REPORT NO. INT 183

AN ESTIMATE OF EMISSIONS FROM VEHICLES IN SOUTH AFRICA

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CONTENTS

1. WORLD SITUATION

1.1 Gasoline

The first country to introduce comprehensive legislation for controlling emissions from road transport was the USA where exhaust limits were set in the Clean Air Act of 1968. Reductions in emissions, amounting to a 90% reduction, were legislated in phases up to 1979. The 1975 interim and subsequent legislation required the use of catalytic converters, and unleaded gasoline had to be provided from that date to allow the use of new cars. Emissions levels for heavy duty engines were originally set in 1970, and much more stringent reductions were imposed in 1977 to take effect from 1981. The emission standards in the USA are shown in Appendix A.

In Europe vehicle emissions levels have been introduced by the United Nations Economic Commission for Europe. This situation has changed with the European Community (EC) taking over the legislative role. The original regulation - the ECE 15/01 code - was introduced in 1970 and changes have been made on occasions resulting in ECE Regulation 83 which sets levels to be implemented between 1988 and 1993 depending on vehicle size. The standards for emissions of carbon monoxide, oxides of nitrogen and hydrocarbons are shown historically in Fig. 1. This figure has been drawn for vehicles in the mass range from 851 kg to 1020 kg as an example. Other size vehicles have different permissible levels, with smaller vehicles having lower limits. Since 1984 the separate emission levels for NOx and HC have been phased out and a combined (NOx + HC) standard has been substituted.

The standards adopted in the USA, in Europe and in other countries have required the gradual introduction of catalytic converters. In the first place use had to be made of two-way catalysts to allow for a significant reduction in CO and HC. The reduction required for the NOx limits could not be effected by the two-way catalyst and recourse was made to the three-way catalyst. The three-way catalyst requires accurate control of the air-fuel ratio, which cannot be achieved using a carburettor, and there has been a move to fuel-injection and the use of computerized engine-management systems.

Besides the USA and the Europe Community, a number of other countries have adopted exhaust emission standards. These include:

Australia
Brazil
Canada
Hong Kong
Japan
Mexico
Singapore
South Korea
Taiwan

In addition India and Chile are developing standards.

Whilst the emission levels fixed by legislation are well documented, there is no estimate of what the effect has been on average emissions from vehicles. In theory the average emissions from vehicles "on-the-road" should be lower than the legislative limits in order to have a measure of safety in the engines being produced. However, once the engine is on the road its tuning will depart from optimum, and levels could increase above the legislative levels.

A limited amount of test data of engine emissions is given in Figs 2 to 5. The values from various engines have been compared with the ECE standards. The figures have been drawn separately for NO, HC and CO. An additional figure (Fig. 5) is included to show the new (HC + NOx) standard. For the historical values the limits for HC and NOx have been added in the historical data.

The cars include European and USA cars with approximately the same mass. The 1977 figures are a combination of Volkswagen and USA vehicles, whilst the 1997 figures are for two Renault models, one with a carburetor and no catalyst and one with fuel-injection and a three-way catalyst. Included in the 1977 data are a number of USA vehicles fitted with two-way catalysts.

With the exception of the carbureted Renault all the vehicles are below the required levels, with the two-way catalytic vehicles having CO levels about 15%, and HC levels 30% of those for the non-catalyst vehicles. There is no significant improvement in terms of NOx levels. The three-way catalyst vehicle has a NOx level about one-tenth of that of its non-catalyst comparison.

In view of the fact that the vehicles used in these tests were set up for the tests, it is likely that the vehicle on the road will have higher emissions.

1.2 Diesel

The USA was again the first country to institute definitive legislation levels for heavy-duty vehicle emissions, with regulations being implemented in 1970. European legislation has followed that of the USA. Vehicles under 3,5 ton Gross Weight have to follow the ECE 15 levels set for passenger vehicles, whilst vehicles over 3,5 tons have been covered by regulation ECE 49 and subsequent modifications. The changes in limits are shown in Table 1.

Table 1. Heavy duty vehicle emissions. European Regulations. (g/kWh)

Regulation	CO	HC	NOX	Particulates
ECE 49	14,0	3,5	18,0	
ECE 49.01	11,2	2,4	14,4	
88/77/EEC	11,2	2,4	14,4	
91/542/EEC	4,5	1,1	8,0	0,36

Directive 88/77/EEC, introduced in 1988, uses the same levels as those of ECE 49.01 but with additional margins, etc. Directive 88/77/EEC is to be applied to all new models from April 1988.

In October 1991 the European Council of Ministers adopted the "Clean Lorry Directive" 91/542/EEC which is to be introduced for new models in October 1995 and for all production in October 1996.

1.3 Particulates

There are no limits on particulate matter in the ECE regulations up to this time. There has been a smoke level set in regulation ECE 24.03 and Directive 72/306/EEC which specified an "absorption coefficient based on a nominal air flow rate. Directive 91/542/EEC makes provision for particulate limits for heavy duty diesel vehicles as from 1992 for new models and from 1993 for all production. The levels will be lowered from 1995, as shown in Table 2.

Table 2. Particulate levels for diesel engines (gram/kWh)

Effective from	g/kWh
1.7.1992	0,36
1.10.1995	0,15

These levels are to be multiplied by 1,7 for engines with a capacity less than 85 kW.

2. SOUTH AFRICA

2.1 Gasoline

South Africa does not have any legislation concerning road vehicle emissions other than a "black smoke" legislation for heavy diesel vehicles. Because of a shortage of inspectors, even this legislation is not being applied. However, South Africa imports vehicle technology from Europe and from Japan and it is therefore likely that there have been decreasing exhaust emission levels because of improving technology. However emission levels implemented in Europe, Japan and North America now require the fitting of three-way catalysts and therefore no further significant exhaust emission reductions are expected.

In terms of the levels of emission from road vehicles in South Africa, no measurements have been made and certain assumptions have to be made as to how overseas developments have affected emission levels.

In the first place the average age of passenger vehicles has been increasing and is now estimated at 11 years. It is likely therefore that the emissions of South African passenger vehicle engines are comparable to those of engines which appeared in the European market in 1982. It can also be assumed that the emissions would be below those set by the relevant regulations but most probably higher than those measured during the tests on which the values of Figs 2 to 5 are based. It will therefore be assumed that the emissions are equal to 75% of the relevant European regulations. This means that the levels are as given in Table 2. Analysis of various published figures for passenger vehicle fuel consumption in the range of engine capacity of 1300 cc to 2000 cc shows that 10 litres per 100 km is a reasonable approximation. On this basis the values of emissions on a per km and per litre of fuel basis are given in Table 3.

Table 3. Average emissions of passenger vehicles in South Africa

Component	Emission	
	g/km	g/litre
CO	16,1	161
HC	1,3	13
NOX	1,9	19

In the future the levels will decrease in line with the ratio of the ECE 15/03 regulation to the later regulations except that the ECE Regulation 83 will not be operative if catalytic converters are not introduced.

2.2 Diesel

It is assumed that the European engine technology will apply to South Africa and that on-road emissions will be 75% of the relevant ECE Regulation. In terms of phasing in the various regulations, it is assumed that the diesel engines on the road in South Africa will be in line with Directive 88/77/ECE and not with that of Directive 91/542/EEC. In fact the average is likely to be biased towards the earlier ECE 49 regulation rather than to the newer 91/542/EEC Directive. However, in view of the levels of uncertainty, the 88/77/ECE levels will give reasonable estimates. The emission levels are given in Table 4 in terms of the per kWh and per litre of fuel basis.

Table 4. Average emission levels of heavy duty vehicles in South Africa

Component	Emission	
	g/kWh	g/litre
CO	8,4	28,5
HC	1,8	6,1
NOX	10,8	36,6

2.3 Particulates

Since there have not been any overseas regulations on particular matter, it is only possible to use measured values obtained overseas. The Environmental Source and Emission Handbook published by the Noyes Data Corporation quotes an EPA reference for the average particulate levels for road transport. This is quoted as 0,24 grams per kilometer for exhaust emissions and 0,12 grams per kilometer for tire

wear. This would translate into figures of 2,4 and 1,2 respectively on a per litre basis if most vehicles were gasoline based. This is most probably true for the USA where large commercial vehicles are largely gasoline powered; however it cannot be applied to South Africa. Ledbetter also quotes an EPA source which quotes 1,4 grams per km for gasoline powered vehicles and 13,2 grams per km for diesel vehicles. This translates into 14 grams per litre for gasoline vehicles and 33 grams per litre for diesel vehicles.

2.4 Summary

Table 5 summarizes the emission levels in South Africa on a per litre basis and based on the assumptions made above.

Table 5. Estimated emissions from road transport in South Africa on a per litre basis (grams per litre)

Component	Gasoline g/litre	Diesel g/litre
CO	161	29
HC	13	6
NOX	19	37
Particulates	~~14~~ 1.4×10^{-3}	33

It is not possible to compare emissions from diesel heavy duty engines with those from passenger vehicles because of the very different duty. For the above calculations it has been assumed that the average passenger vehicle in a typical driving cycle will use 10 litres of fuel per 100 kilometers. For heavy duty diesel vehicles the average fuel consumption varies from 30 to 50 litres per 100 kilometers for engines in the power range from 60 to 120 kW. In the larger range, from a capacity of 200 to 300 kW the consumption varies from 70 to 80 litres per 100 kilometers.

The Table below has therefore been drawn up on a per kilometer basis for gasoline passenger vehicles and on a per kWh basis for heavy duty diesel vehicles.

Table 6. Estimated emissions in South Africa

Component	Gasoline g/km	Diesel g/kWh
CO	16,1	8,4
HC	1,3	1,8
NOX	1,9	10,8
Particulates	1,4	3,9

It must be stressed that these values have been based on very rough estimates and on a large number of assumptions. The results can be taken as an order of magnitude answer, but a limited amount of testing of typical vehicles on the road would be required for a better estimate.

FIGURES

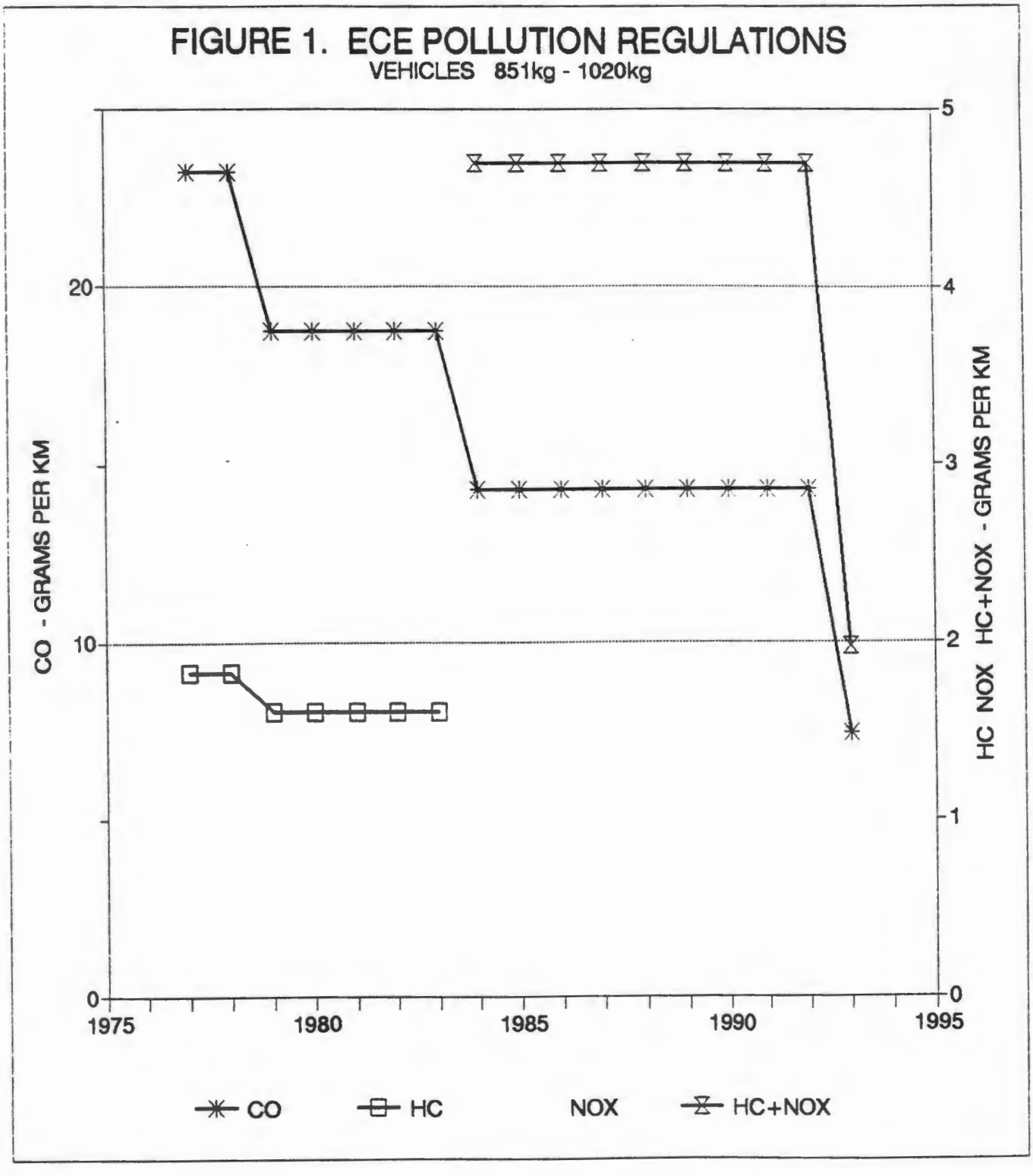


FIGURE 1. ECE POLLUTION REGULATIONS
VEHICLES 851kg - 1020kg
CO - GRAMS PER KM
HC NOX HC+NOX - GRAMS PER KM
20
10
0
5
4
3
2
1
0
1975
1980
1985
1990
1995
CO
HC
NOX
HC+NOX

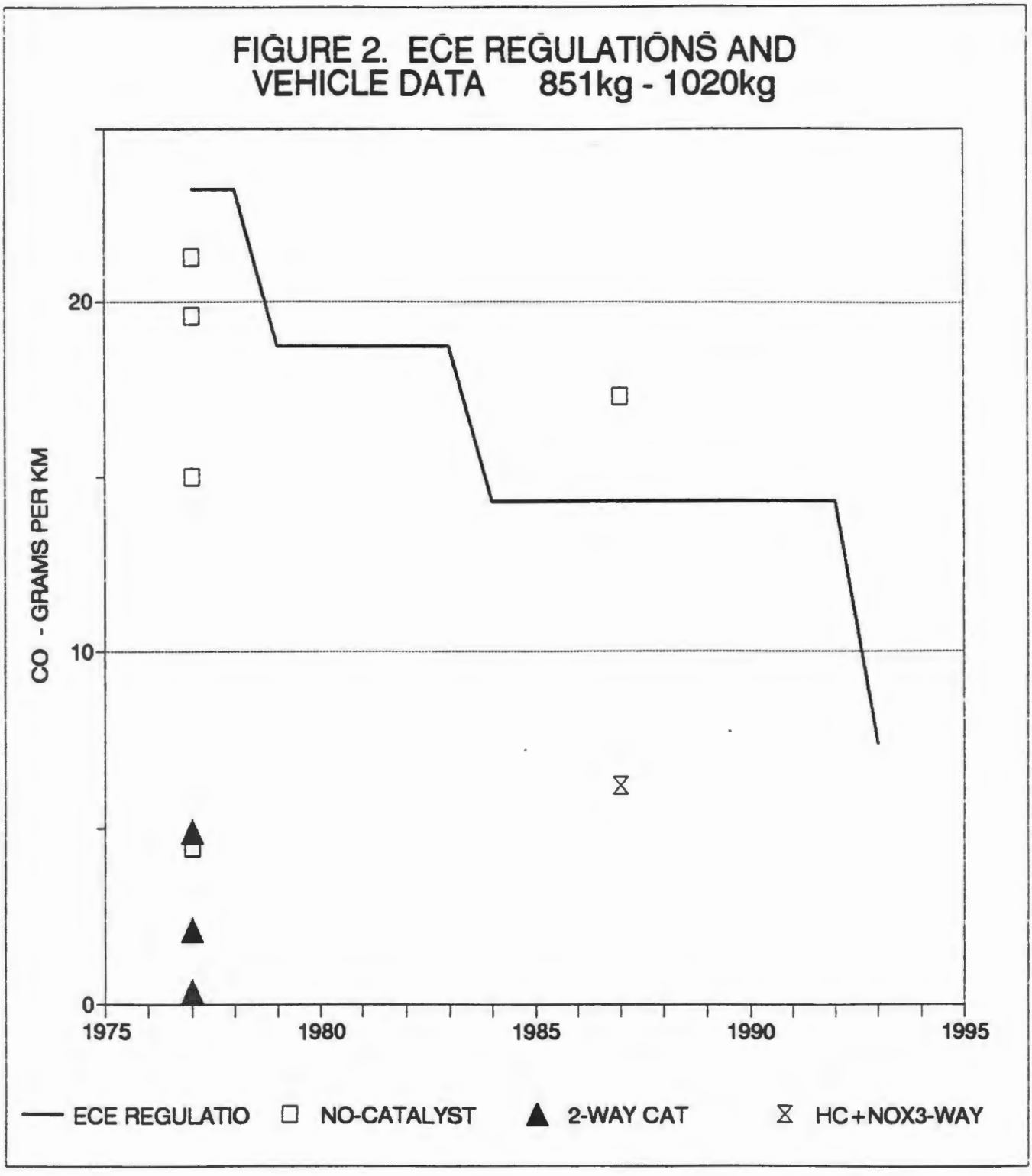


FIGURE 2. ECE REGULATIONS AND
VEHICLE DATA 851kg - 1020kg
CO - GRAMS PER KM
20
10
0
1975
1980
1985
1990
1995
ECE REGULATIO
NO-CATALYST
2-WAY CAT
HC+NOX3-WAY

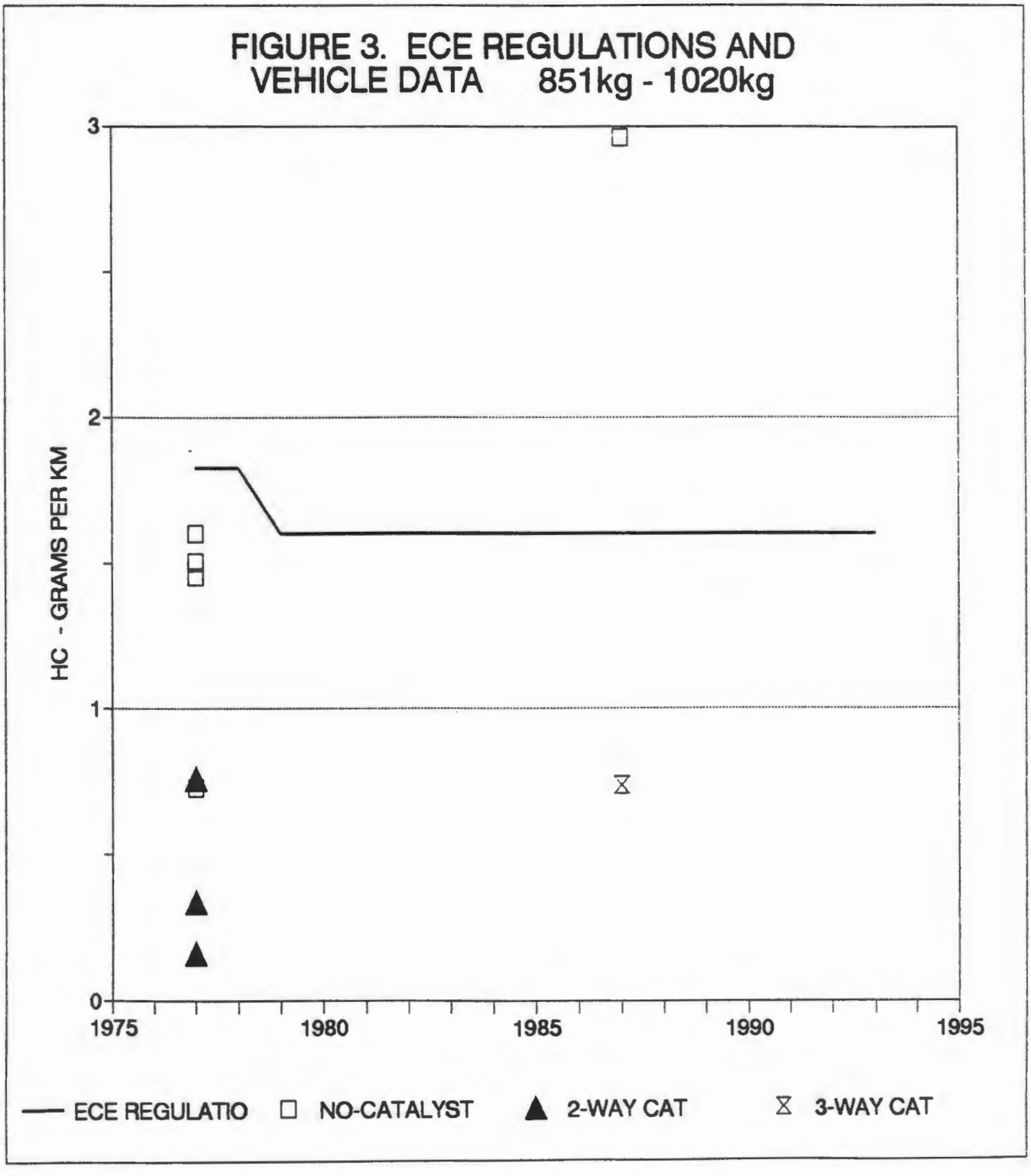


FIGURE 3. ECE REGULATIONS AND
VEHICLE DATA 851kg - 1020kg
HC - GRAMS PER KM
3
2
1
0
1975
1980
1985
1990
1995
ECE REGULATIO
NO-CATALYST
2-WAY CAT
3-WAY CAT

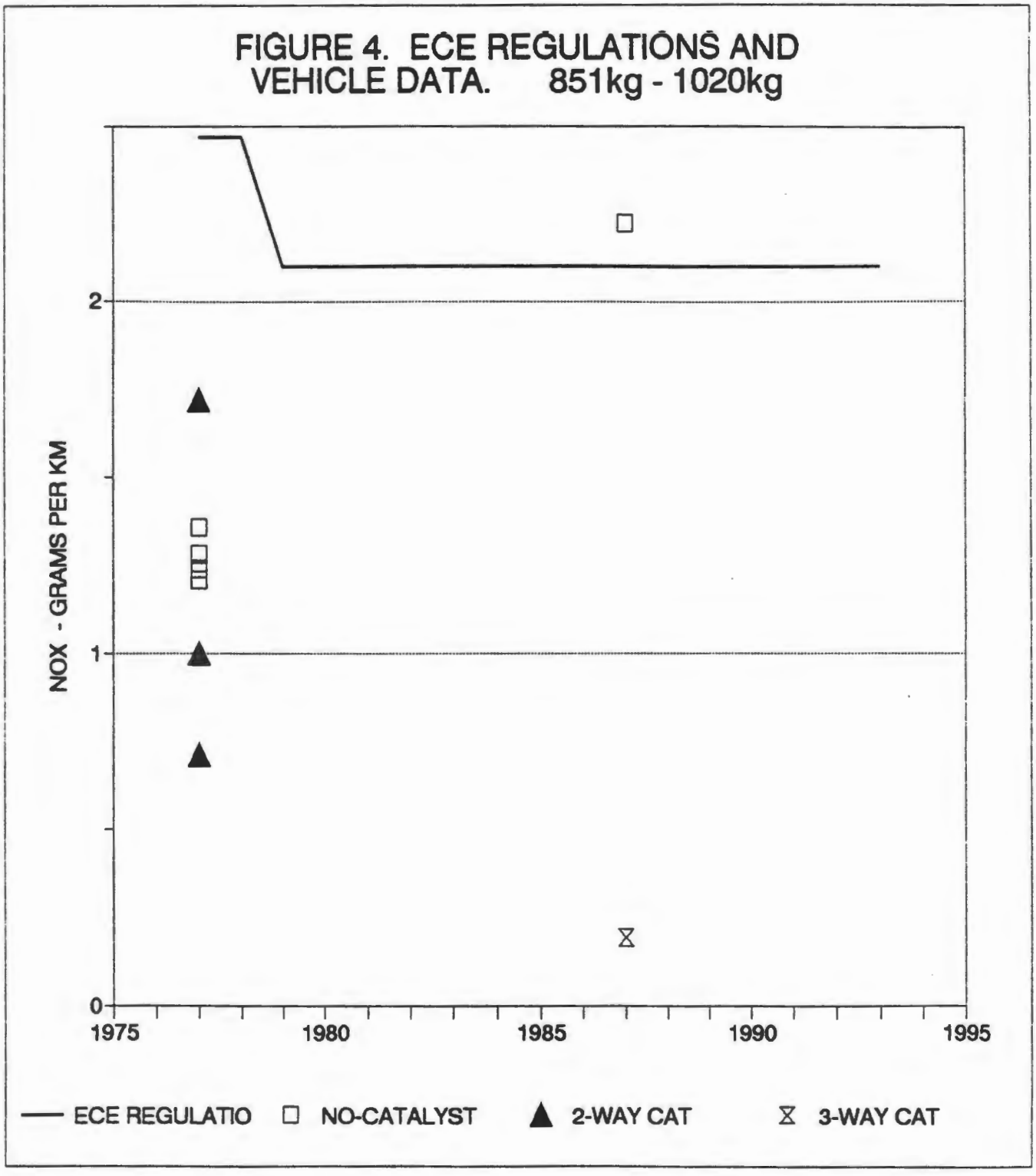
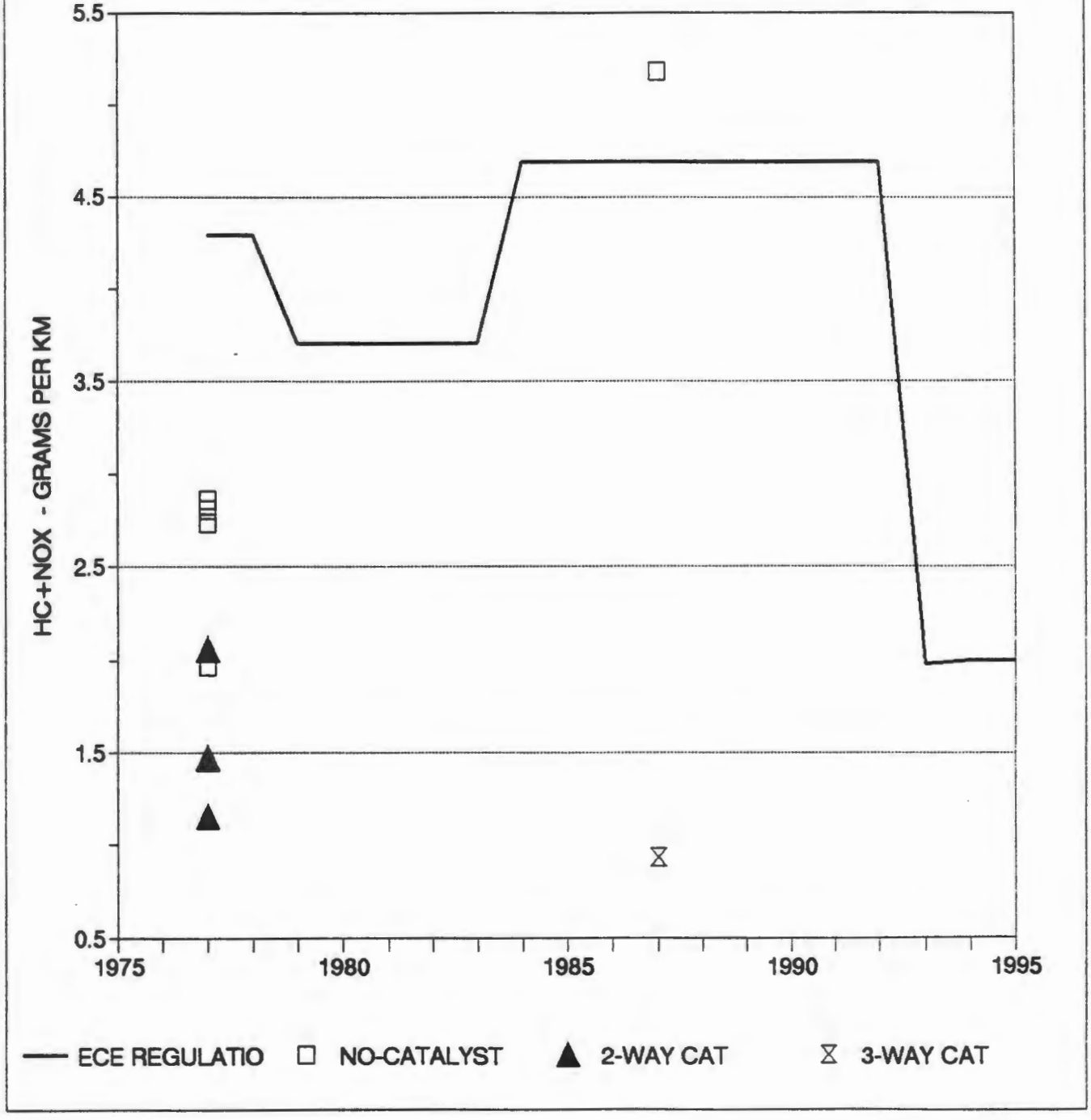


FIGURE 4. ECE REGULATIONS AND VEHICLE DATA. 851kg - 1020kg
NOX - GRAMS PER KM
2
1
0
1975
1980
1985
1990
1995
ECE REGULATIO
NO-CATALYST
2-WAY CAT
3-WAY CAT

FIGURE 5. ECE REGULATIONS AND VEHICLE DATA. 851kg - 1020kg



APPENDIX A

Historical Review of US light vehicle emissions regulations

Federal						California					
Exhaust Emission Standards - (g/mile)											
Model year	HC	CO	NO_x	Evap. g/test	Pm g/mile		HC	CO	NO_x	Evap. g/test	Pm g/mile
Pre-control	15	90	6.2	6.0	-		15	90	6.2	6.0	-
1970	4.1	34	-	-	-		4.1	34	-	6.0	-
1971	4.1	34	-	6.0	-		4.1	34	6.2	6.0	-
1972	3.0	28	-	2.0	-		2.8	28	3.2	2.0	-
1973-74	3.0	28	3.1	2.0	-		2.8	28	2.0	2.0	-
1975-76	1.5	15	3.1	2.0	-		0.9	9.0	2.0	2.0	-
1977	1.5	15	2.0	2.0	-		0.41	9.0	1.5	2.0	-
1978-79	1.5	15	2.0	6.0	-		0.41	9.0	1.5	6.0	-
1980	0.41	7.0	2.0	6.0	-	50 000 mile	0.39	9.0	1.0	2.0	-
						100 000 mile	A 0.39	9.0	1.5		-
							B 0.46	10.6	1.5		-
1981	0.41	3.4	1.0	2.0	-	50 000 mile	A 0.39	3.4	1.0	2.0	-
							B 0.39	7.0	0.7		-
						100 000 mile	A 0.39	3.4	1.5		-
							B 0.46	4.0	1.5		-
1982-83	NO CHANGE.....				0.6	50 000 mile	A 0.39	7.0	0.4	2.0	0.6
							B 0.39	7.0	0.7	2.0	0.6
						100 000 mile	A 0.39	7.0	1.5	2.0	0.6
							B 0.46	8.3	1.5	2.0	0.6
1984	NO CHANGE		.....			50 000 mile	A 0.39	7.0	0.4	2.0	0.6
							B 0.39	7.0	0.7	2.0	0.6
						100 000 mile	A 0.39	7.0	1.0	2.0	0.6
							B 0.46	8.3	1.0	2.0	0.6
1985	NO CHANGE		.....	.....		NO CHANGE.....					0.4
1986	NO CHANGE		.....	.....		NO CHANGE.....					0.2
1987-88	NO CHANGE		..		0.2	NO CHANGE.....					
1989-92	NO CHANGE		.....			NO CHANGE.....					0.2
1993-94	NO CHANGE		.....			50 000 miles	0.25	3.4	0.4	2.0	0.08
						100 000 miles	0.31	4.2	0.7	2.0	0.08
1994-96											
50 000 miles	0.25	3.4	0.4	2.0	0.08	TLEV	0.125	3.4	0.4	2.0	0.08
100 000 miles	0.31	4.2	0.6	2.0	0.10	LEV	0.075	3.4	0.2	2.0	0.08
1999-2003	NO CHANGE		.....			ULEV	0.04	1.7	0.2	2.0	0.04
						ZEV	0	0	0	0	0
2004-	0.125	1.7	0.2	2.0	0.08						

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