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Motor Vehicle Emission Factors for Estimates of Highway Impact on Air Quality

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16. Abstract

Highway engineers must play an important role in the enhancement and protection of the environment. They will have to consider a variety of factors in the environmental impact of any highway project and complete a number of studies prior to writing an impact statement. One of these studies is concerned with the gathering of field data, analysis of such data, and writing an air quality report. As an important part of that study this manual reports on the emission factors which are most representative of vehicles using freeways, local roads and streets. The emission factors take into account the vehicle deterioration factors, model year, annual mileage traveled, and average route speed. The developed emission factors are based on the best data currently available.

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FOREWORD

A number of studies must be completed prior to the writing of an Environmental Impact Statement for a highway project. One of these studies is concerned with the gathering of field data, analysis of such data, and writing an air quality report.

The California Division of Highways has embarked on a program of equipping and training district personnel to prepare air quality reports. This requires a two-week training course and the preparation of air quality manuals to be used as guides in the gathering of field data, analysis of results, and writing the report.

This volume is the second in a series of eight volumes, the titles of which follows:

1. Meteorology and Its Influence on the Dispersion of Pollutants from Highway Line Sources.

2. Motor Vehicle Emission Factors for Estimates of Highway Impact on Air Quality.

3. Traffic Information Requirements for Estimates of Highway Impact on Air Quality.

4. Mathematical Approach to Estimating Highway Impact on Air Quality.

5. Appendix to Volume 4.

6. Analysis of Ambient Air Quality for Highway Environmental Projects.

7. A Method for Analyzing and Reporting Highway Impact on Air Quality.

8. Synopsis of Air Quality.

The material presented in these volumes is subject to change as further research provides information. The following items are not discussed or, if presented, are subject to care in the interpretation of results.

1. There is no accepted emission factors for oxides of nitrogen relating emissions to speed.

2. There are no statistically validated photochemical models for different meteorological conditions which will permit calculations of oxidant formed downwind from a line source.

3. Further research is required to fully validate model calculations when winds blow parallel to the line source.

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This work was accomplished in cooperation with the United States Department of Transportation, Federal Highway Administration. The opinions, findings, and conclusions expressed in this publication are those of the California Division of Highways and not necessarily those of the Federal Highway Administration.

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INTRODUCTION

This manual summarizes the work done by the California Division of Highways, Materials and Research Department, in preparing emission factors for motor vehicles based on California and Federal test standards. The first part of this summary covers emission factors which are most representative of vehicles using freeways, and the second part presents the emission factors which are most representative of vehicles on city streets. The third part discusses the applications and limitations of the emission factors that are developed. These emission factors take into account the deterioration factors, model year, mileage travelled per year and average route speed. The basic relationship between emissions and average route speed was derived by Rose[1] in earlier research.

This manual is based primarily on the work of Harrison W. Sigworth, Jr. [2], Environmental Protection Agency (EPA), Research Triangle Park, North Carolina. The main differences between the approaches by Sigworth and the California Division of Highways are that this manual includes the vehicle mix, annual mileage travelled per model year, average route speed and emission factors based on conditions that exist in California. It is the concensus of the agencies involved that the California Air Resources Board test procedure is more realistic for freeway use while the emission factors based on the 1972 Federal test procedures are more representative of city type emission rates. Both of these procedures were used in developing the emission factors.

In order to determine the impact of highway on the local environment, a comparison must be made of vehicular emissions from highways and city streets. This comparison should indicate the increase or decrease of pollutant load as a function of traffic volume and associated average route speed. The emission factor curves developed in this manual can be used to determine separate emission factors for carbon monoxide and hydrocarbons on highways and city streets as a function of average route speed. On this basis, a mesoscale analysis of these pollutants can be made. In addition, these carbon monoxide emission factors are suitable for use as input into a highway line source dispersion model to estimate pollution concentrations on and within the highway corridor [3].

While carbon monoxide emission factors may be used for both corridor and mesoscale analysis, hydrocarbon emission factors are only applied on a mesoscale basis since hydrocarbons are not considered a localized health hazard in the concentrations produced by vehicular traffic.

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The developed emission factors are based on the best data obtainable. At present no statistically significant data are available to establish a relationship between oxides of nitrogen emissions and average route speed. As a consequence, no current realistic analysis of NO_x concentrations can be made on either a corridor or mesoscale basis. When more data become available for NO_x or any other pollutant, these factors will be updated or developed to reflect such changes.

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EMISSION FACTORS FOR VEHICLES USING FREEWAYS

Emission Standards: California Air Resources Board

A summary of the emission standards for light duty vehicles (LDV) and heavy duty vehicles (HDV) including past and present model years is presented in Table 1. These standards are for carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NO_x). Also included in the table are the crankcase and evaporative losses of HC for both light and heavy duty vehicles. The emission standards in this table were established by the California Air Resources Board (ARB).

These standards are based on the ARB hot test procedure using the 7-mode test cycle outlined below:

Sequence No.	Mode MPH	Acceleration MPH in Secs.	Elapsed Time Seconds	Cumulative Time Seconds
1	Idle	-	20	20
2	0 to 30	2.2	14	34
3	30	-	15	49
4	30 to 15	-1.4	11	60
5	15	-	15	75
6	15 to 50	1.2	29	104
7	50 to 0	-1.5	33	137

The total distance traveled is 0.86 miles and the average speed of this 7-mode cycle is 22.6 mph.

The 7-mode cycle is based on typical driving modes on Los Angeles freeways during peak traffic hours. It should be stressed at this time that emission factors for a cruise-type operating mode would be less than those indicated by the ARB test procedure, especially for the year 1974 and earlier model cars. However, more research will be required to indicate the amount of reduction. This is discussed in more detail in a later section of this manual.

Deterioration Factors for Controlled Vehicles Using Freeways

The deterioration of exhaust emission controls for light and heavy duty vehicles has been estimated by regression equations as described by Sigworth [2]. The deterioration equations are described below for each pollutant for the year indicated:

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Carbon Monoxide CO

1966, 1967 LDV CO:

$$D.F. = 0.950 + 0.0150(MI) - 0.00036(MI)^2 + 0.0000032(MI)^3 + 0.00375(Q) \quad (1)$$

1968 & later LDV CO:

$$D.F. = 0.930 + 0.02(MI) - 0.00043(MI)^2 + 0.0000037(MI)^3 + 0.00456(Q) \quad (2)$$

1973 & later HDV CO:

Same as equation (2).

Hydrocarbons HC

1966, 1967 LDV HC:

$$D.F. = 0.937 + 0.0186(MI) - 0.00042(MI)^2 + 0.00000368(MI)^3 + 0.00412(Q) \quad (3)$$

1968 & later LDV HC:

$$D.F. = 0.951 + 0.0146(MI) - 0.00034(MI)^2 + 0.0000031(MI)^3 + 0.00345(Q) \quad (4)$$

1970 & later HDV HC:

Same as equation (4).

In all of the above equations the respective parameters are as follows:

D.F. = deterioration factor

MI = vehicle mileage up to 50,000 miles in thousands of miles

Q = vehicle mileage over 50,000 miles (total miles - MI) in thousands of miles.

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These deterioration equations were derived by Sigworth, using ARB data for California LDV with less than 50,000 miles. Deterioration factors for mileage greater than 50,000 miles were estimated using straight line interpolations from the 50,000 miles deterioration factors and the slope at that point. The maximum mileage used in the deterioration equations is 109,800 miles. The deterioration factor for mileage beyond this is assumed equal to the 109,800 mile value. Because of lack of quantitative data for HDV, the deterioration equations for LDV were assumed applicable to HDV as indicated in the equations except that deterioration factors beyond 109,800 miles are computed from the equations directly. Values for these deterioration factors for LDV and HDV at estimated cumulative year-end mileages are given in Tables 2 and 3, respectively. Estimates for the year-end mileages are shown in Tables 4 and 5.

Estimated HDV Travel Per Year

In order to obtain a composite emission factor for the total vehicles using a highway (HDV plus LDV) for a given time period the percentage of LDV and HDV must be known.

A summary of the light duty vehicle mix for a given age of vehicle versus annual miles traveled and percentage of miles traveled is given in Table 4. These data were obtained from the California Air Resources Board (4) as being the representative vehicle mix that exists in California for light duty vehicles.

In order to take into account the percent contribution of both LDV and HDV traveled on a highway it is necessary to consider annual miles traveled by HDV to be used in the deterioration equations. The best available information on the estimated average yearly mileage of HDV was obtained from the California Trucking Association in San Francisco. This estimate from the California Trucking Association was 14,000 miles per year for HDV which includes long and short haul trips.

In this report an average mileage of 14,000 miles per year was assumed for all HDV. A table of vehicle travel vs. age for HDV is given in Table 5.

Overall Emission Factors for Vehicles Using Freeways

A summary of the emission factors (1972-2000) for LDV and HDV using freeways, based on ARB standards is given in Table 6 for a 0% HDV mix. The values in the table were computed by multiplying the emission factor (Table 1) times the appropriate deterioration factor (Table 2 and 3), and then weighting according to the vehicle age vs. travel data obtained from Tables 4 and 5. This procedure was followed for both LDV and HDV and the resulting emission factors for each were then weighted according

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to the percentage of LDV and HDV using the highway to give an overall average emission rate. A sample calculation for the year 1972 is presented in Appendix A. These emission rates, when multiplied by the total vehicle miles traveled on freeways for a given time period, will give the total mass of CO and HC emitted by LDV and HDV. This includes the vehicle model year mix during that time period and assumes an average route speed of 22.6 mph. Although Table 6 indicates emission factors for a 0% HDV mix, most highways carry a significant percentage of HDV. In order to be able to estimate the emission factors for these conditions, HDV mixes of 5%, 10%, 15% and 20% are presented in Tables 7 through 10. If the percentage of HDV using the highway is between these values a straight line interpolation can be used to estimate the emission factor.

Emission Factors vs. Average Route Speeds for Vehicles Using Freeways

It is known that the amount of emissions of carbon monoxide and hydrocarbons* from the exhaust of an uncontrolled vehicle will depend mainly on the average route speed and engine operating mode (1) (idle, acceleration, deceleration and cruise). This relationship was studies by Rose and was developed using 1963 and earlier model year vehicles with no exhaust emission controls. The relationship is shown in Figures 1 and 12. At present no statistically significant relationship between oxides of nitrogen and average route speed has been established, by ARB or EPA so development of such curves is dependent upon further research in this area. From the limited data available, however, it appears that NO_x emissions increase with higher average route speeds (6).

Sigworth of the Environmental Protection Agency indicates that Rose's work (shape of curves) is probably valid for vehicles without exhaust emission controls but is probably less valid though still roughly applicable for pre-1975 vehicles with exhaust emission controls. For these latter vehicles the emission factors would be reduced, when compared to the uncontrolled curve as derived by Rose, but probably would have the same slope. Sigworth points out that because of the radically different emission characteristics of 1975 and later vehicles, he expects the curves would have little applicability to them.

*Automotive Hydrocarbon emissions are pertinent to air quality analyses primarily because of their role in oxidant formation by photochemical reactions. The ARB has no ambient air quality standard for hydrocarbons because it is felt that their standard for photochemical oxidants automatically limits ambient hydrocarbon concentrations. The EPA has set an air quality standard for hydrocarbons, not for health purposes, but as extra insurance that the oxidant standards are met.

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Information received from the Air Resources Board [4] indicates that, with the present schedule of automotive emission reductions, the 1975 and later vehicle will be essentially "pollution free". The emissions from these vehicles should be independent of route speed. This means that some time after all the pre-1975 model vehicles are phased out or non-operative, the emission levels from vehicles will remain constant except for some deterioration in the devices themselves.

In order to relate the average route speed vs. emission factors for CO and HC with the yearly vehicle mix subsequent to 1974, the following assumptions were made:

1) For highway travel, emission estimates, it is valid to use the ARB 7-mode test cycle procedure. It was further assumed that Rose's curve was valid for the ARB test procedure.

2) The characteristic shapes and slopes of Rose's curves are valid up to the pre-1975 model year.

3) In 1986 the vehicle mix on freeways will be entirely 1975 models or later (essentially "pollution free") and the emission factor will be relatively independent of route speed. (This estimate was obtained from data received from ARB and is illustrated in Tables 6 through 10 with the emission factors remaining constant from 1986 and later.)

4) The use of the emission factors from Tables 6-10 for the years 1972 through 1986 with an average route speed of 22.6 mph is valid.

5) It is sufficiently accurate to extrapolate the slopes of the emission factors vs. average route speed curves for post 1975 highway vehicles from the known ARB emission factors and from the boundary curves for 1974 and 1986.

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The carbon monoxide and hydrocarbon emission factors for a 0% HDV mix versus average route speed of vehicles using freeways are shown in Figures 2 and 13 respectively. These curves take into consideration the vehicle mix per year indicated, the emission standards, and the deterioration factors. The two series of curves, for an indicated year, represent the amount of carbon monoxide or hydrocarbons, with respect to the average route speed, that is emitted from vehicles using freeways. These curves also illustrate that an increase in the average route speed of vehicles using freeways will reduce the load of these two pollutants. The curves also show that, as the pre-1975 models are phased out, the emission factors become more independent of route speed. Similar curves for 5%, 10%, 15% and 20% HDV mixes are given in Figures 3-6 for carbon monoxide and Figures 14-17 for hydrocarbons. If the HDV mix is between these values, a straight line interpolation can be used to estimate the emission factors.

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EMISSION FACTORS FOR VEHICLES USING CITY STREETS

This section discusses the 1972 Federal test procedure and emission standards. The computational methodology is similar to that of Sigworth[2]. The only exception is that the vehicle mix and percentage of miles traveled annually by LDV and HDV are based on conditions that exist in California as was previously discussed.

Emission Standards: 1972 Federal Test Procedures

A summary of the past and present Federal Emission standards for LDV and HDV are presented in Table 11.

These standards are based on the 1972 Federal test procedure[5] using a driving cycle representative of the "LA-4" route near downtown Los Angeles during peak traffic periods. The average driving cycle speed is 19.6 mph and its length is 7.5 miles. Exhaust is collected by constant volume sampling equipment during this driving cycle, after a 12 hour cold soak prior to turning on the vehicle's ignition key. The collected exhaust is then analyzed for CO, NO_x, and HC content and converted to mass emission. This Federal test procedure using a cold start is representative of the driving mode of vehicles using city streets.

Deterioration Factors for Controlled Vehicles Using City Streets

The deterioration factors and assumptions for the Federal test procedure for LDV and HDV are the same as used for freeway emission factors. (See Tables 2 and 3.)

Estimated HDV Travel Per Year

The estimated HDV travel per year assumptions used with the Federal test procedure are the same as those used for the freeway emission factors.

Overall Emission Factors for Vehicles Using City Streets

A summary of the emission factors (1972-2000) for vehicles using city streets, based on the 1972 Federal test procedure, is given in Table 12 for a 0% HDV mix. The values in the table were computed similarly to those in Table 6 except that Federal standards, as given in Table 11, were used for LDV and HDV emission factors. A sample calculation for the year 1972 is presented in Appendix B. These emission factors, when multiplied by the total vehicle miles traveled on city streets for a given time period, will give the total mass concentration of CO and HC

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emitted by LDV and HDV. This includes the vehicle model year mix during that time period and assumes an average route speed of 19.6 mph. Other emission factors are given in Tables 13 through 16, inclusive, for HDV mixes of 5%, 10%, 15%, and 20%. If the percentage of HDV using the highway is between these values, a straightline interpolation can be used to estimate the emission factors.

Emission Factors vs. Average Route Speed for Vehicles Using City Streets

This section will discuss the development of emission factor curves for carbon monoxide and hydrocarbons vs. average route speed of vehicles using city streets. The analysis is very similar to the emission factors vs. average route speed of vehicles using freeways. The following assumptions were made for this analysis for a 0%, 5%, 10%, 15%, and 20% HDV mix:

1) The characteristic shapes and slopes of Rose's curves are valid up to the pre-1975 model year.

2) The Federal test procedure is valid for estimating vehicle emissions in city street trips.

3) In 1986 the vehicle mix on city streets will be entirely 1975 models or later.

4) The emission factors in Tables 12-16 for the years 1972 through 1986 are valid for an average route speed of 19.6 mph.

5) It is sufficiently accurate to extrapolate the slopes of the emission factor vs. average route speed curves for post 1975 vehicles from the known EPA emission factors and from the boundary curves for 1974 and 1986.

The carbon monoxide and hydrocarbon emission factors for various HDV mixes vs. average route speed of vehicles using city streets are illustrated in Figures 7-11 and 18-22 respectively. These curves take into consideration the vehicle mix per year indicated, the emission standards, and the deterioration factors. These curves, for an indicated year, represent the amount of carbon monoxide or hydrocarbons with respect to average route speed that is emitted from vehicles using city streets. These curves also illustrate that if the average route speed on city streets is increased it will reduce the pollutant load of carbon monoxide and hydrocarbons. If the HDV mix is between these values a straight line interpolation can be used to estimate the emission factors.

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APPLICATIONS AND LIMITATIONS

Application of Emission Factors

The carbon monoxide emission factors vs. average route speed presented in Figures 2 through 6 will be used as input into a highway line source dispersion model [3] to estimate the pollution levels on and within the highway corridor. Hydrocarbon emission factors will not enter into a corridor analysis because the hydrocarbon concentrations involved are not considered a health hazard by either the California Air Resources Board or the Environmental Protection Agency.

In order to estimate the mesoscale pollution levels in the immediate air basin, a comparison must be made of CO and HC emission factors from freeways and city streets. This comparison will indicate the increase or reduction of pollutant load as a function of traffic volume on freeways and city streets and changes in their associated route speeds. The curves in Figures 2-11 and Figures 13-22, depending on the HDV mix, will determine the CO and HC emission factors as a function of average route speed. A final determination of the pollutant load can then be made, based on the increased freeway traffic and the reduction of traffic on city streets, together with the associated average route speeds.

Limitation of Results

The emission factors and curves presented in this report are developed from two entirely different test procedures and equipment, that is, the ARB hot test and 1972 Federal test procedures. These differences in procedures influence the emission factors since they are not totally compatible. The relationship between oxides of nitrogen emission factors and average route speed has not been presented in this report due to a lack of quantitative data in this area at the present time. Until further research results become known, the emission factors which are included in this report are considered by the Division of Highways as being the best available. When more data become available, emission factors will be updated or developed to reflect such changes.

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Table 1

VEHICLE EMISSION STANDARD - AIR RESOURCES BOARD (ARB)

(All Standards are in GMS./MI.

Year	Light Duty Vehicles (LDV) (under 6000 lbs.)						Heavy Duty Vehicles (HDV) (over 6000 lbs.)					
	Exhaust CO	Exhaust NO_x	Exhaust HC	Crank HC	Evap. HC	HC Total	Exhaust CO	Exhaust NO_x	Exhaust HC	Crank HC	Evap. HC	HC Total
1965	80	4.0	11	0	3.0	14	160	8	22	5.2	3.0	30.2
1966	34	5.5	3.5			6.5	160	8	22	5.2		30.2
1967	34	5.5	3.5			6.5	160	8	22	5.2		30.2
1968	34	5.5	3.5			6.5	160	8	22	0		25.0
1969	34	5.5	3.5		3.0	6.5	160	8	22			25.0
1970	23	5.0	2.2		0	2.2	70	8	7.0			10
1971	23	4.0	2.2			2.2	70	8	7.0			10
1972	23	3.0	1.5			1.5	46	8	4.5			7.5
1973	23	1.3	1.5			1.5	39.5	7.6	4.5		3.0	7.5
1974	23	1.3	1.5			1.5	39.5	7.6	4.5		0.8	5.3
1975	12	1.0	0.5			0.5	23	2.7	1.6			2.4
1976	2.5							2.7				
2000	2.5	1.0	0.5	0	0	0.5	23	2.7	1.6	0	0.8	2.4

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TABLE 2

EMISSION CONTROL

DETERIORATION FACTOR VALUES FOR LIGHT DUTY VEHICLES (LDV)

Factor	Deterioration Factor at Miles										
	15000	28000	39000	48600	57000	64000	69300	74300	78700	82900	86400
CO: 1966 1967	1.16	1.16	1.18	1.20	1.23	1.25	1.27	1.29	1.31	1.32	1.34
CO: 1968 & later	1.15	1.23	1.28	1.31	1.35	1.38	1.41	1.43	1.45	1.47	1.49
HC: 1966 1967	1.13	1.21	1.24	1.27	1.31	1.34	1.36	1.38	1.40	1.42	1.43
HC: 1968 & later	1.10	1.16	1.19	1.21	1.24	1.27	1.29	1.30	1.32	1.33	1.35

*Note: For CO and HC pre-1966 vehicles deterioration factors are 1.00.

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TABLE 3

EMISSION CONTROL

DETERIORATION FACTOR VALUES FOR HEAVY DUTY VEHICLES (HDV)

Factor	Deterioration Factor at Miles										
	14000	28000	42000	56000	70000	84000	98000	112000	126000	140000	154000
CO: 1970 & later	1.15	1.23	1.29	1.35	1.41	1.48	1.54	1.60	1.67	1.73	1.79
HC: 1970 & later	1.10	1.16	1.19	1.24	1.29	1.34	1.39	1.43	1.48	1.53	1.58

*Note: For CO and HC 1970 vehicle deterioration factors are 1.0

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Table 4

Vehicle Travel vs. Age (LDV)

Age (Yrs)	% of Vehicles	Annual Mileage	% Distribution of Total Vehicle Miles*
1	10.8	15,000	19.9
2	10.5	13,000	16.7
3	10.2	11,000	13.7
4	9.8	9,600	11.5
5	9.3	8,400	9.5
6	8.8	7,000	7.5
7	8.1	5,300	5.2
8	7.2	5,000	4.4
9	6.2	4,400	3.4
10	5.1	4,200	2.6
>10	13.0	3,500	5.6

*Determined by calculating the weighted distribution of the products of (% of vehicles) x (annual mileage).

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Table 5

Vehicle Travel vs. Age (HDV)

Age (Yrs)	% of Vehicles	Annual Mileage	% Distribution of Total Vehicle Miles*
1	10.8	14,000	10.9
2	10.5	14,000	10.5
3	10.2	14,000	10.3
4	9.8	14,000	9.9
5	9.3	14,000	9.5
6	8.8	14,000	8.9
7	8.1	14,000	8.2
8	7.2	14,000	7.2
9	6.2	14,000	6.2
10	5.1	14,000	5.1
>10	13.0	14,000	13.1

*Determined by calculating the weighted distribution of the products of (% of vehicles) x (annual mileage).

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TABLE 6

EMISSION FACTORS FOR VEHICLES USING FREEWAYS (ARB) - 0% HDV MIX

Year	CO	HC
1972	41.73	6.14
1973	38.81	5.15
1974	36.43	4.34
1975	32.08	3.46
1976	25.08	2.62
1977	20.64	2.13
1978	17.07	1.72
1979	13.81	1.41
1980	10.53	0.96
1981	8.74	0.87
1982	7.35	0.76
1983	6.21	0.72
1984	5.32	0.68
1985	4.04	0.61
1986-2000	3.25	0.61

All factors in grams per mile (gm/mi).

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TABLE 7

EMISSION FACTORS FOR VEHICLES USING FREEWAYS (ARB) - 5% HDV MIX

Year	CO	HC
1972	46.29	6.98
1973	43.0	5.94
1974	40.25	5.06
1975	35.56	4.11
1976	28.39	3.20
1977	23.68	2.64
1978	19.86	2.14
1979	16.37	1.81
1980	12.75	1.25
1981	10.81	1.12
1982	9.08	.97
1983	7.84	.90
1984	6.92	.84
1985	5.51	.73
1986-2000	4.76	.73

All factors in grams per mile (gm/mi).

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TABLE 8

EMISSION FACTORS FOR VEHICLES USING FREEWAYS (ARB) - 10% HDV MIX

Year	CO	HC
1972	50.87	7.82
1973	47.20	6.73
1974	44.07	5.78
1975	39.04	4.76
1976	31.69	3.78
1977	26.73	3.15
1978	22.63	2.55
1979	18.92	2.21
1980	14.98	1.53
1981	12.88	1.37
1982	10.82	1.17
1983	9.47	1.09
1984	8.52	.99
1985	6.98	.86
1986-2000	6.27	.86

All factors in grams per mile (gm/mi).

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TABLE 9

EMISSION FACTORS FOR VEHICLES USING FREEWAYS (ARB) - 15% HDV MIX

Year	CO	HC
1972	55.43	8.66
1973	51.39	7.51
1974	47.89	6.50
1975	42.52	5.40
1976	34.99	4.36
1977	29.76	3.65
1978	25.42	2.97
1979	21.48	2.61
1980	17.20	1.81
1981	14.95	1.63
1982	12.55	1.38
1983	11.10	1.27
1984	10.12	1.15
1985	8.45	.99
1986-2000	7.78	.99

All factors in grams per mile (gm/mi).

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TABLE 10

EMISSION FACTORS FOR VEHICLES USING FREEWAYS (ARB) - 20% HDV MIX

Year	CO	HC
1972	59.99	9.50
1973	55.58	8.30
1974	51.70	7.22
1975	45.99	6.05
1976	38.29	4.95
1977	32.81	4.16
1978	27.59	3.39
1979	24.04	3.00
1980	19.42	2.10
1981	17.01	1.88
1982	14.28	1.59
1983	12.72	1.46
1984	11.72	1.30
1985	9.92	1.12
1986-2000	9.29	1.12

All factors in grams per mile (gm/mi).

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TABLE 11

VEHICLE EMISSION STANDARDS- 1972 FEDERAL TEST PROCEDURES
ALL STANDARDS ARE IN GMS/MI.

Year	Light Duty Vehicles (LDV) (under 6000 lbs.)						Heavy Duty Vehicles (HDV) (over 6000 lbs.)					
	Exhaust CO	Exhaust NO_x	Exhaust HC	Crank HC	Evap. HC	HC Total	Exhaust CO	Exhaust NO_x	Exhaust HC	Crank HC	Evap. HC	HC Total
1965	110	6.4	13.1	0	3.0	16.1	129	9.5	18.7	5.2	3.0	26.9
1966	62	7.1	5.9		3.0	8.9	129					26.9
1967	62	7.1	5.9		3.0	8.9	129					26.9
1968	50	7.1	5.6		3.0	8.6	129			5.2		26.9
1969	50	7.1	5.6		3.0	8.6	129		18.7	0		21.7
1970	35	5.5	3.5		0.49	4.0	80		15.1			18.1
1971	35	4.4	3.5		0.49	4.0	80		15.1			18.1
1972	31	4.4	3.1		0.16	3.3	53		9.9		3.0	12.9
1973	31	2.7	3.1			3.3	43		7.8		0.8	8.6
1974	31	1.7	3.1			3.3	43	9.5	7.8			8.6
1975	4.7	1.2	0.5			0.7	27	3.0	2.4			3.2
1976	4.1	0.5	0.4			0.6						
1977	4.1	0.4	0.4			0.6						
1978	4.1	0.4	0.4			0.6						
2000	4.1	0.4	0.4	0	0.16	0.6	27	3.0	2.4	0	0.8	3.2

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TABLE 12

EMISSION FACTORS FOR VEHICLES USING CITY STREETS (EPA) - 0% HDV MIX

Year	CO	HC
1972	61.9	8.51
1973	56.82	7.46
1974	52.80	6.58
1975	43.54	5.33
1976	34.57	4.18
1977	28.25	3.37
1978	22.68	2.16
1979	18.39	2.16
1980	14.13	1.52
1981	11.99	1.31
1982	9.96	1.10
1983	8.63	0.98
1984	7.60	0.88
1985	5.38	0.68
1986-2000	5.33	0.68

All factors in grams per mile (gm/mi).

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TABLE 13

EMISSION FACTORS FOR VEHICLES USING CITY STREETS (EPA) - 5% HDV MIX

Year	CO	HC
1972	64.58	9.25
1973	59.41	8.17
1974	55.27	7.27
1975	46.08	5.98
1976	37.18	4.79
1977	30.82	3.94
1978	25.20	2.68
1979	20.83	2.61
1980	16.57	1.97
1981	14.27	1.70
1982	11.88	1.40
1983	10.42	1.22
1984	9.37	1.10
1985	7.07	0.86
1986-2000	7.03	0.85

All factors in grams per mile (gm/mi).

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TABLE 14

EMISSION FACTORS FOR VEHICLES USING CITY STREETS (EPA) - 10% HDV MIX

Year	CO	HC
1972	67.26	9.99
1973	62.00	8.89
1974	57.74	7.95
1975	48.62	6.63
1976	39.80	5.41
1977	33.40	4.51
1978	27.73	3.20
1979	23.26	3.06
1980	19.01	2.42
1981	16.54	2.09
1982	13.81	1.71
1983	12.21	1.46
1984	11.14	1.33
1985	8.77	1.04
1986-2000	8.73	1.03

All factors in grams per mile (gm/mi).

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TABLE 15

EMISSION FACTORS FOR VEHICLES USING CITY STREETS (EPA) - 15% HDV MIX

Year	CO	HC
1972	69.93	10.73
1973	64.59	9.60
1974	60.21	8.64
1975	51.16	7.28
1976	42.40	6.03
1977	35.97	5.07
1978	30.25	3.72
1979	25.70	3.52
1980	21.45	2.87
1981	18.82	2.48
1982	15.73	2.01
1983	14.00	1.70
1984	12.91	1.55
1985	10.46	1.21
1986-2000	10.42	1.21

All factors in grams per mile (gm/mi).

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TABLE 16

EMISSION FACTORS FOR VEHICLES USING CITY STREETS (EPA) - 20% HDV MIX

Year	CO	HC
1972	72.61	11.46
1973	67.18	10.32
1974	62.68	9.33
1975	53.70	7.93
1976	45.02	6.64
1977	38.55	5.64
1978	32.78	4.24
1979	28.14	3.97
1980	23.89	3.32
1981	21.09	2.87
1982	17.66	2.31
1983	15.79	1.93
1984	14.69	1.77
1985	12.16	1.39
1986-2000	12.12	1.39

All factors in grams per mile (gm/mi).

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Figure 1

CARBON MONOXIDE EMISSIONS VS AVERAGE ROUTE SPEED
FOR UNCONTROLLED VEHICLES-PRE 1966 MODELS
(ROSE'S WORK)

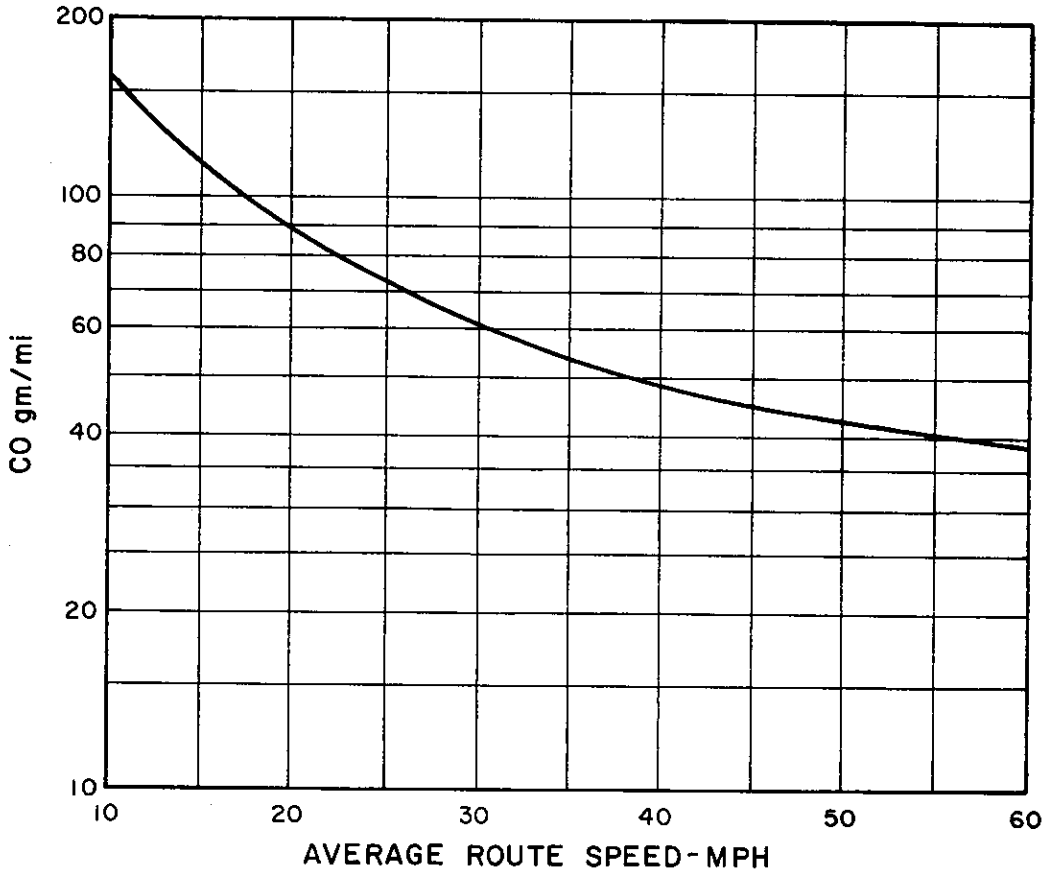

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Figure 2

EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON FREEWAYS 0% HDV

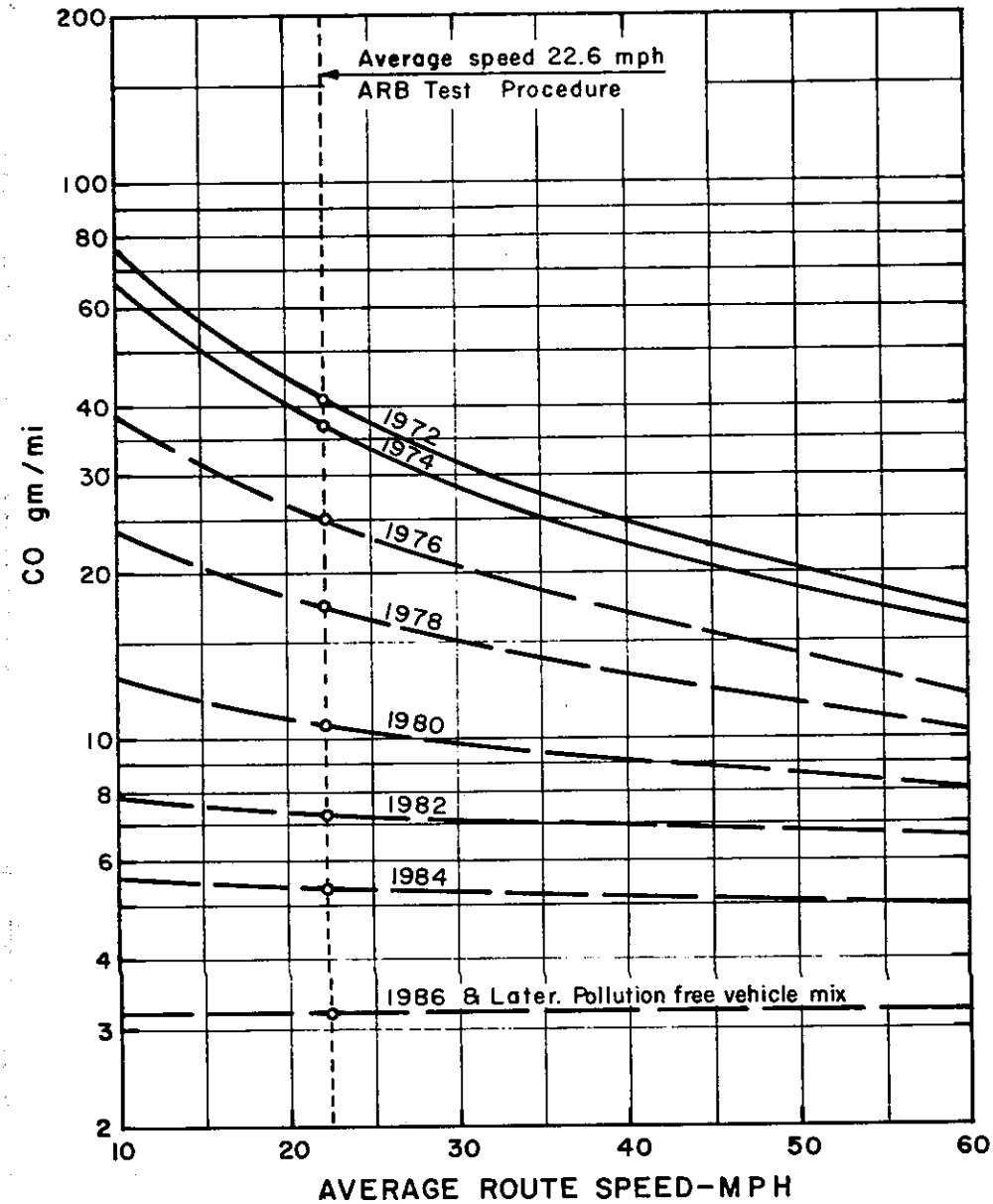

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Figure 3

EMISSION FACTORS FOR CARBON MONOXIDE
VS AVERAGE ROUTE SPEED
ON FREEWAYS
5% HDV

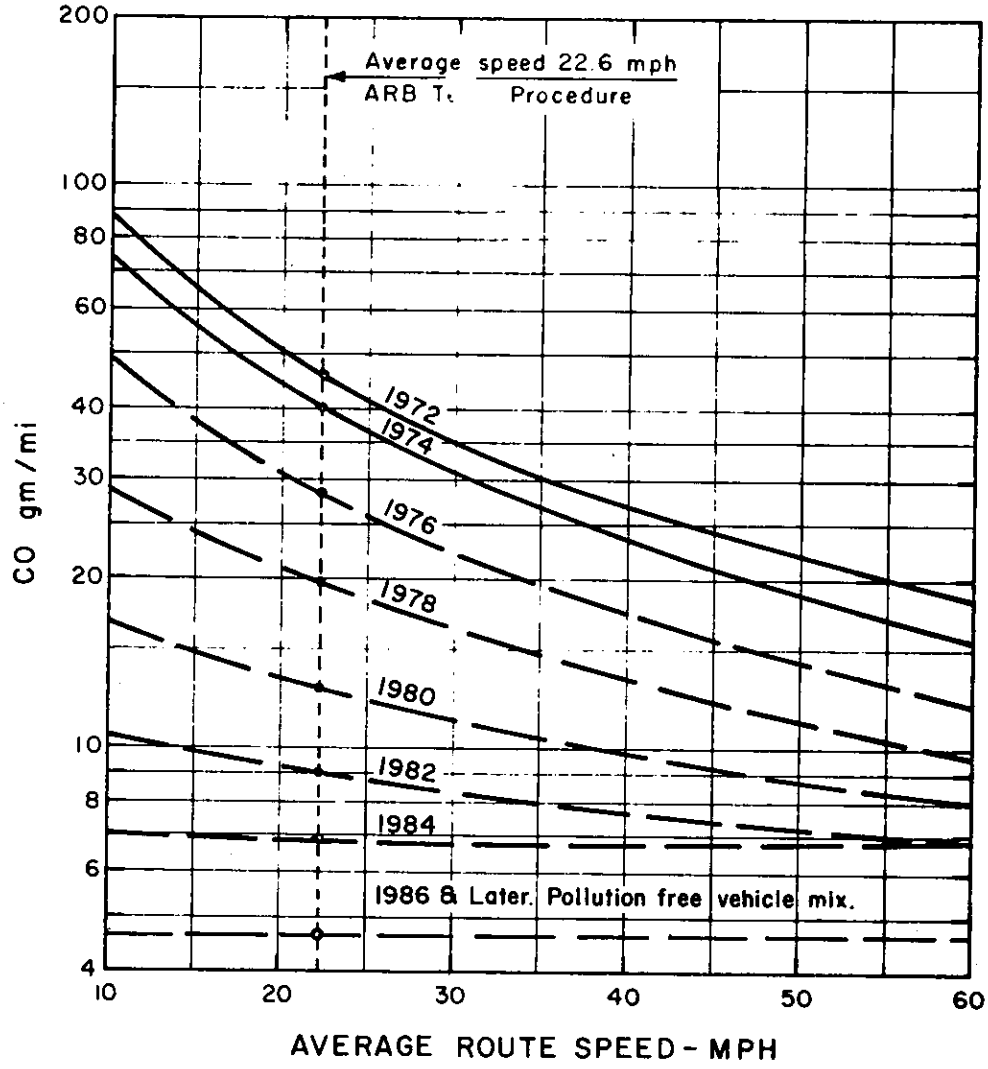

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Figure 4

EMISSION FACTORS FOR CARBON MONOXIDE
VS AVERAGE ROUTE SPEED
ON FREEWAYS
10% HDV

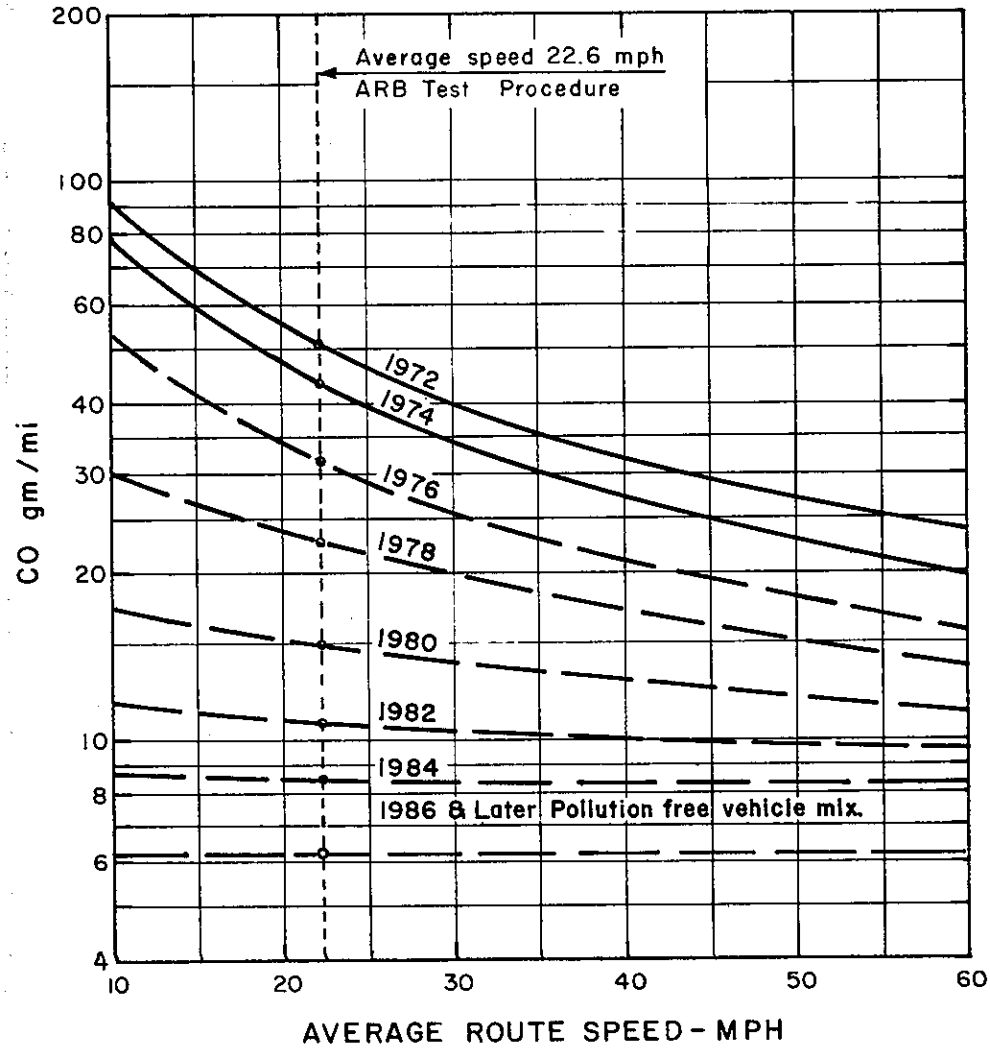

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Figure 5

EMISSION FACTORS FOR CARBON MONOXIDE
VS AVERAGE ROUTE SPEED
ON FREEWAYS
15% HDV

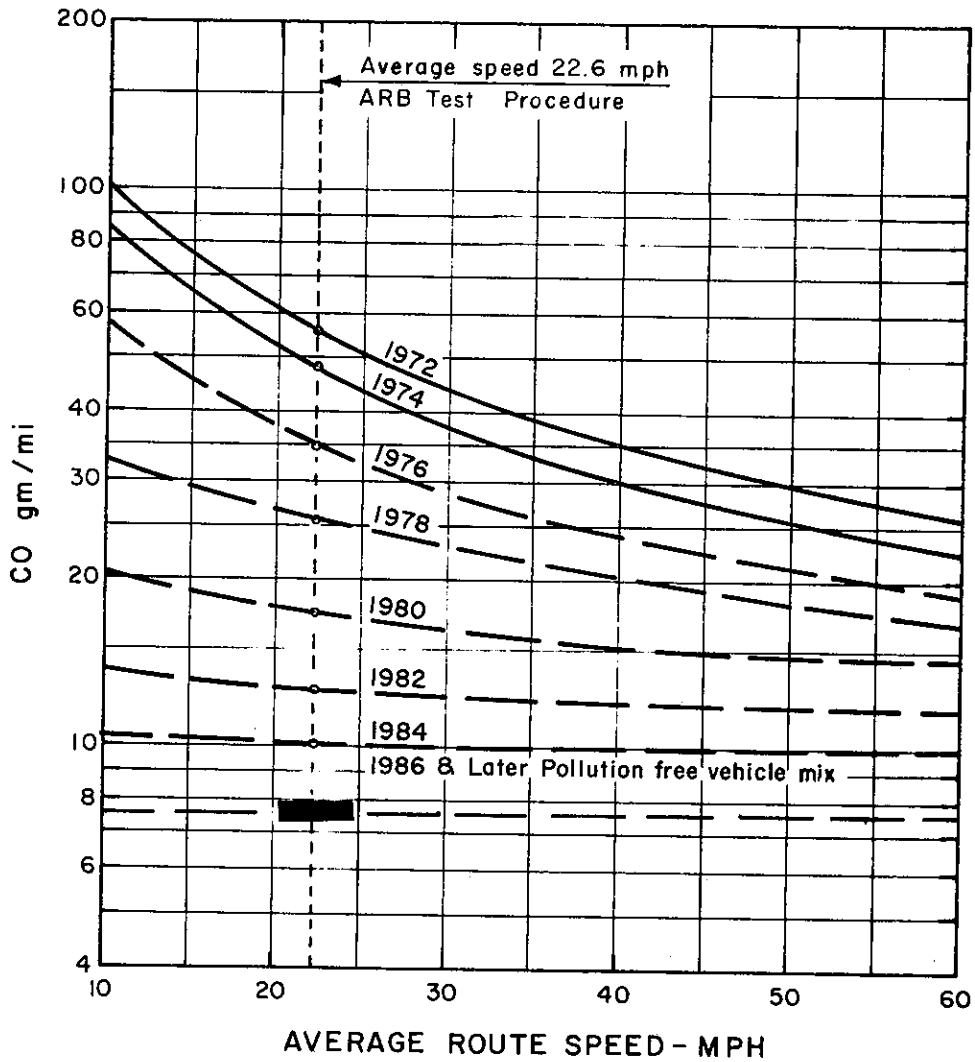

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Figure 6

EMISSION FACTORS FOR CARBON MONOXIDE
VS AVERAGE ROUTE SPEED
ON FREEWAYS
20% HDV

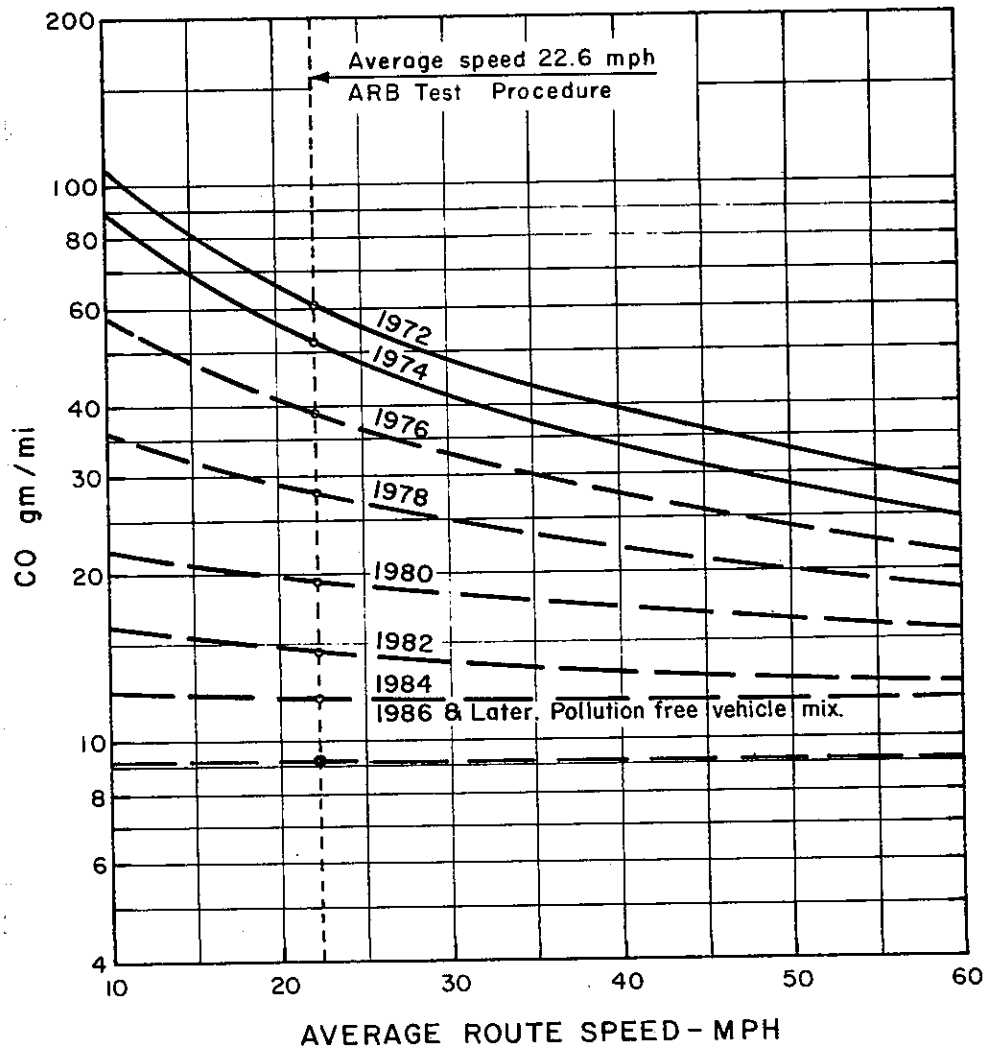

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Figure 7

EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON CITY STREETS 0 % HDV

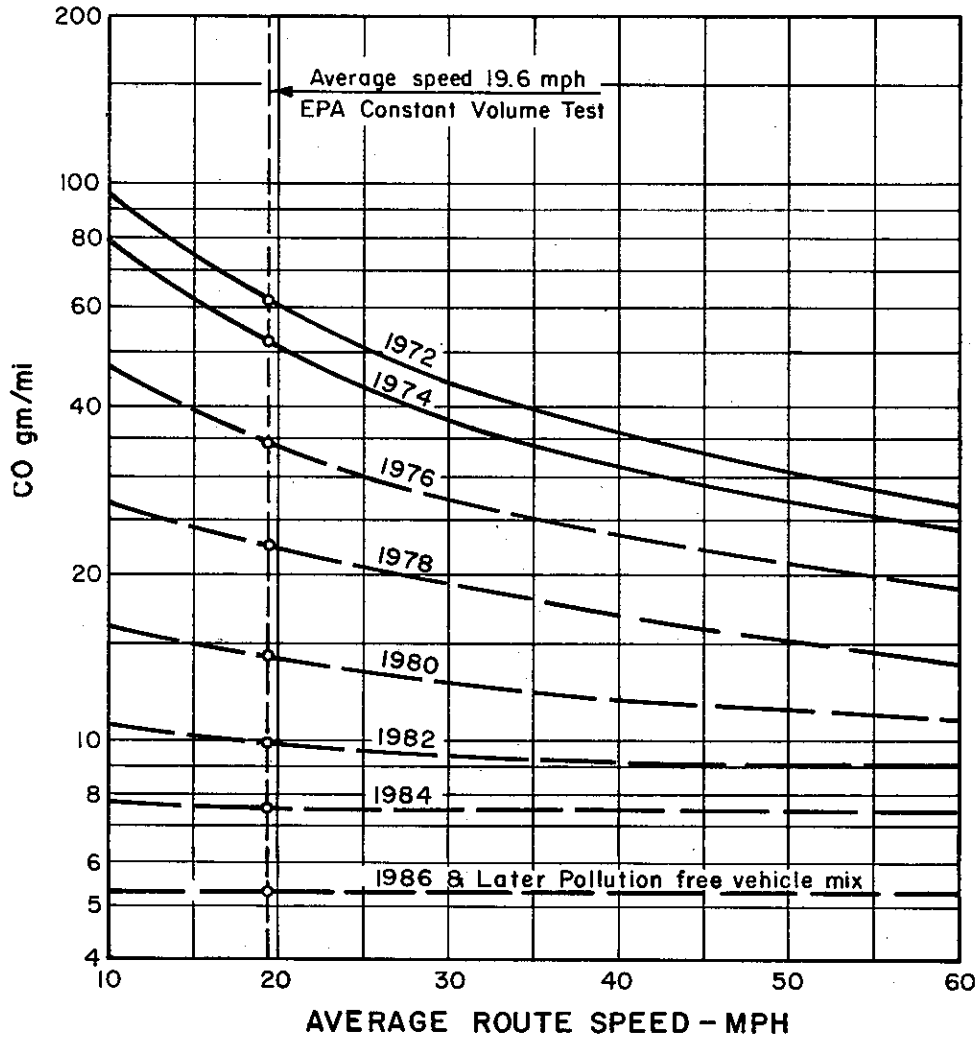

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Figure 8

EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON CITY STREETS 5% HDV

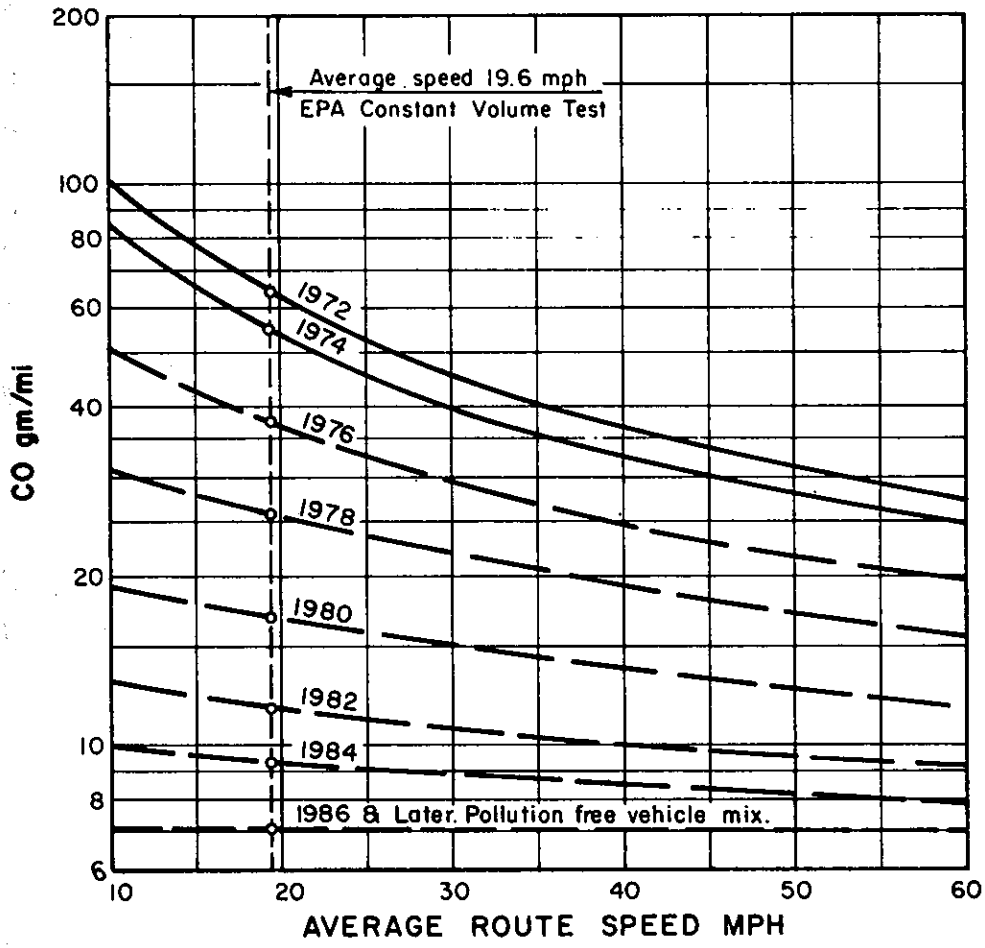

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Figure 9

EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON CITY STREETS 10 % HDV

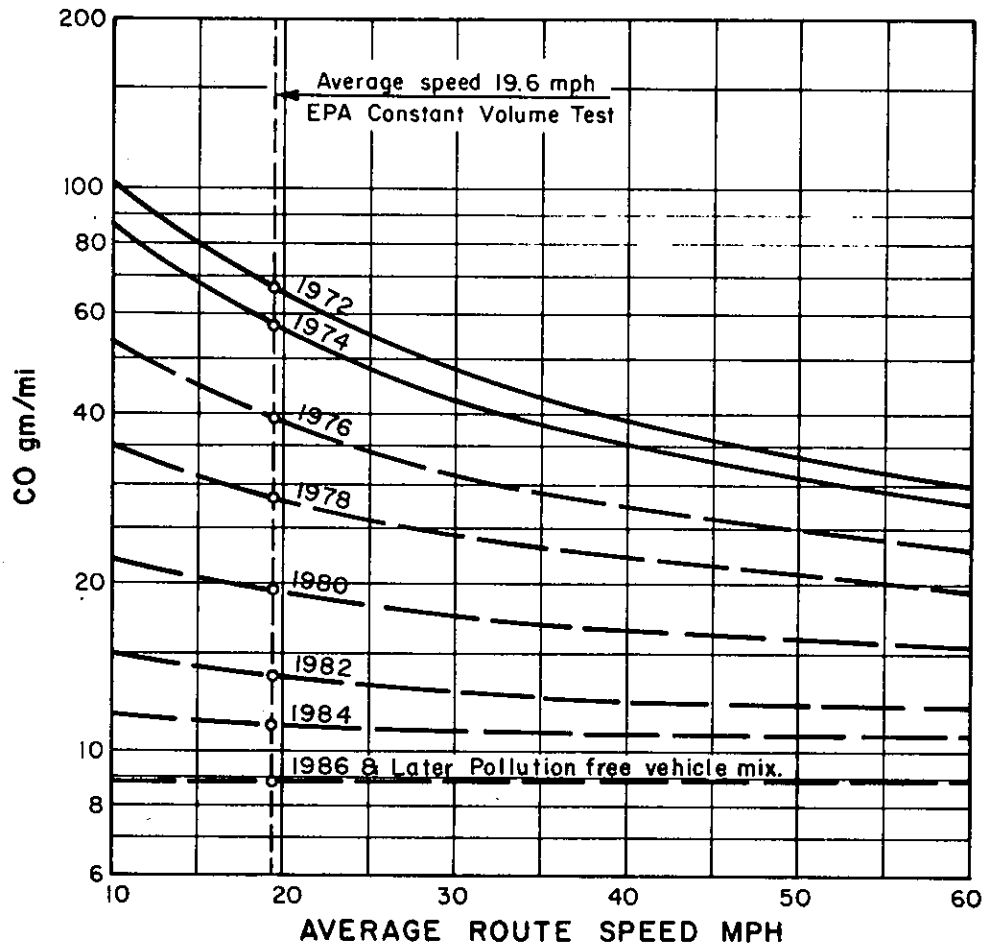

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Figure 10

EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON CITY STREETS 15 % HDV

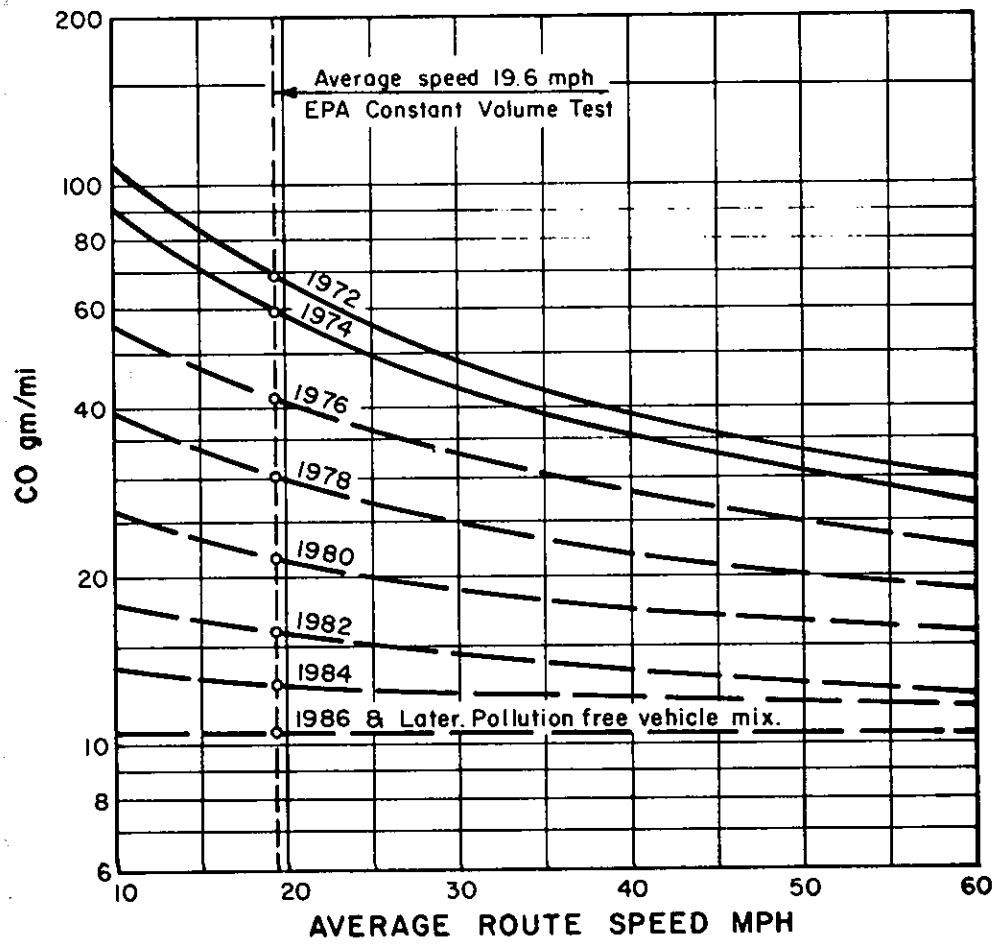

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Figure II

EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON CITY STREETS 20 % HDV

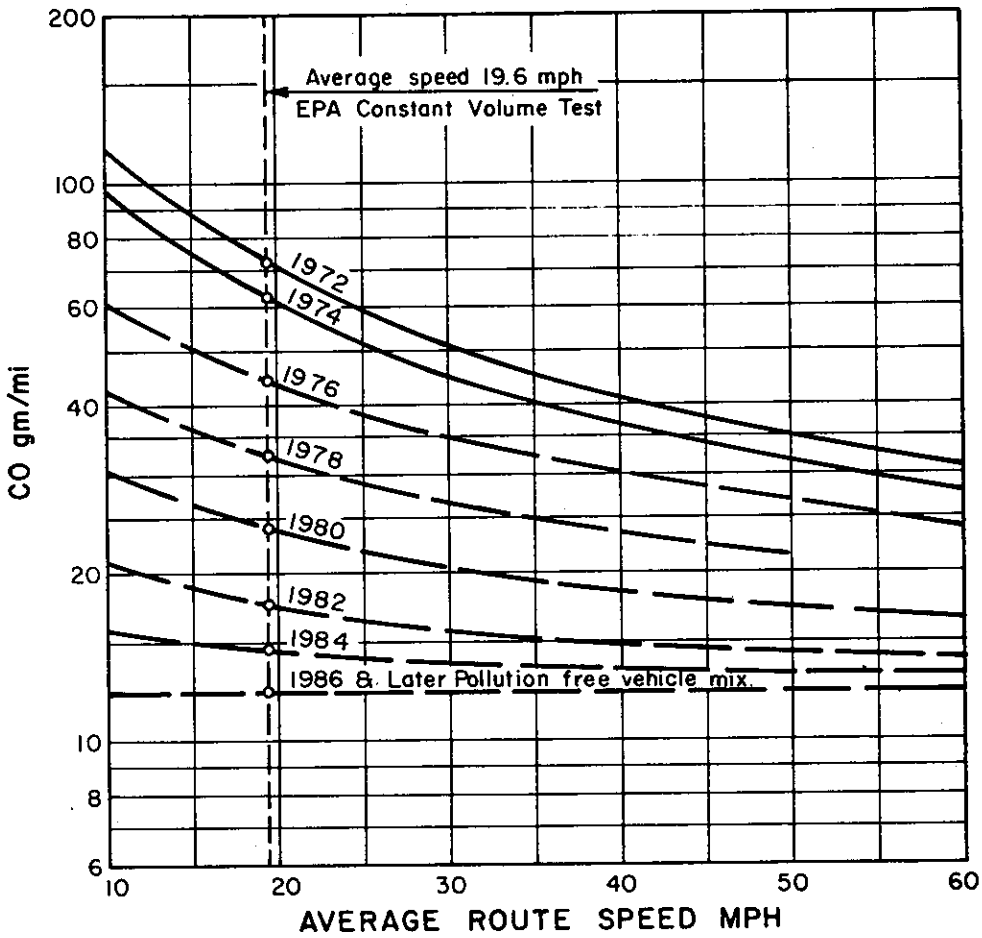

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Figure 12

HYDROCARBON EMISSIONS VS AVERAGE ROUTE SPEED FOR UNCONTROLLED VEHICLES- PRE 1966 MODELS (ROSE'S WORK)

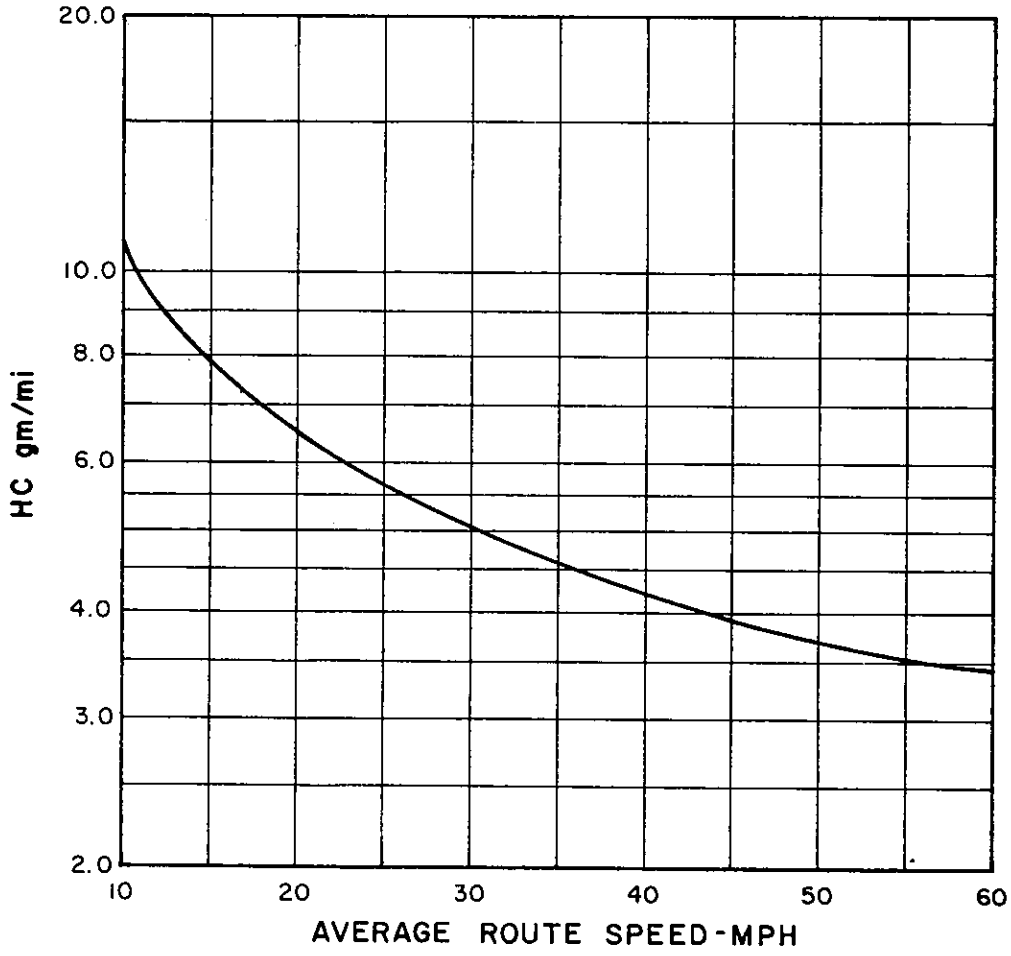

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Figure 13

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON FREEWAYS 0% HDV

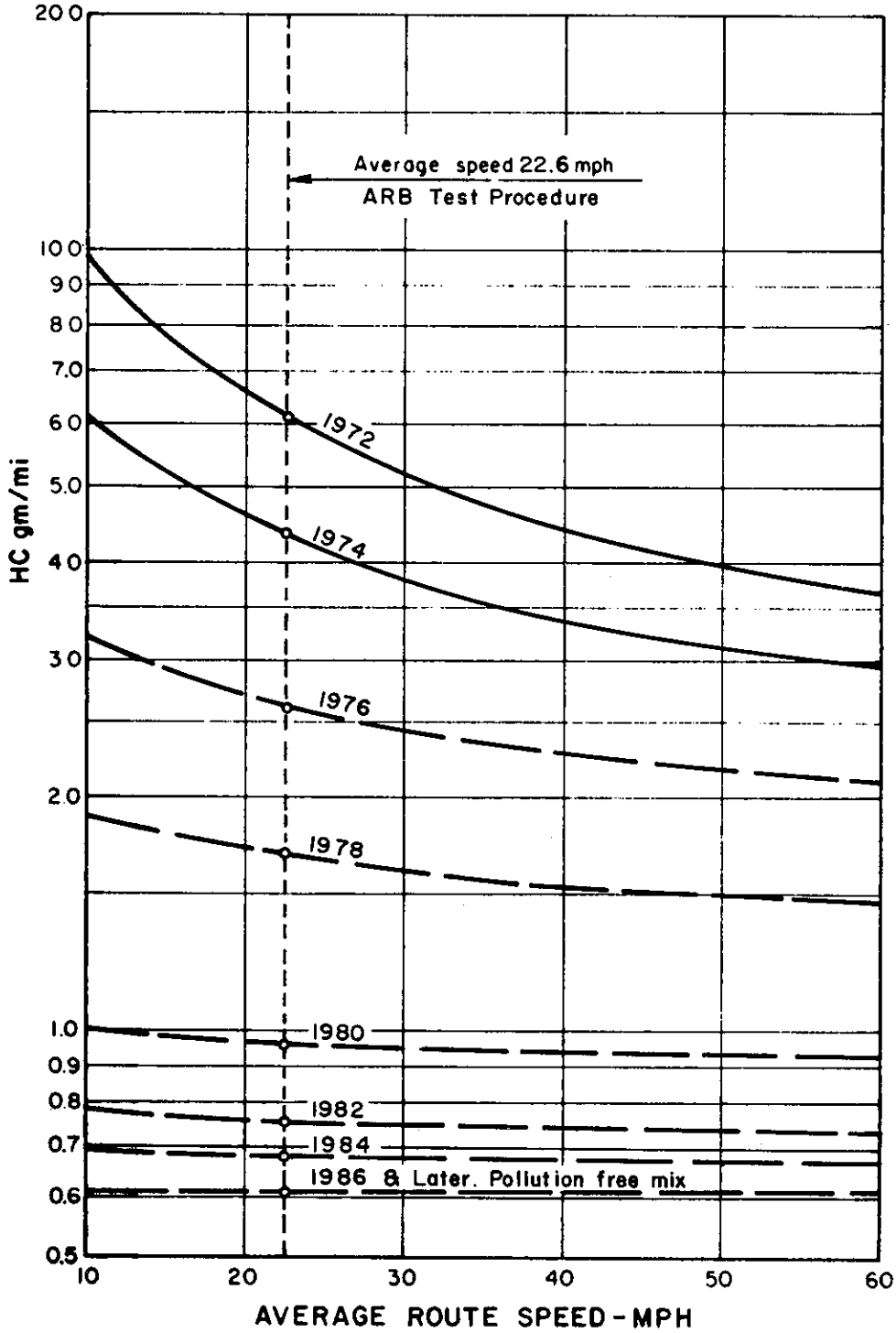

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Figure 14

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON FREEWAYS 5% HDV

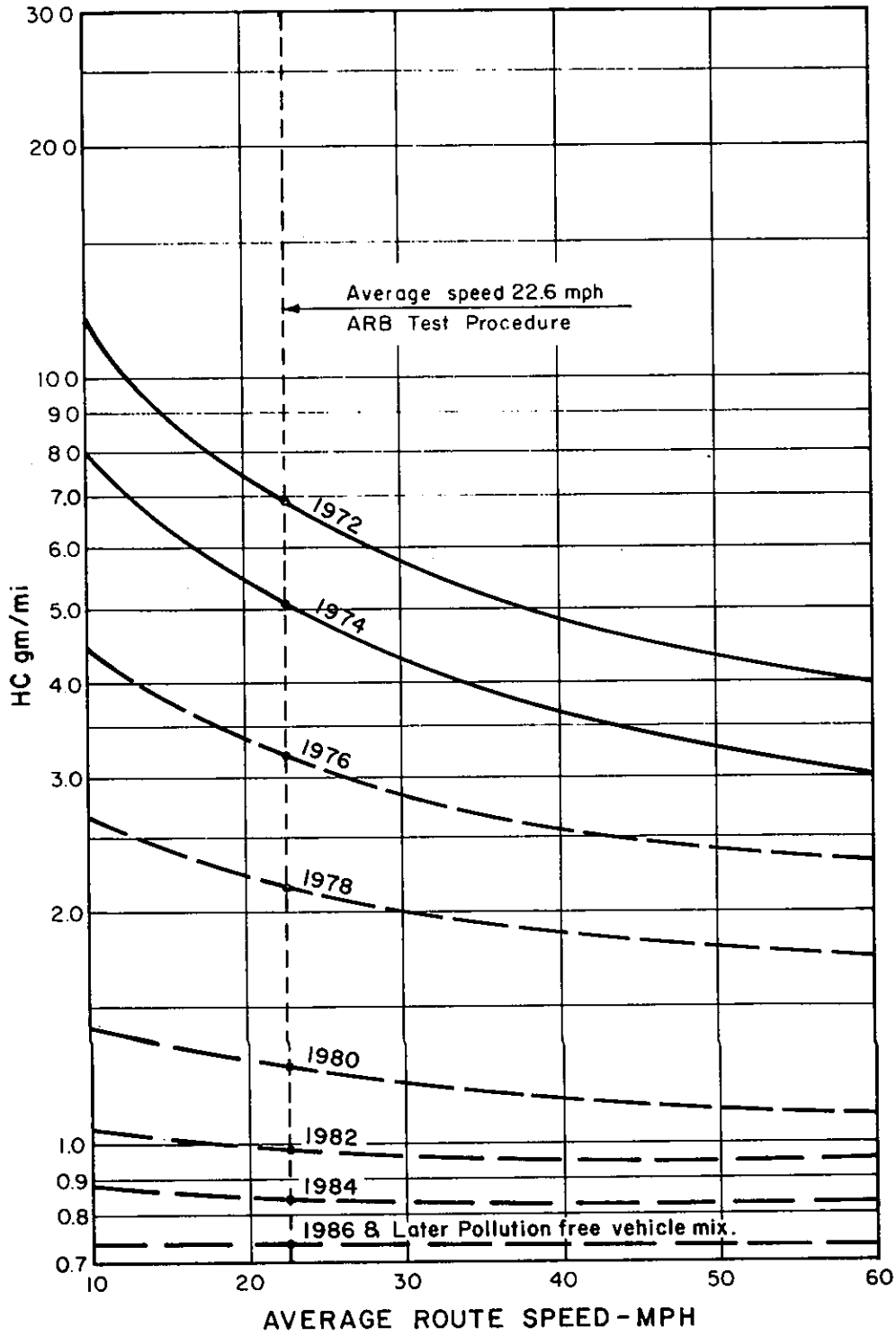

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Figure 15

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON FREEWAYS 10% HDV

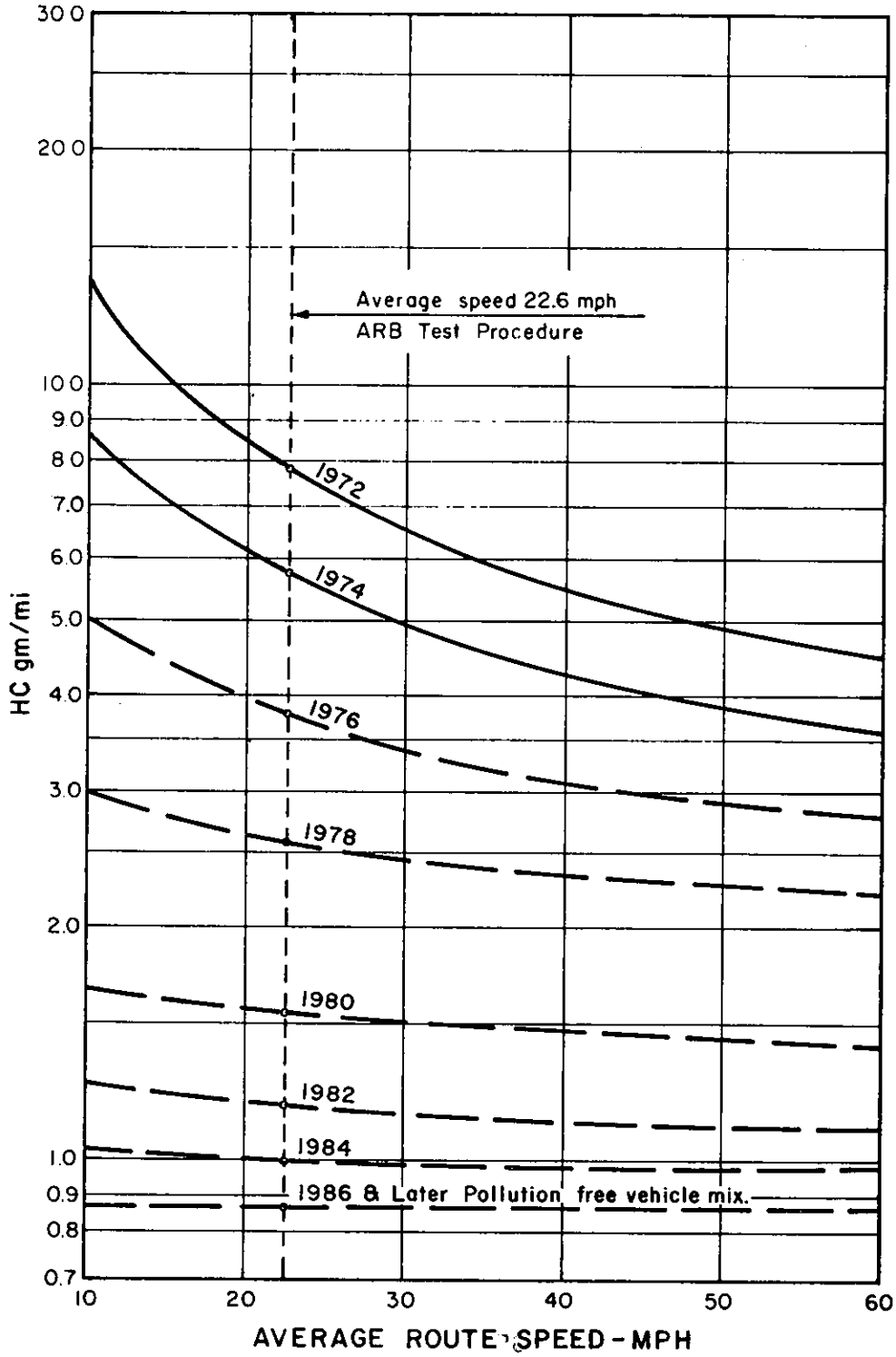

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Figure 16

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON FREEWAYS 15% HDV

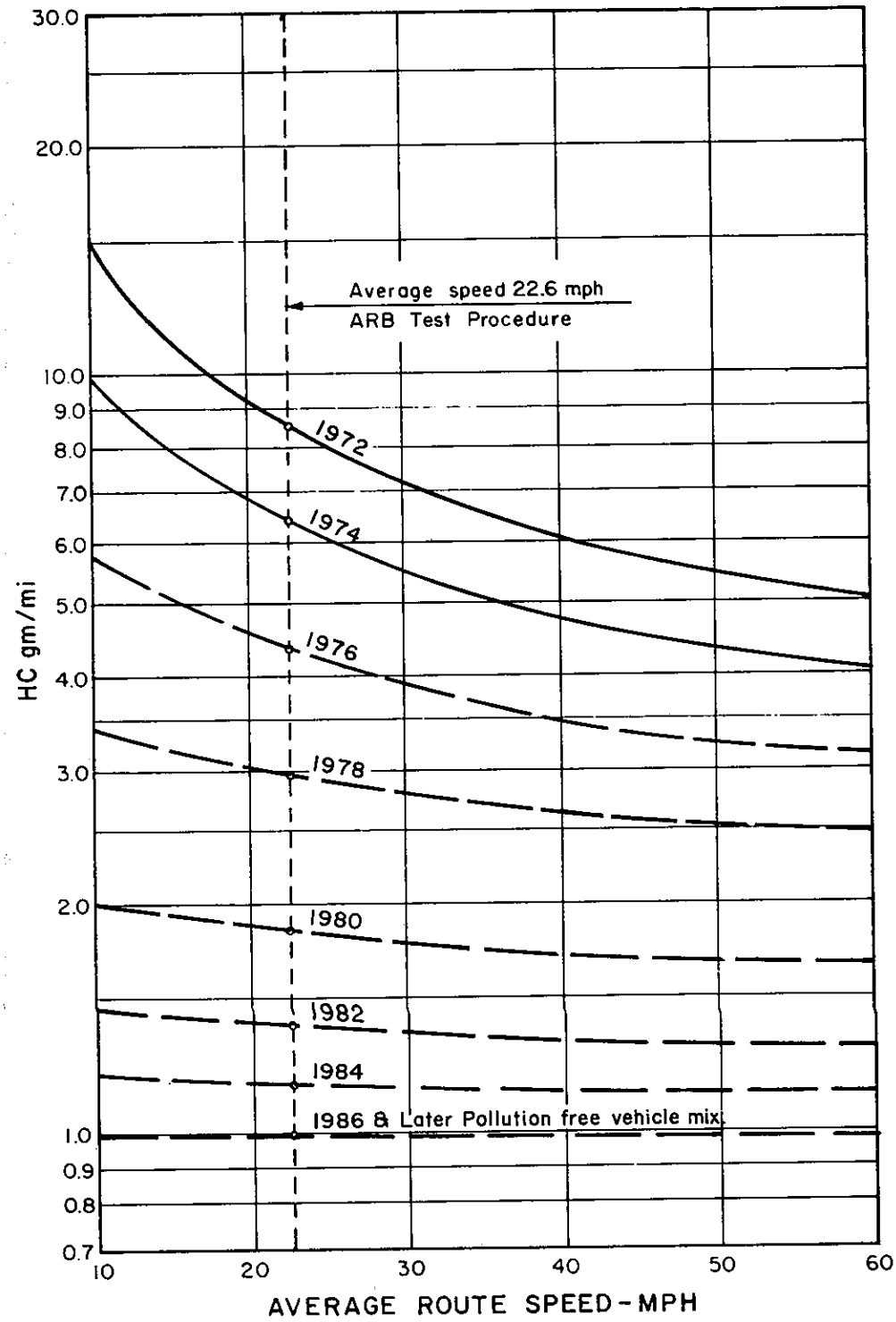

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Figure 17

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON FREEWAYS 20% HDV

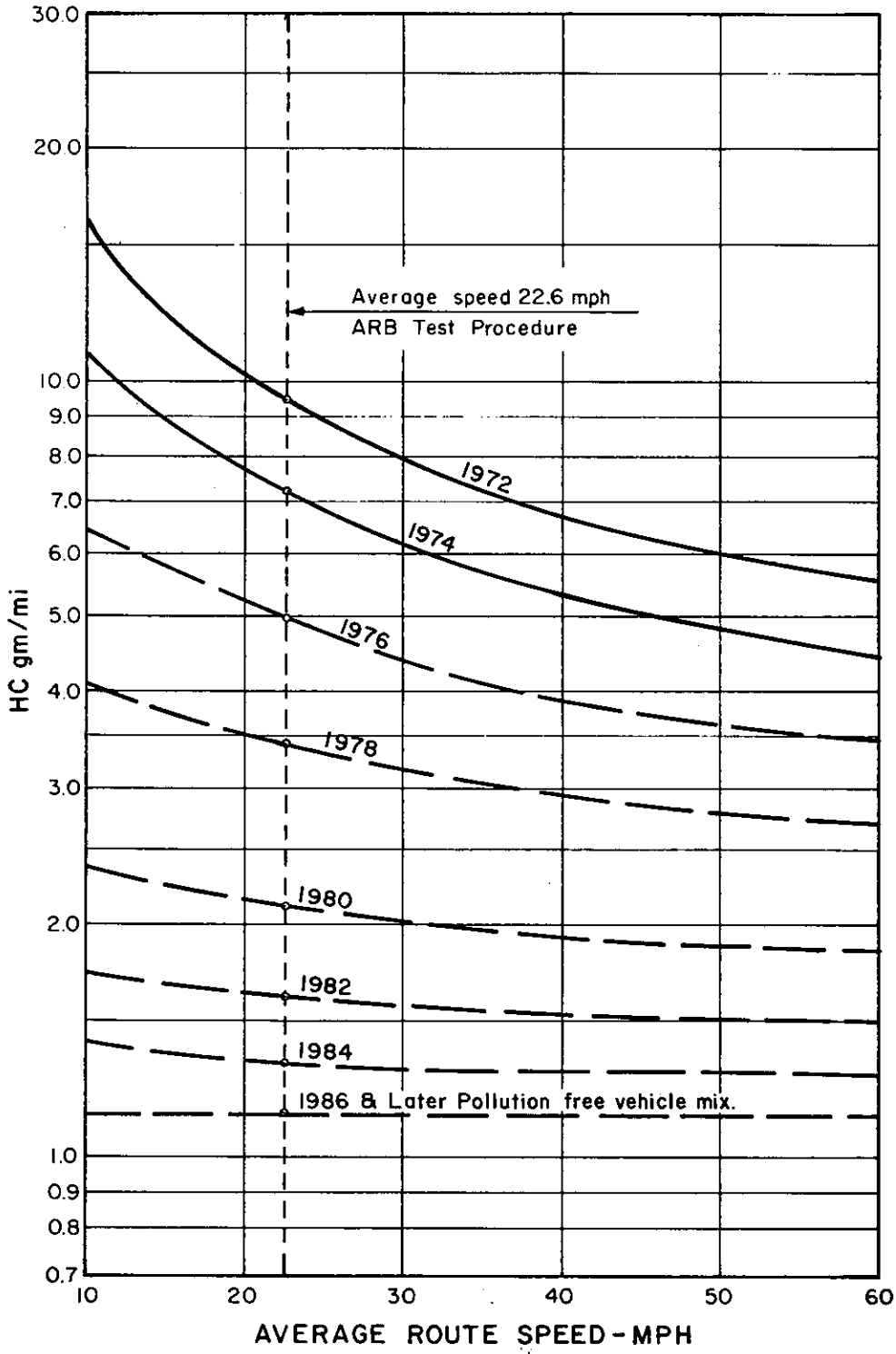

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Figure 18

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON CITY STREETS 0% HDV

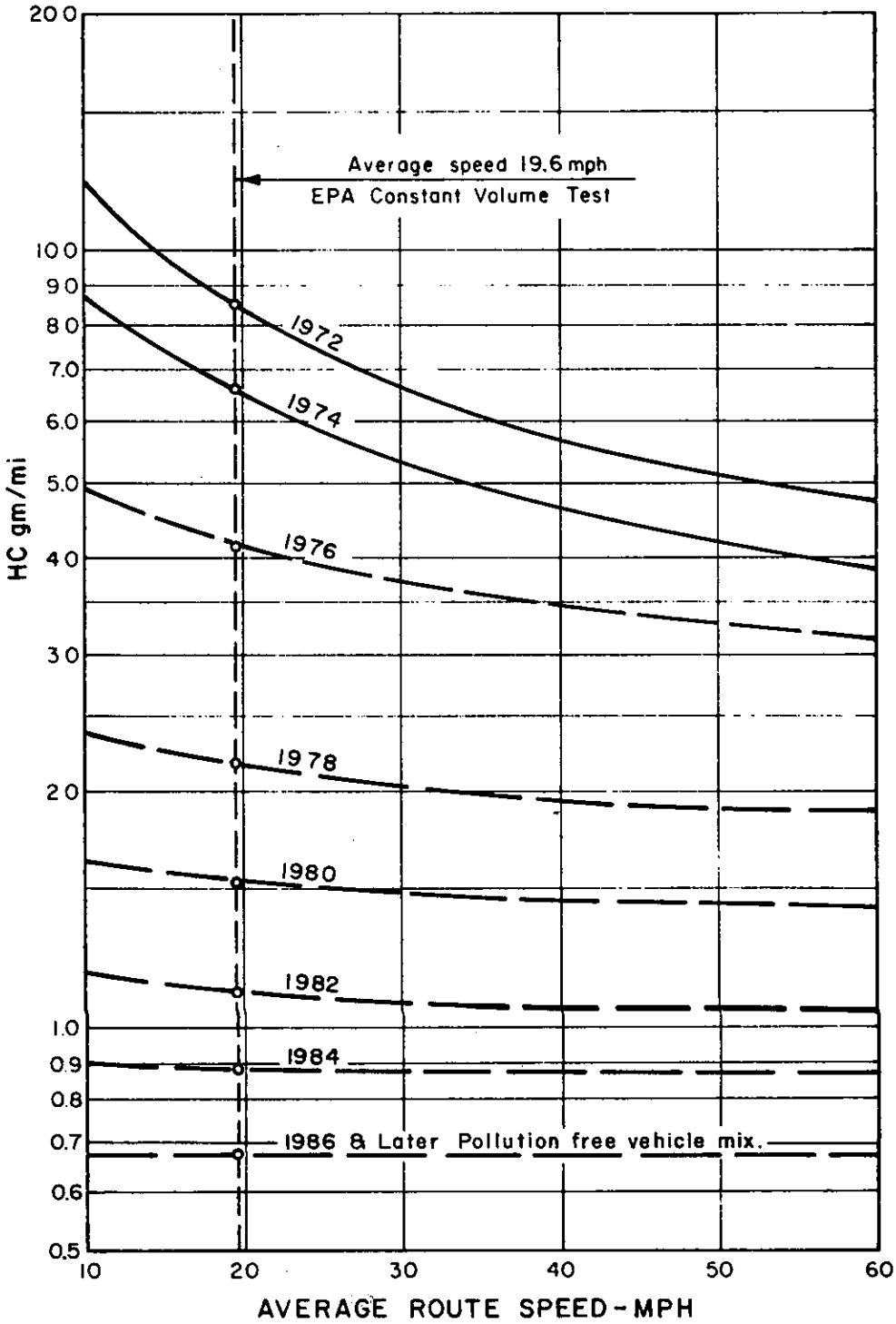

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Figure 19

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON CITY STREETS 5% HDV

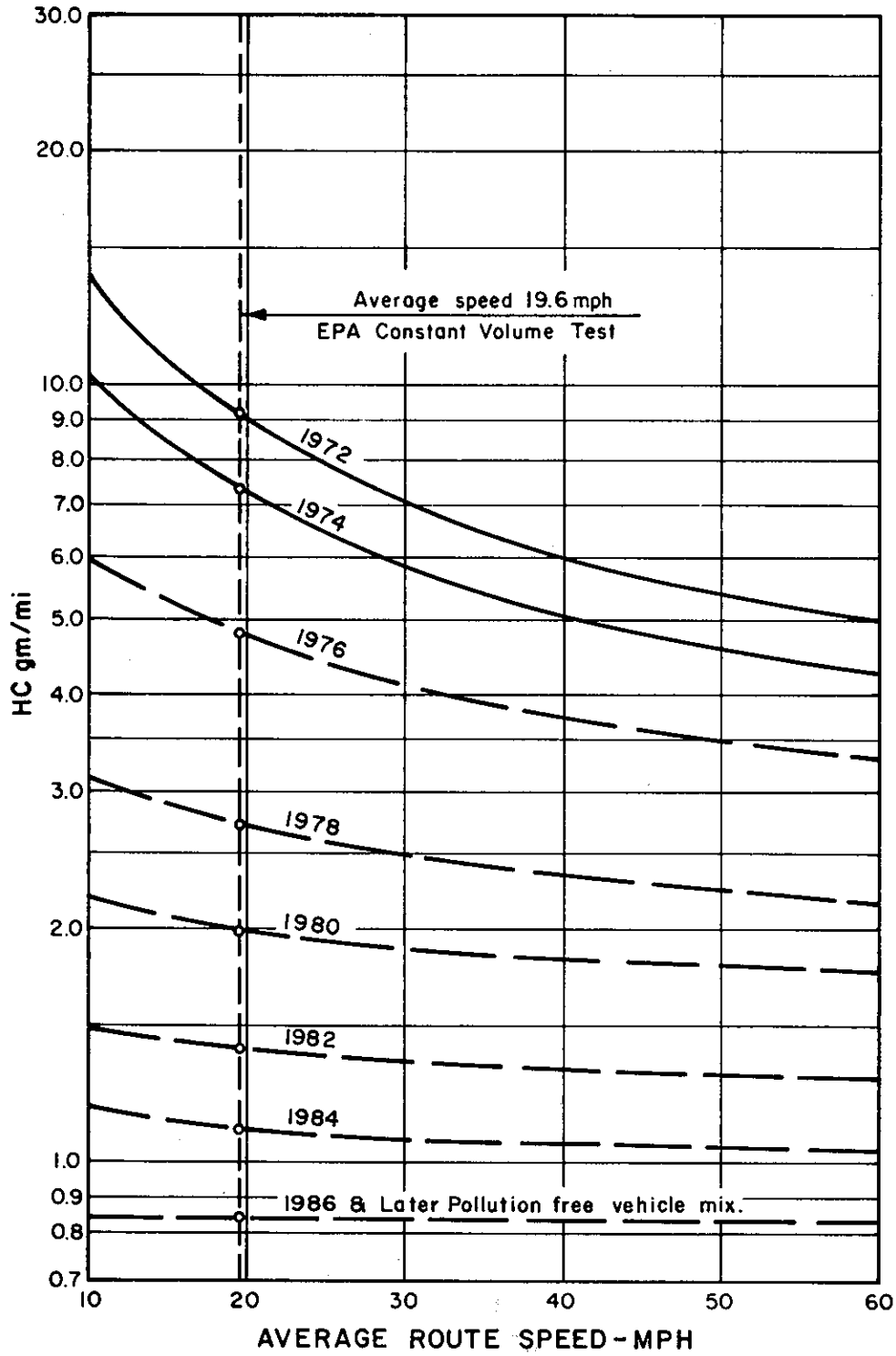

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Figure 20

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON CITY STREETS 10% HDV

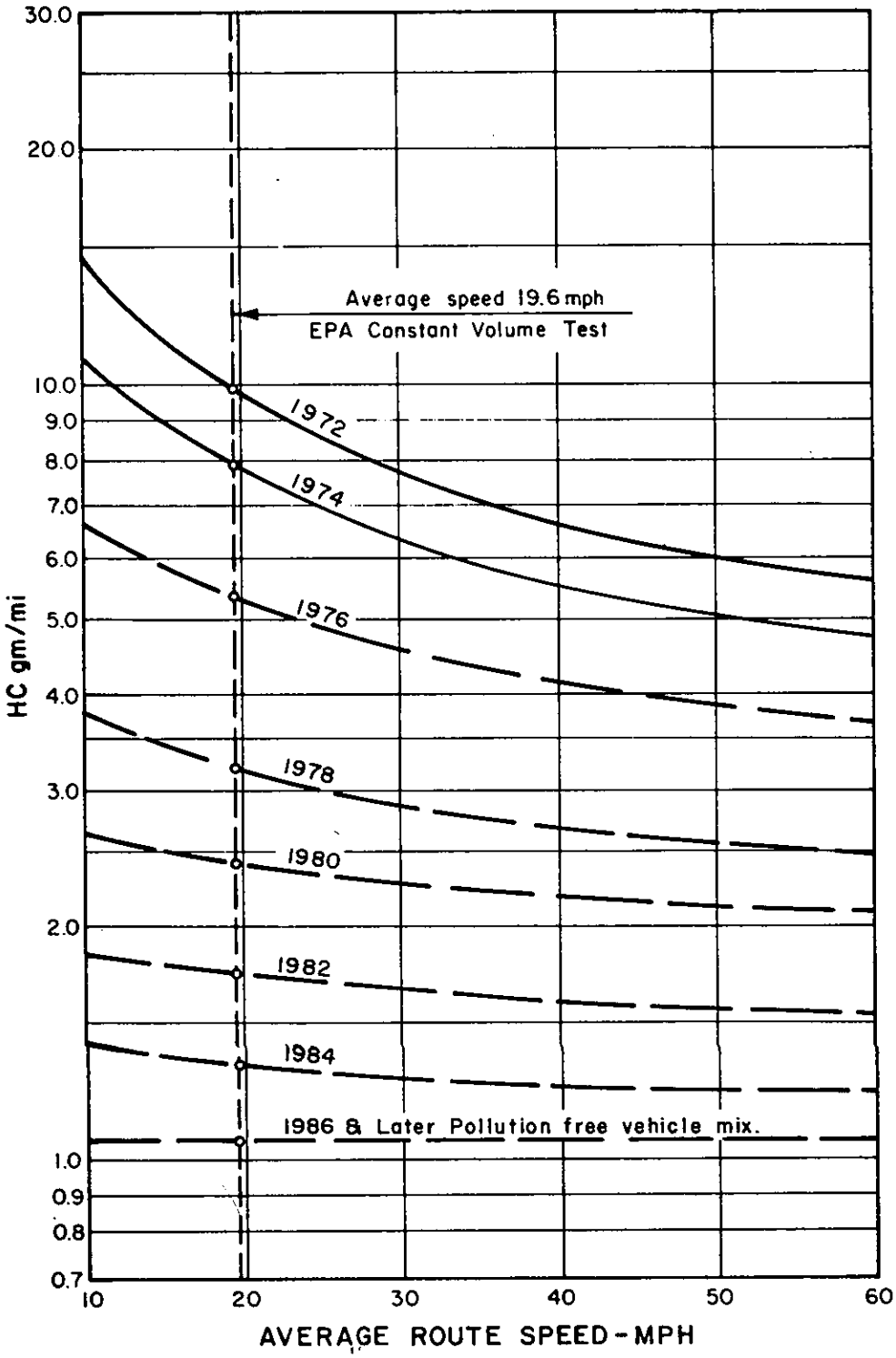

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Figure 21

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON CITY STREETS 15% HDV

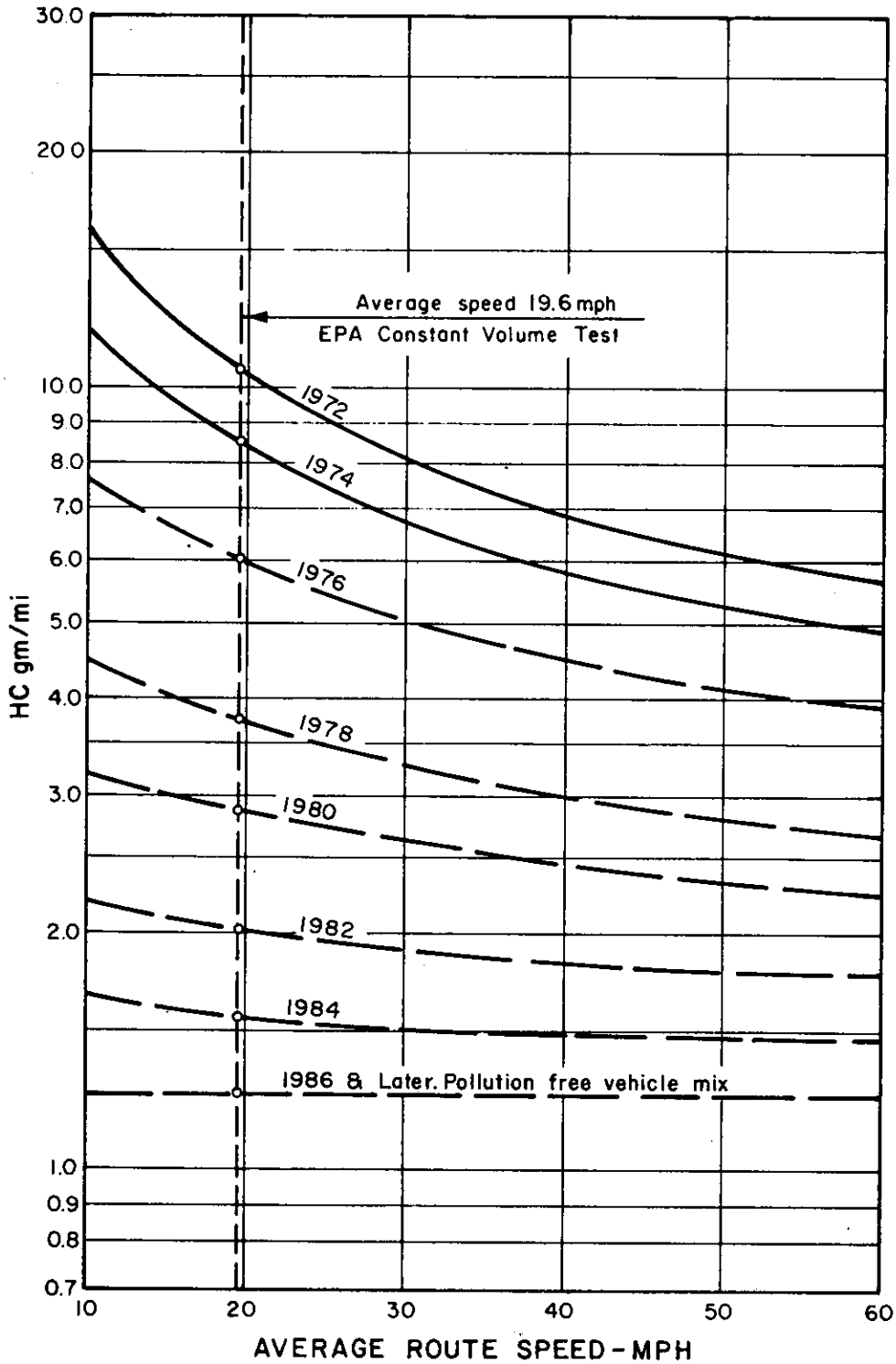

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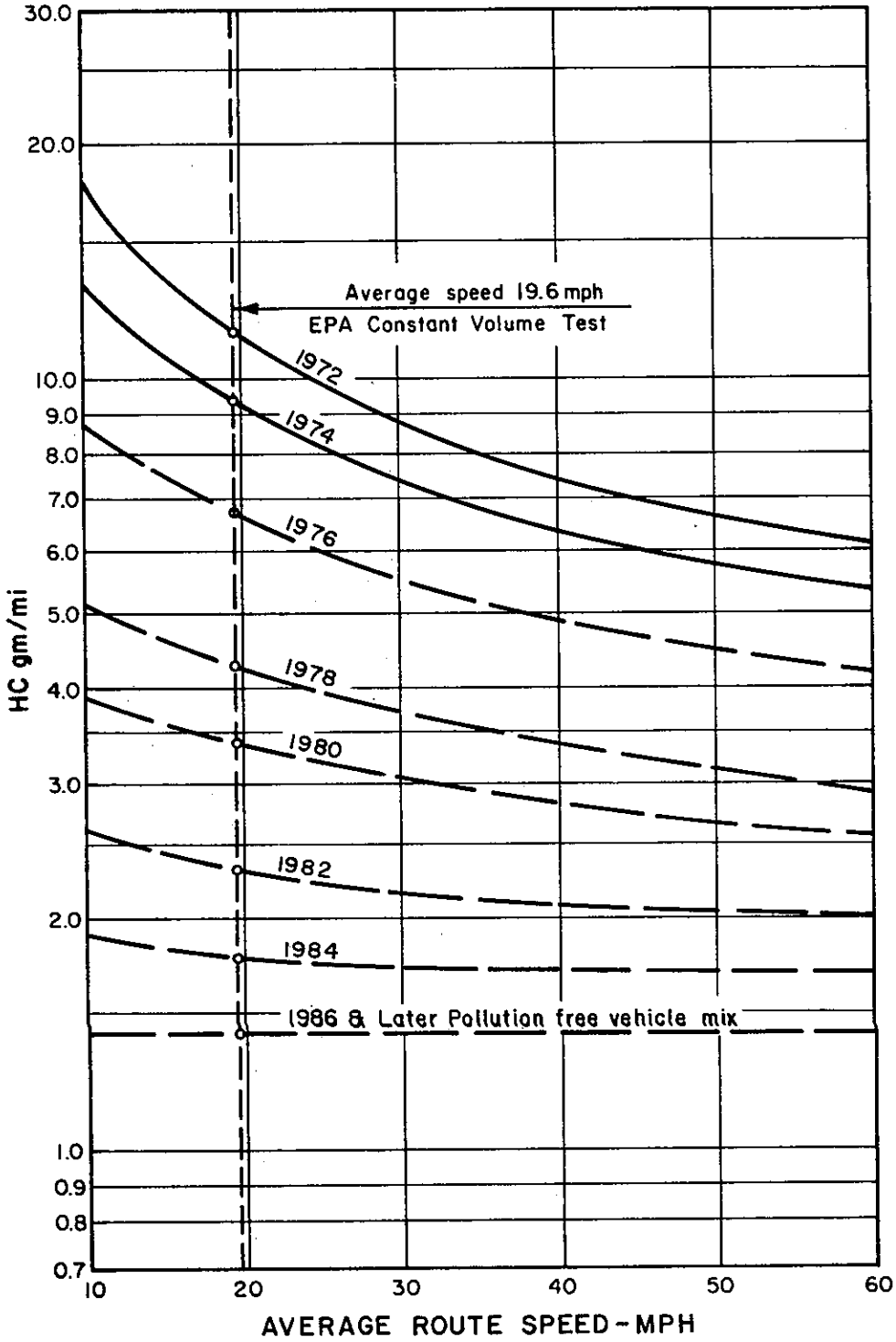
Figure 22

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON CITY STREETS 20 % HDV



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APPENDIX A

SAMPLE CALCULATION OF ARB EMISSION FACTORS FOR 1972

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The following tables summarize the calculations made of ARB Emission Factors for the calendar year 1972. Additional data for later years may be obtained upon request to the Division of Highways, Materials and Research Department in Sacramento.

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APPENDIX A

SAMPLE CALCULATIONS OF ARB EMISSION FACTORS FOR 1972

CO:

	Light Duty Vehicles						Heavy Duty Vehicles					
YEAR	ARB Emission Standards (Table 1)	Mileage (Table 4)	Deterior. Factor (Table 2)	Standard x Deterior.	% Distrib. of Total Vehicle Miles (Table 4)	Distrib. x Standard x Deterior. Factor	ARB Emission Standards (Table 1)	Mileage (Table 5)	Deterior. Factor (Table 3)	Standard x Deterior.	% Distrib. of Total Vehicle Miles (Table 5)	Distrib. x Standard x Deterior. Factor
72	23	15,000	1.15	26.45	19.9	5.26	46	14,000	1.15	52.9	10.9	5.77
71	23	28,000	1.23	28.29	16.7	4.72	70	28,000	1.23	86.1	10.5	9.04
70	23	39,000	1.28	29.44	13.7	4.03	70	42,000	1.0	90.3	10.3	9.30
69	34	48,600	1.31	44.54	11.5	5.12	160	56,000	1.0	160	9.9	15.84
68	34	57,000	1.35	45.90	9.5	4.36	160	70,000	1.0	160	9.5	15.20
67	34	64,000	1.25	42.50	7.5	3.19	160	84,000	1.0	160	8.9	14.24
66	34	69,300	1.27	43.18	5.2	2.25	160	98,000	1.0	160	8.2	13.12
65	80	74,300	1.00	80.00	4.4	3.52	160	112,000	1.0	160	7.2	11.52
64	80	78,7000	1.00	80.00	3.4	2.72	160	126,000	1.0	160	6.2	9.92
63	80	82,900	1.00	80.00	2.6	2.08	160	140,000	1.0	160	5.1	8.16
62	80	86,400	1.00	80.00	5.6	4.48	160	154,000	1.0	160	13.1	20.96
					Total = 41.7 gm/mi						Total =	133.07 gm/mi

Table 6

Assume 5% HDV Mix

Overall total = 0.95(41.7) + .05 (133.07) = 46.29 gm/mi

Table 7

HC:

	Light Duty Vehicles						Heavy Duty Vehicles					
YEAR	ARB Emission Standards (Table 1)	Mileage (Table 4)	Deterior. Factor (Table 2)	Standard x Deterior.	% Distrib. of Total Vehicle Miles (Table 4)	Distrib. x Standard x Deterior. Factor	ARB Emission Standards (Table 1)	Mileage (Table 5)	Deterior. Factor (Table 3)	Standard x Deterior.	% Distrib. of Total Vehicle Miles (Table 5)	Distrib. x Standard x Deterior. Factor
72	1.5	15,000	1.10	1.65	19.9	.328	7.5	14,000	1.10	8.25	10.9	.90
71	2.2	28,000	1.16	2.56	16.7	.426	10	28,000	1.16	11.60	10.5	1.22
70	2.2	39,000	1.19	2.62	13.7	.359	10	42,000	1.19	11.90	10.3	1.23
69	6.5	57,000	1.21	7.87	11.5	.904	25.0	56,000	1.0	25.0	9.9	2.48
68	6.5	57,000	1.24	8.06	9.5	.766	25.0	70,000		25.0	9.5	2.38
67	6.5	64,000	1.34	8.71	7.5	.653	30.2	84,000		30.2	8.9	2.69
66	6.5	69,300	1.36	8.84	5.2	.460	30.2	98,000			8.2	2.48
65	14.0	74,300	1.00	14.0	4.4	.616	30.2	112,000			7.2	2.17
64	14.0	78,700	1.0		3.4	.476		126,000			6.2	1.87
63	14.0	82,900	1.0		2.6	.364		140,000			5.1	1.54
62	14.0	86,400	1.0	14.0	5.6	.784	30.2	154,000	1.0	30.2	13.1	3.96

Total = 6.14 gm/mi

Table 6

Total = 22.92 gm/mi

Assume 5% HDV Mix

Overall total = 0.95(6.14) + 0.05(22.92) = 6.98 gm/mi

Table 7

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APPENDIX B

SAMPLE CALCULATION OF EPA EMISSION FACTORS FOR 1972

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The following tables summarize the calculations made of EPA Emission Factors for the calendar year 1972. Additional data for later years may be obtained upon request to the Division of Highways, Materials and Research Department in Sacramento.

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APPENDIX B

SAMPLE CALCULATIONS OF EPA EMISSION FACTORS FOR 1972

CO:

	Light Duty Vehicles						Heavy Duty Vehicles					
YEAR	EPA Emission Standards (Table 11)	Mileage (Table 4)	Deterior. Factor (Table 2)	Standard x Deterior.	% Distrib. of Total Vehicle Miles (Table 4)	Distrib. x Standard x Deterior. Factor	EPA Emission Standards (Table 11)	Mileage (Table 5)	Deterior Factor (Table 2)	Standard x Deterior.	% Distrib. of Total Vehicle Miles (Table 5)	Distrib. x Standard x Deterior. Factor
72	31	15,000	1.15	35.7	19.9	7.09	53	14,000	1.15	60.95	10.9	6.64
71	35	28,000	1.23	43.1	16.7	7.19	80	28,000	1.23	98.4	10.5	10.33
70	35	39,000	1.28	44.8	13.7	6.14	80	42,000	1.29	103.2	10.3	10.63
69	50	48,600	1.31	65.5	11.5	7.53	129	56,000	1.0	129	9.9	12.77
68	50	57,000	1.35	67.5	9.5	6.41		70,000			9.5	12.26
67	62	64,000	1.25	77.5	7.5	5.91		84,000			8.9	11.48
66	62	69,300	1.27	78.7	5.2	4.03		98,000			8.2	10.58
65	110	74,300	1.00	110	4.4	4.84		112,000			7.2	9.29
64		78,700			3.4	3.74		126,000			6.2	8.00
63		82,900			2.6	2.86		140,000			5.1	6.58
62	110	86,400	1.00	110	5.6	6.16	129	154,000	1.0	129	13.1	16.90

Total = 61.90 gm/mi ← Table 12

Total = 115.46 gm/mi

Assume 5% HDV Mix

Overall total = 0.95(61.90) + 0.05(115.46) = 64.58 gm/mi ← Table 13

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HC:

YEAR	Light Duty Vehicles: EPA Emission Standards (Table 11)	Mileage (Table 4)	Deterior. Factor (Table 2)	Standard x Deterior.	% Distrib. of Total Vehicle Miles (Table 4)	Distrib. x Standard x Deterior. Factor	Heavy Duty Vehicles: EPA Emission Standards (Table 11)	Mileage (Table 5)	Deterior. Factor (Table 2)	Standard x Deterior.	% Distrib. of Total Vehicle Miles (Table 5)	Distrib. x Standard x Deterior. Factor
72	3.26	15,000	1.10	3.59	19.9	.714	12.9	14,000	1.10	14.19	10.9	1.55
71	3.99	28,000	1.16	4.63	16.7	.773	18.1	28,000	1.16	21.0	10.5	2.20
70	3.99	39,000	1.19	4.75	13.7	.650	18.1	42,000	1.19	21.5	10.3	2.22
69	8.6	48,600	1.21	10.4	11.5	1.20	21.7	56,000	1.0	21.7	9.9	2.15
68	8.6	57,000	1.24	10.7	9.5	1.01	21.7	70,000		21.7	9.5	2.06
67	8.9	64,000	1.34	11.9	7.5	.894	26.9	84,000		26.9	8.9	2.39
66	8.9	69,300	1.36	12.1	5.2	.629		98,000			8.2	2.21
65	16.1	74,300	1.0	16.1	4.4	.708		112,000			7.2	1.94
64	16.1	78.700	1.0	16.1	3.4	.547		125,000			6.2	1.67
63	16.9	82,900	1.0	16.9	2.6	.440		140,000			5.1	1.37
62	16.9	86,400	1.0	16.9	5.6	.948	26.9	154,000	1.0	26.9	13.1	3.52

Total = 8.51 gm/mi

Table 12

Total = 23.28 gm/mi

Assume 5% HDV Mix

Overall total = 0.95(8.51) + 0.05(23.28) = 9.25 gm/mi

Table 13

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