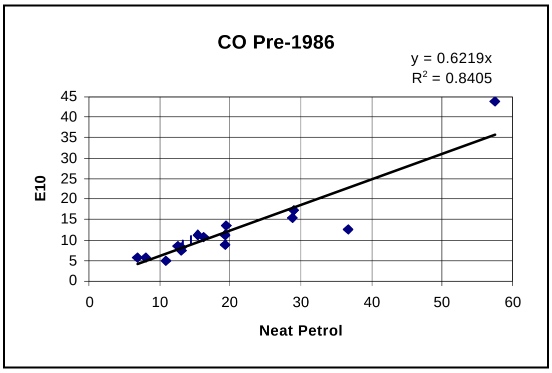
FIGURE APPENDIX H:-2: SCATTER GRAPHS - EXHAUST - POST-TUNE NO_X EMISSIONS



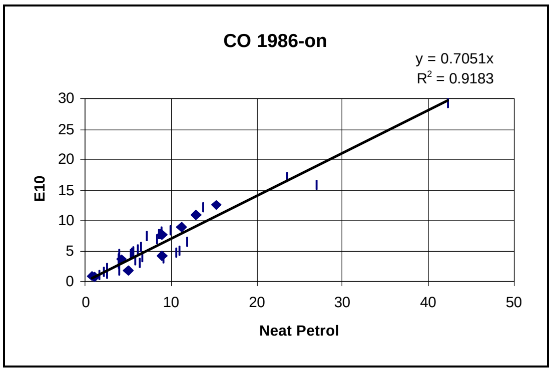


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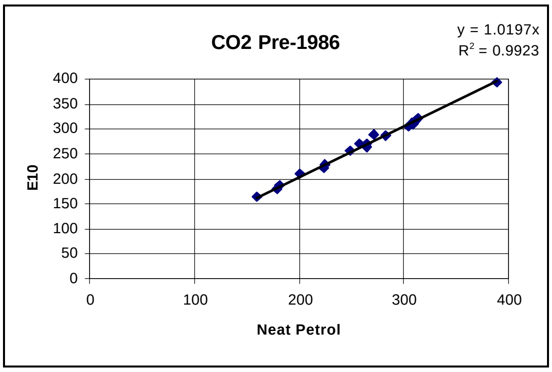
FIGURE APPENDIX H:-3:SCATTER GRAPHS - EXHAUST - POST-TUNE CO EMISSIONS

Non-Regulated Exhaust Emissions



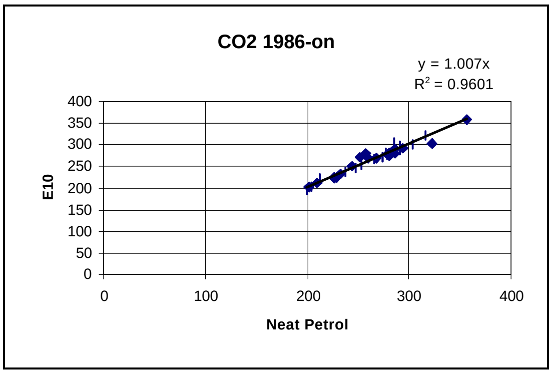


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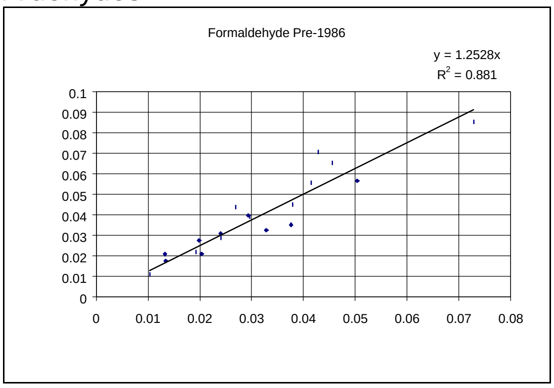
FIGURE APPENDIX H:-4:SCATTER GRAPHS - EXHAUST - POST-TUNE CO_2 EMISSIONS

Aldehydes



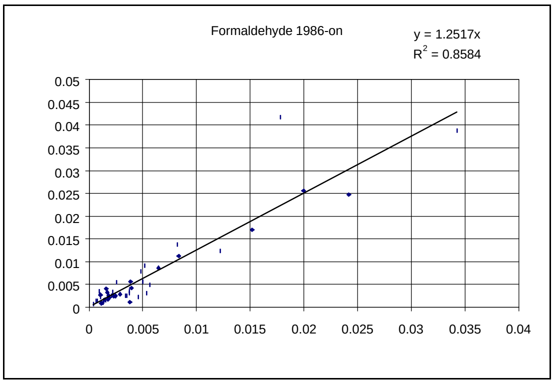


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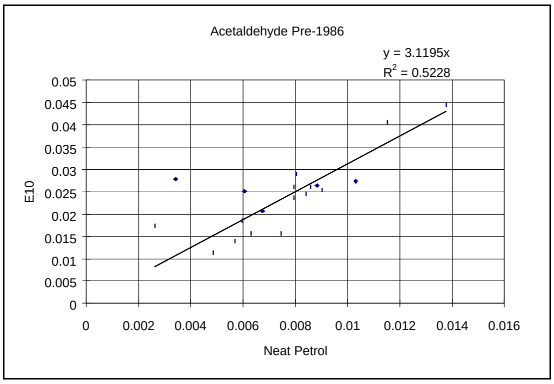
FIGURE APPENDIX H:-5:SCATTER GRAPHS - EXHAUST - POST-TUNE FORMALDEHYDE EMISSIONS



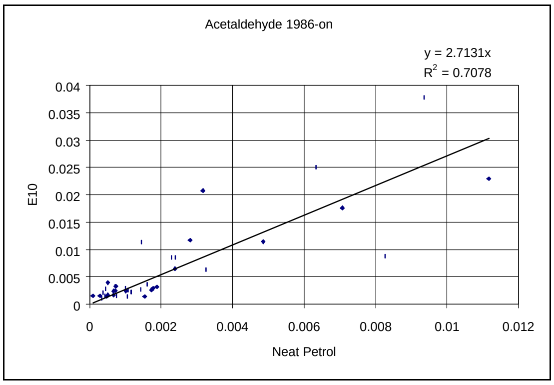


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FIGURE APPENDIX H:-6:SCATTER GRAPHS - EXHAUST - POST-TUNE ACETALDEHYDE EMISSIONS

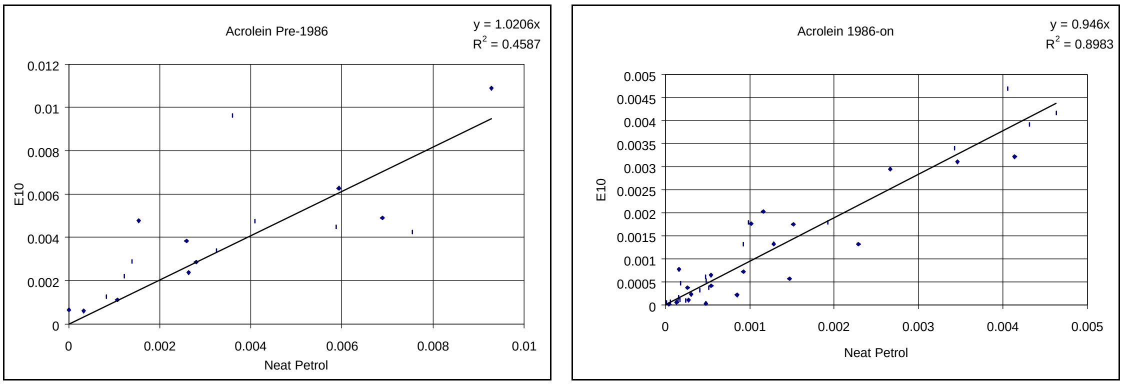

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FIGURE APPENDIX H:-7:SCATTER GRAPHS - EXHAUST - POST-TUNE ACROLEIN EMISSIONS

Toxics

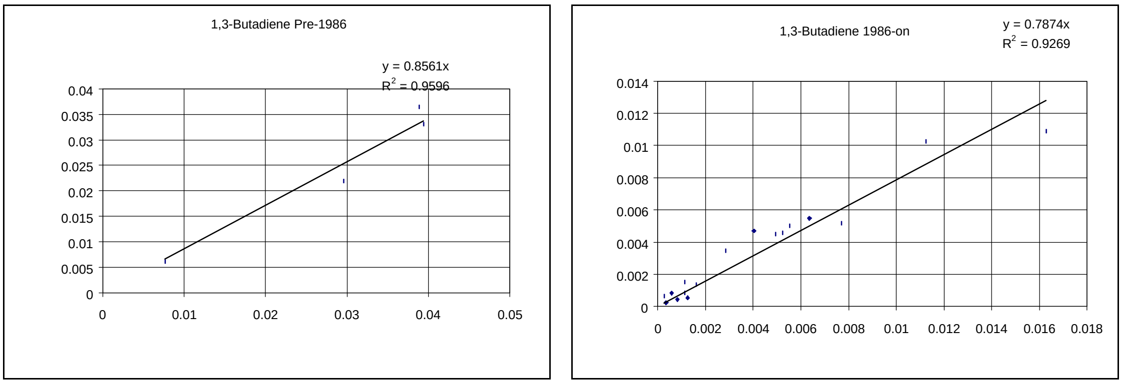

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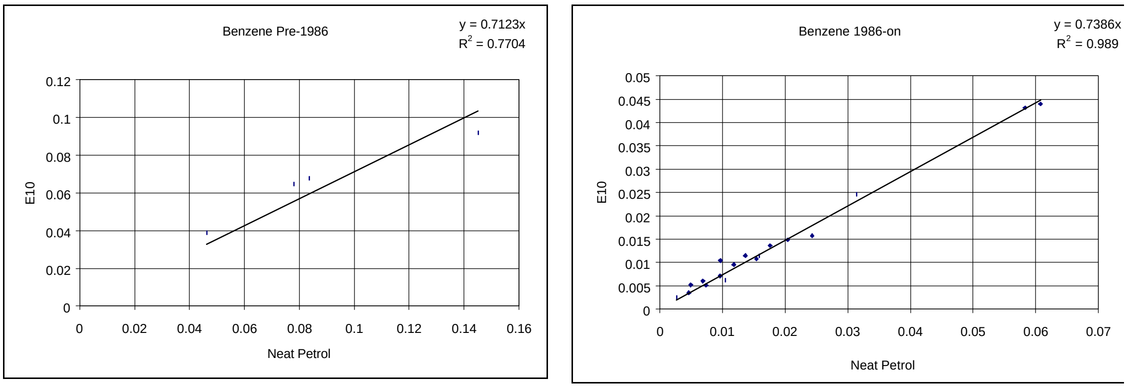
FIGURE APPENDIX H:-8:SCATTER GRAPHS - EXHAUST - POST-TUNE 1,3-BUTADIENE EMISSIONS



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a

FIGURE APPENDIX H:-9:SCATTER GRAPHS - EXHAUST - POST-TUNE BENZENE EMISSIONS

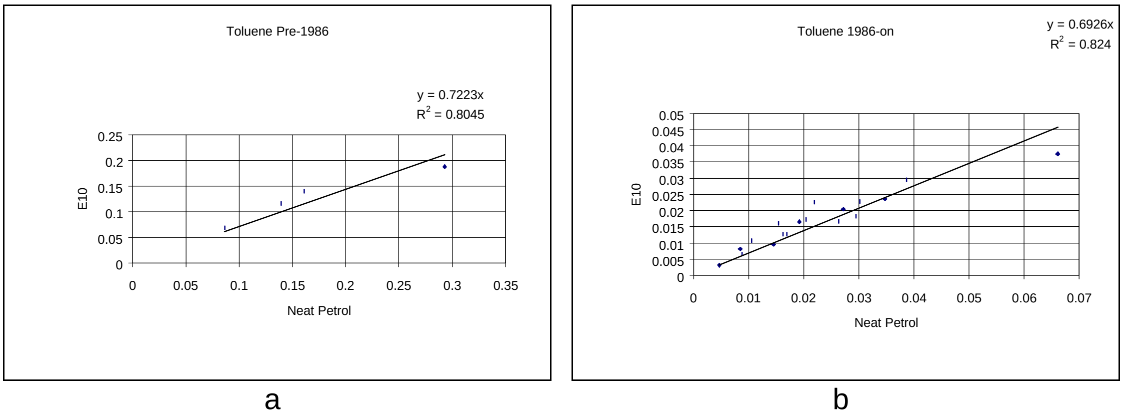

FIGURE APPENDIX H:-10:SCATTER GRAPHS - EXHAUST - POST-TUNE TOLUENE EMISSIONS

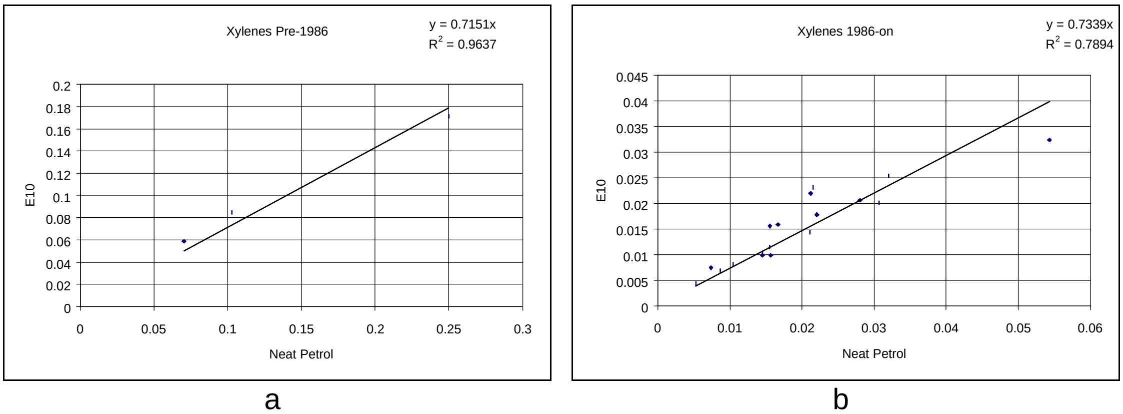

FIGURE APPENDIX H:-11: SCATTER GRAPHS - EXHAUST - POST-TUNE XYLENE EMISSIONS

Evaporative Emissions

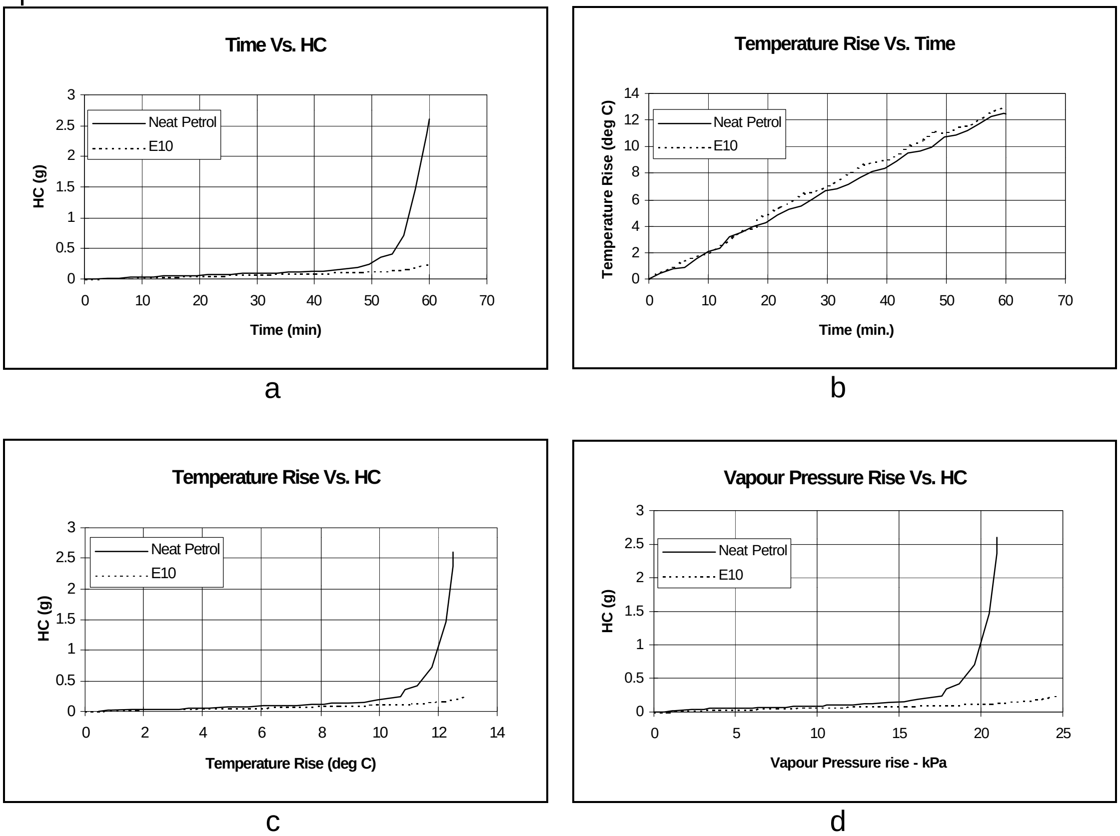

FIGURE APPENDIX H:-12: EVAPORATIVE EMISSIONS - DIURNAL PHASE - HOLDEN COMMODORE VR

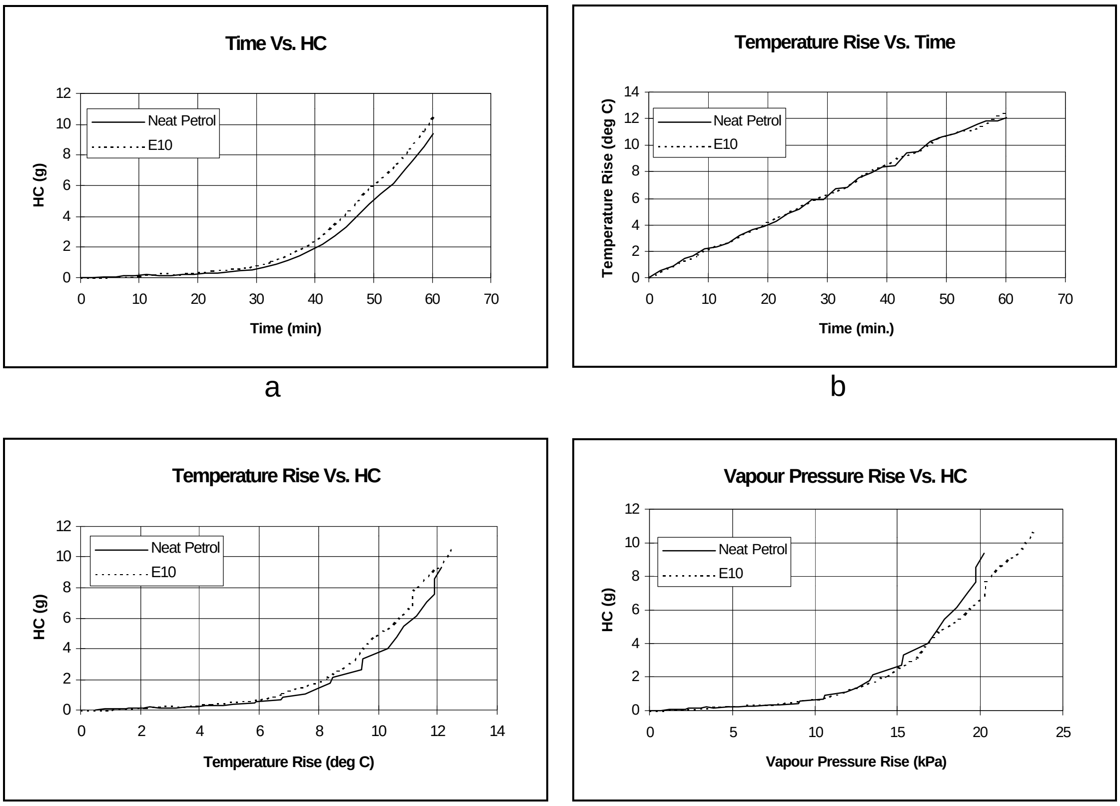

FIGURE APPENDIX H:-13: EVAPORATIVE EMISSIONS - DIURNAL PHASE - FORD LASER KF

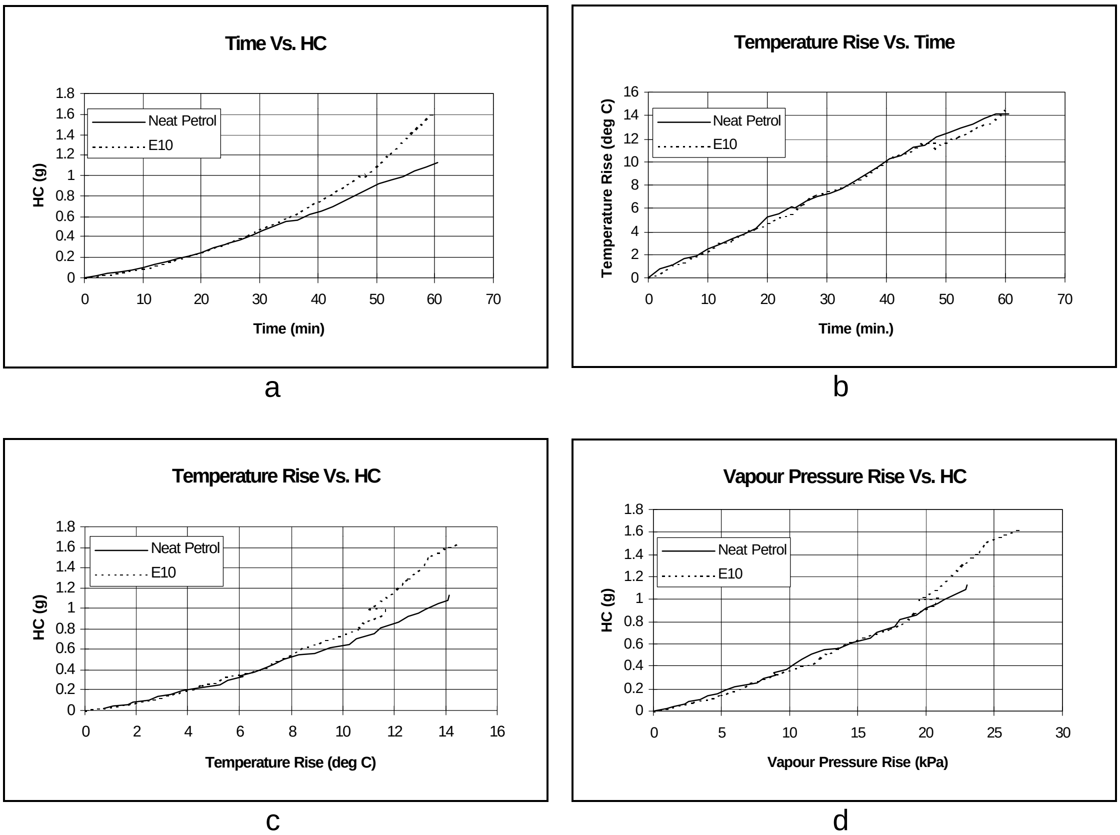

FIGURE APPENDIX H:-14: EVAPORATIVE EMISSIONS - DIURNAL PHASE - HOLDEN COMM. VH

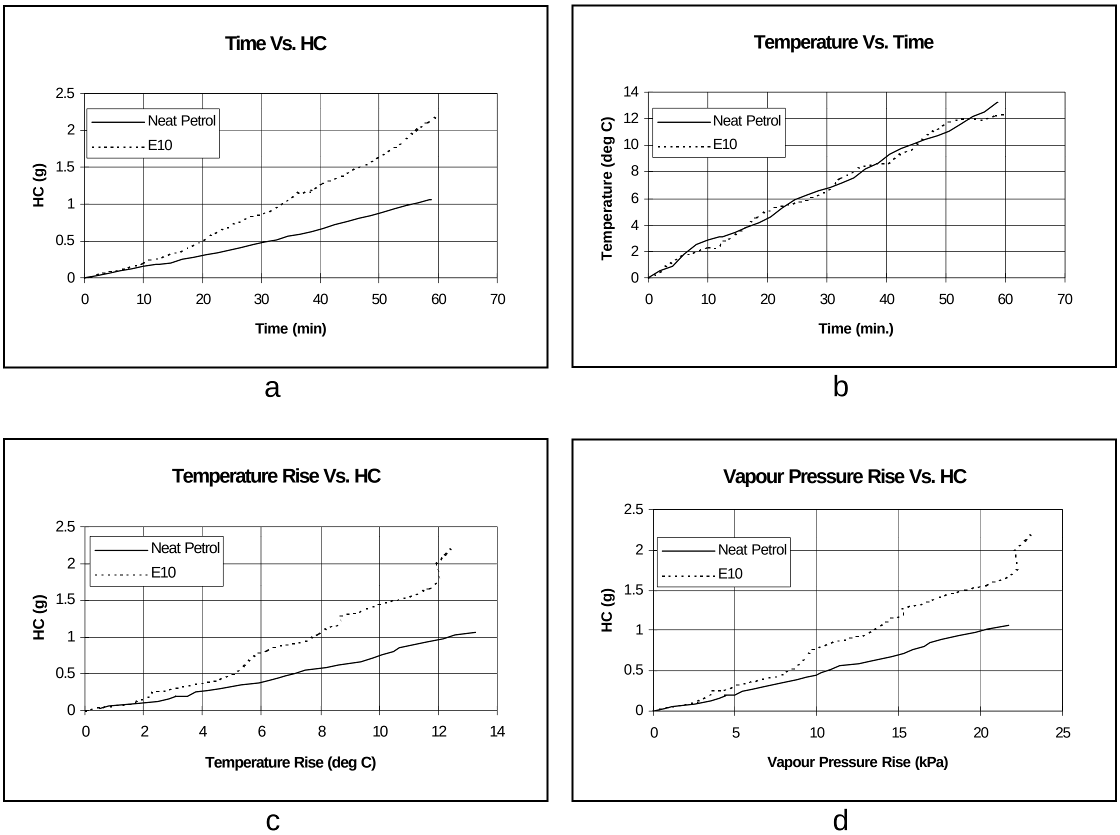

FIGURE APPENDIX H:-15: EVAPORATIVE EMISSIONS - DIURNAL PHASE - FORD FALCON XF

Diurnal and Hot-Soak scatter graphs

The tests ignored are as follows:

- ♦ Diurnal Test Nos. - LP - 21998/21997, 22006/22005, 21887/21886, 21793/21792

  ULP- 21863/21862, 21762/21761, 22014/22013, 21881/21880, 21854/21853, 21732/21726

- ♦ Hot Soak Test Nos. - LP- 21887/21886, 21793/21792, 21783/21782, 21909/21908

  ULP- 21777/21776, 21863/21862, 21949/21948, 1889/2190, 21879/21878, 21919/21918

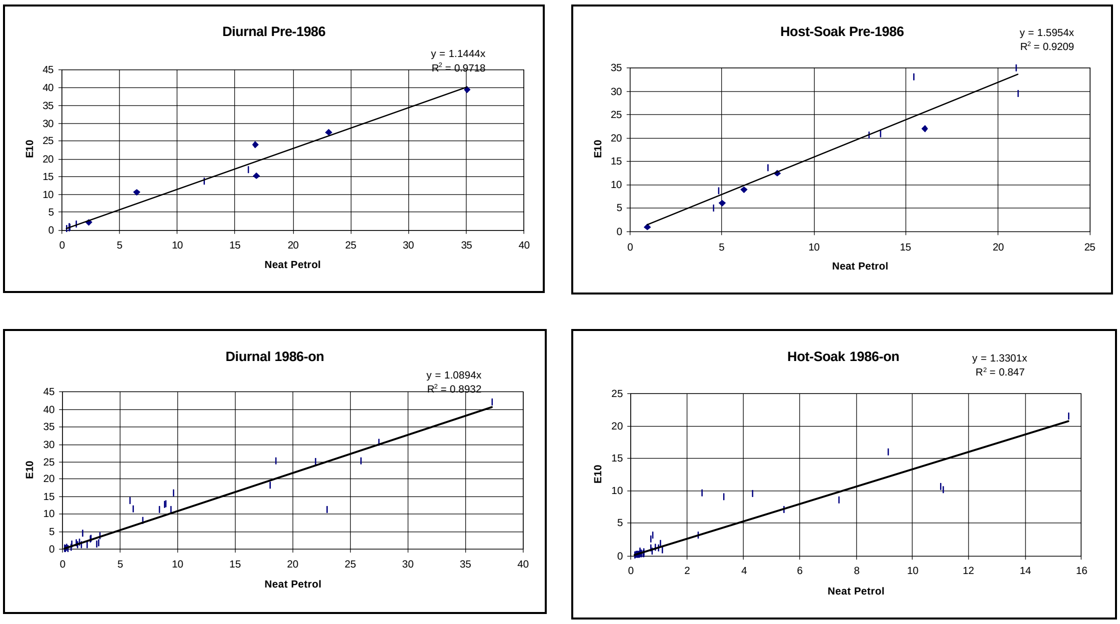

FIGURE APPENDIX H:-16: SCATTER GRAPHS FOR DIURNAL & HOT-SOAK

APPENDIX I: CARBON LIFE-CYCLE

Certain naturally occurring gases in the atmosphere trap the sun's heat like the glass roof in a greenhouse. This natural "greenhouse effect" helps keep the Earth's average temperature at a comfortable 15°C. Without these greenhouse gases, the Earth would be about -18°C°, like deep frozen food.

Since around 1800 and especially during the past few decades, human activities have increased the atmospheric levels of several greenhouse gases. To name a few:

- Carbon dioxide (CO_2) has increased from about 280 ppmv (parts per million by volume) in the year 1800 through 315 ppmv in 1958 to about 358 ppmv in 1994, an increase of 27% (IPCC 95, p 16, 78) (Keeling).
- Methane (CH_4) has increased from roughly 0.8 ppmv in 1800 to more than 1.7 ppmv in 1992, an increase of more than 110%.
- Nitrous oxide (N_2O) rose from a pre-industrial level of about 0.275 ppmv to about 0.310 ppmv in 1992, an increase of almost 13%. (IPCC 94, p 87-8, 91-2).

It has now become imperative that global emissions of greenhouse gases be reduced to avoid the undesirable effects of global warming.

The introduction of biomass derived fuels reduces the net emission of CO_2 when the full carbon cycle is considered.

With a 10% v/v petrol/ethanol blend (E10) there is a 1-2% increase in CO_2 in exhaust emissions as a result of increased fuel consumption. However, when the whole life cycle of petrol and ethanol is taken into account there is a nett reduction in the total CO_2 emitted. Estimates of the reduction vary widely and depend on several factors including:

- biomass source;
- agricultural inputs including manufacture of fertiliser;
- raw material transport;
- chemical inputs;
- effluent treatment and disposal;
- distribution of ethanol fuel;
- plant amortisation; and,
- cogenerated electrical power.

NRMA

The method adopted by NRMA for estimating life cycle CO_2 emissions considers the energy inputs and their sources. For neat petrol these include:

- heating value of 46.0 MJ/kg;
- CO_2 produced on complete combustion = 3.18 kg/kg
- energy of oil production and shipping of crude;
- refining; and,
- distribution of the final product.

The following is included in the case of ethanol:

- heating value of 26.8 MJ/kg ;
- no contribution of CO_2 to the environment on combustion;
- energy input to sugarcane farming, mainly based on diesel fuel;
- ethanol yield per tonne of feedstock;
- assumption that energy from bagasse combustion is used in juice extraction, brew preparation and fermentation;
- distillation energy requirements;
- levy for the disposal of dunder; and,
- distribution.

For the 1993 Energy Challenge event, NRMA estimated life-cycle CO_2 emission of 1.12 kg CO_2/kg ethanol for ethanol sourced from sugarcane and 3.51kg CO_2/kg neat petrol. On this estimate E10 blend would have a CO_2 life-cycle emission of 3.29 kg CO_2/kg E10, a reduction of approximately 6% compared to neat petrol.

Apace Research

The calculation used by Apace is based on the paper "Fuel Ethanol from Cellulosic Biomass" by Lynd, L.R. et al published in Science, Volume 251, pp. 1318-1323, 15 March 1991.

An indication of the contribution of various ethanol fuel production scenarios to carbon dioxide accumulation in the atmosphere is the net carbon dioxide produced per unit energy N. This parameter may be estimated from:

$$N = \frac{f}{R} \times C_f$$

where :	f	=	fraction of energy inputs met by fossil fuels;
	C_f	=	CO_2 produced per unit energy for fossil energy inputs;

and,

R = ratio of energy output to energy input for any ethanol production scenario

$$R = \frac{1 + (3 \times E)}{A + T + S + C + D + P}$$

where:
E = cogenerated electrical power;
A = agricultural energy inputs;
T = raw material transport;
S = steam and electricity process energy;
C = chemical inputs in processing;
D = distribution of ethanol fuel; and
P = plant amortisation.

where all energy flows are expressed as fractions of the lower calorific value of ethanol; and,

the multiplier of E reflects the displacement of thermal energy for conventional coal-fired electrical power generation.

C_f for diesel and petrol and calculated values of N for different ethanol production scenarios are shown in Table Appendix I:-1.

TABLE APPENDIX I:-1: CO_2 RELEASED PER UNIT ENERGY

Diesel and petrol	80mg/kJ LHV
Ethanol (Manildra)	36mg/kJ LHV
Ethanol (dedicated lignocellulosic crops)	16mg/kJ LHV
Ethanol (lignocellulosic residues)	6mg/kJ LHV

In the case of E10 this would result in the mass emissions of CO_2 shown in Table Appendix I:-2. A 2% increase in fuel consumption is assumed. Numbers in parentheses are the percentage reductions compared to neat petrol.

TABLE APPENDIX I:-2: MASS EMISSIONS OF CO_2.

Petrol	2.44kg/L	
E10 based on Ethanol (Manildra)	2.27kg/L	(-5.1%)
E10 based on Ethanol (dedicated lignocellulosic crops)	2.23kg/L	(-6.8%)
E10 based on Ethanol (lignocellulosic residues)	2.21kg/L	(-7.6%)

Further reductions in net CO_2 emission can be achieved by introduction of new technologies for the production of fuel ethanol and replacement of all fossil fuel inputs into the ethanol production process with renewables.

Others

Estimates of CO_2 life cycle emissions vary widely. For example John Sheehan of NREL quotes net CO_2 reductions of 72% to 117% (but assumes that the range is from 73% to 93%) for bioethanol compared to neat petrol. (1998 National Conference on Ethanol Policy and Marketing, Albuquerque, New Mexico, Feb 26-27 1998).