AUTOMOBILE EMISSIONS AND FUEL ECONOMY AT LOW AMBIENT TEMPERATURES

by

N. Ostrouchov and J. Polak

Mobile Sources Division
Abatement and Compliance Branch
Air Pollution Control Directorate

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ABSTRACT

In January 1975, the Emission Testing Laboratory of the Air Pollution Control Directorate, Environment Canada initiated a second program to investigate further the effect of cold ambient temperature on exhaust emissions and fuel consumption. The effect has been studied using a variety of automobiles representing three different emission control levels and testing them at ambients of 30°C down to -30°C.

It was found that emissions of the three gaseous pollutants demonstrated a mild power relationship with ambient (soaking) temperatures. All regulated pollutants and fuel consumption were higher at -30°C than at 20°C: hydrocarbons (HC) - 3.5 to 9.2 times; carbon monoxide (CO) - 2.4 to 6.4 times; oxides of nitrogen (NO_x) - only 1.1 to 1.4 times; and fuel consumption 1.2 to 1.8 times higher. Analysis of the data has indicated that HC and CO emissions from the cold start phase of the Federal test were the most sensitive to soaking temperature. With NO_x emissions the soaking temperature sensitivity was fairly constant throughout the three phases of the Federal test.

The data also indicate that the temperature sensitivity of both fuel economy and, to a lesser extent, emissions is a function of inertia weight.

RÉSUMÉ

Le laboratoire d'essais sur les émissions de la Direction générale de l'assainissement de l'air à Environnement Canada a entrepris, en janvier 1975, un second programme d'études des effets du froid sur les émanations et la consommation de carburant des véhicules automobiles. Divers types de véhicules représentant trois taux d'efficacité des dispositifs antipollution ont fait l'objet d'essais à des températures variant entre 30°C et -30°C.

Les recherches ont démontré l'existence d'une certaine corrélation entre polluants gazeux et la température extérieure. Le taux des polluants réglementés et la consommation de carburant sont plus élevés à -30°C qu'à 20°C. Les hydrocarbures (HC) sont de 3,5 à 9,2 fois supérieurs; le monoxyde de carbone (CO) de 2,4 à 6,4 fois; les oxydes d'azote (NO_x) de 1,1 à 1,4 fois seulement et la consommation de carburant est de 1,2 à 1,8 fois plus forte. L'analyse des données des essais révèle que les émissions de HC et de CO sont le plus sensibles à la température extérieure au cours de la phase de démarrage à froid. Cependant les émissions de NO_x sont demeurées a peu près constantes pendant les trois phases de l'épreuve, malgré les variations de la température ambiante.

Les chiffres indiquent aussi que le rapport entre la température, l'économie de carburant et, dans une moindre mesure, les émissions, est fonction du poids inerte.

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1 INTRODUCTION

The fact that ambient temperature affects the character and quantity of emissions from automobiles has been known for many years (1, 2, 3, 4, 6). However, as a matter of practical uniformity, the Canadian Motor Vehicle Safety Test Methods provide that emission measurements be made with the vehicle operated in a controlled environment with temperature limits of 20°C to 30°C (5).

Pollutants to which the automobile contributes are a matter of concern in a number of urban areas that have climatic conditions which differ vastly from the standard test conditions. It was therefore desirable that additional information on the effect of ambient temperature on emissions, fuel economy and emission control systems be obtained and made generally available.

This experimental program was not designed to yield all information needed for statistically valid results from all or any given segment of the automobile population. Instead, the study was made to characterize the more prominent trends in an association of ambient temperature, emission levels and fuel economy, and to examine the difference in temperature sensitivity of vehicles representing differing control technologies.

A previous study involving testing of a fleet of five light-duty motor vehicles was conducted by EPS (Environmental Protection Service) during the winter of 1972/73 and yielded results over a temperature range of -19°C to 22°C (1). The study indicated that exhaust emissions from light-duty vehicles increase as ambient temperature decreases.

To confirm the results of this initial study as well as to assess the effect of various emission control systems, further cold weather testing was required including evaluation of a larger fleet. The testing of a fleet of twelve 1975-model vehicles and one 1974-model vehicle began in January 1975 and continued until March 1977. This test period yielded results over a temperature range of -30°C to 30°C. More than 650 tests were performed on vehicles of widely varying control technology and inertia weight.

2 EQUIPMENT AND TEST PROCEDURE

The emission testing equipment and procedures used for this project (including dynamometer warm-up) were the same as those used in emission testing of motor vehicles for compliance with emission standards.

To obtain test data under cold ambient conditions, the test vehicles were left outside overnight (soaked) and pulled into the cold cell onto the pre-warmed dynamometer at test time, see Appendix C. The door from the cell was open to the outside and the air temperature of the cell was maintained equal to the outside ambient temperatures.

The test cell and the vehicles were equipped with thermocouples to monitor temperatures outside and inside the cell as well as intake air, engine coolant and oil temperatures. Because of lack of an instrument capable of measuring atmospheric humidity at temperatures below freezing point, the humidity data were taken from a meteorological laboratory located approximately 1 1/4 miles from the Emission Testing Laboratory.

The hood-up procedure was used because the original concept of the temperature effects program was to duplicate as closely as possible the standard test procedure but with temperature as a variable and thus to determine emissions as they would be generated under those conditions. The standard fans used in CVS testing were placed in front of the test vehicle to simulate road air stream velocity.

The vehicle was started and run through the simulated urban driving cycle while its exhaust was sampled in three segments of the test. The first segment, known as the cold transient phase (Bag 1), included the cold start and initial 505 seconds of the 23-minute cycle. The second segment, referred to as the stabilized phase (Bag 2), included that portion of the test beginning after 505 seconds and continuing to the end of the 23-minute cycle. At this point the engine was turned off and the vehicle allowed to stand for 10 minutes. The engine was then restarted and the first 505 seconds of the cycle was repeated to provide the third segment or hot transient phase (Bag 3).

The emissions measurement by this procedure, designated "1975 CVS composite," is expressed in grams per mile. It is calculated by weighting the cold transient mass emissions by 43%, the hot transient by 57%, adding these to the stabilized phase emissions, and dividing by the 7.5-mile trip length. This is equivalent to assuming that, on an average, 43% of the vehicle's urban trips are made from a cold start, 57% from a hot start, and that the mass emissions during the stabilized phase are unaffected by the engine status, i.e., hot or cold at start.

Lead-free winter fuel was used in tested vehicles for both cold weather and baseline testing.

Criteria for vehicle selection were to use a fleet of late model cars reflecting all three levels of emission specification (Canada, 49 States, California), the full size range of engines, and the more commonly used emission control approaches including simple engine modifications.

Thirteen cars, Table 1 (this table is, for convenience, also repeated in Appendix A as Table A-1), were used in the study. All were standard production vehicles and had more than 1000 miles before the start of testing. During the testing, 7500 to about 15 000 miles were accumulated on each car.

To establish a logical basis for consolidation of the data according to similitude in vehicle control technology, units of the test fleet were grouped and results averaged as follows:

(a) Three 1975 models (No. 1, 2, 3) of California specification with air injection (AI), exhaust gas recirculation (EGR), oxidizing catalytic converter (OC), and with positive crankcase ventilation - Fleet Code 75CAL (AI, EGR, OC)3;

(b) Two 1975 models (No. 4, 5) of the 49 States specification (U.S.) with EGR, OC, and with positive crankcase ventilation - Fleet Code 75US(EGR, OC)2;

(c) Two 1975 models (No. 6, 7) of Canadian specification, with AI, EGR, and positive crankcase ventilation - Fleet Code 75CAN(AI, EGR)2;

(d) Three 1975 models (No. 8, 9, 10) of Canadian specification with EGR and positive crankcase ventilation - Fleet Code 75CAN(EGR)3. Car No. 8 was not used for analysis in this group to maintain approximate similitude in vehicle sizes with the other groupings;

(e) One 1974 model (No. 11) of 49 States specification with rotary engine, thermal reactor (TR), and positive crankcase ventilation - Fleet Code 74US(TR)1;

(f) Two 1975 Honda models (No. 12, 13) of California specification with the Compound Vortex Controlled Combustion (CVCC) and positive crankcase ventilation - Fleet Code 75CAL(CVCC)2.

TABLE 1 VEHICLE TEST FLEET

Fleet Code	Car No.	Make & Model	Cyl. No.	Disp. in.^{3}	Vent-uris	Trans.	Inertia Weight lb	No. of Tests
75CAL(AI, EGR, OC)3	1	Chev. Monza	4	140	2	A3	3500	53
	2	Chev. Impala	8	350	4	A3	5000	43
	3	Dodge Dart	8	318	2	A3	4000	59
75US(EGR, OC)2	4	Chev. Biscayne	8	350	2	A3	5000	57
	5	Chev. Nova	6	250	1	A3	4000	60
75CAN(AI, EGR)2	6	Ford Custom	8	351	2	A3	5000	51
	7	Ford Maverick	6	250	1	A3	3500	44
75CAN(EGR)3	8	AMC Hornet	6	258	1	A3	3000	40
	9	Dodge Dart	6	225	1	A3	4000	53
	10	Dodge Monaco S/W	8	440	4	A3	5500	40
74US(TR)1	11	Mazda RX4	2R	80	4	M4	3000	51
75CAL(CVCC)2	12	Honda Civic	4	90.8	3	M4	2000	48
	13	Honda Civic	4	90.8	3	M4	2000	52

Fleet Codes

75, 74 - model year
CAL - California specific
US - 49 state specific
CAN - Canada specific
AI - manifold air injection
EGR - exhaust gas recirculation
OC - oxidizing catalytic converter
TR - thermal reactor
CVCC - compound vortex controlled combustion
1, 2, 3 - no. of cars used in the fleet

3 VEHICLE INSPECTION

Vehicle inspection was performed according to the manufacturer's maintenance timetable. The following items were examined for proper condition and repaired or replaced as necessary: spark plugs, breaker points, advance and dwell settings, idle speed and mixture, automatic choke function, heat riser valve, carburetor air heater, air filter, PCV valve, and fuel evaporation control system. No internal carburetor adjustments were made.

4 RESULTS AND DISCUSSION

A summary of the data obtained for each vehicle is presented in the listing of Appendix A, Tables A-2 to A-13. The average data of these tables are presented in terms of grams/mile for emissions of hydrocarbon, carbon monoxide, oxides of nitrogen and carbon dioxide, and in terms of miles/imp. gallon for fuel economy. Summarized and averaged emission data for grouped units of the test fleets are also presented in Appendix A in the listings of Table A-14, A-15 and A-16. To facilitate comparison, the averaged emissions data of these tables are presented for each vehicle group in forms of grams/mile in Figure 1(a), (b) and (c), and contributions of test phase emission to the composite are presented in Figure 2(a) to (f) for hydrocarbons,Figure 3(a) to (f) for carbon monoxide, and in Figure 4(a) to (f) for nitrogen oxides.

In some vehicles the trend of emission dependence on lower temperatures was slightly negative because an unusually high instrument range was used to measure sample bag concentrations. In these vehicles the trend was rejected and average baseline emission values were used as a constant throughout the ambient temperature range (see Appendix A, Tables A-3, A-5, A-7, A-9, A-11, A-12 and A-13).

4.1 Influence of Ambient Temperature on HC, CO and NO_x Emissions

Figure 1(a) and (b) indicates that vehicles in all categories have a common characteristic of HC and CO emissions sharply increasing at low ambient temperature. The change in oxides of nitrogen with variation in ambient temperature is less pronounced, Figure 1(c), but also increases at lower ambients. Figures 5, 6 and 7 show graphically the effect of lower ambient temperatures on emission increases for vehicle groups.

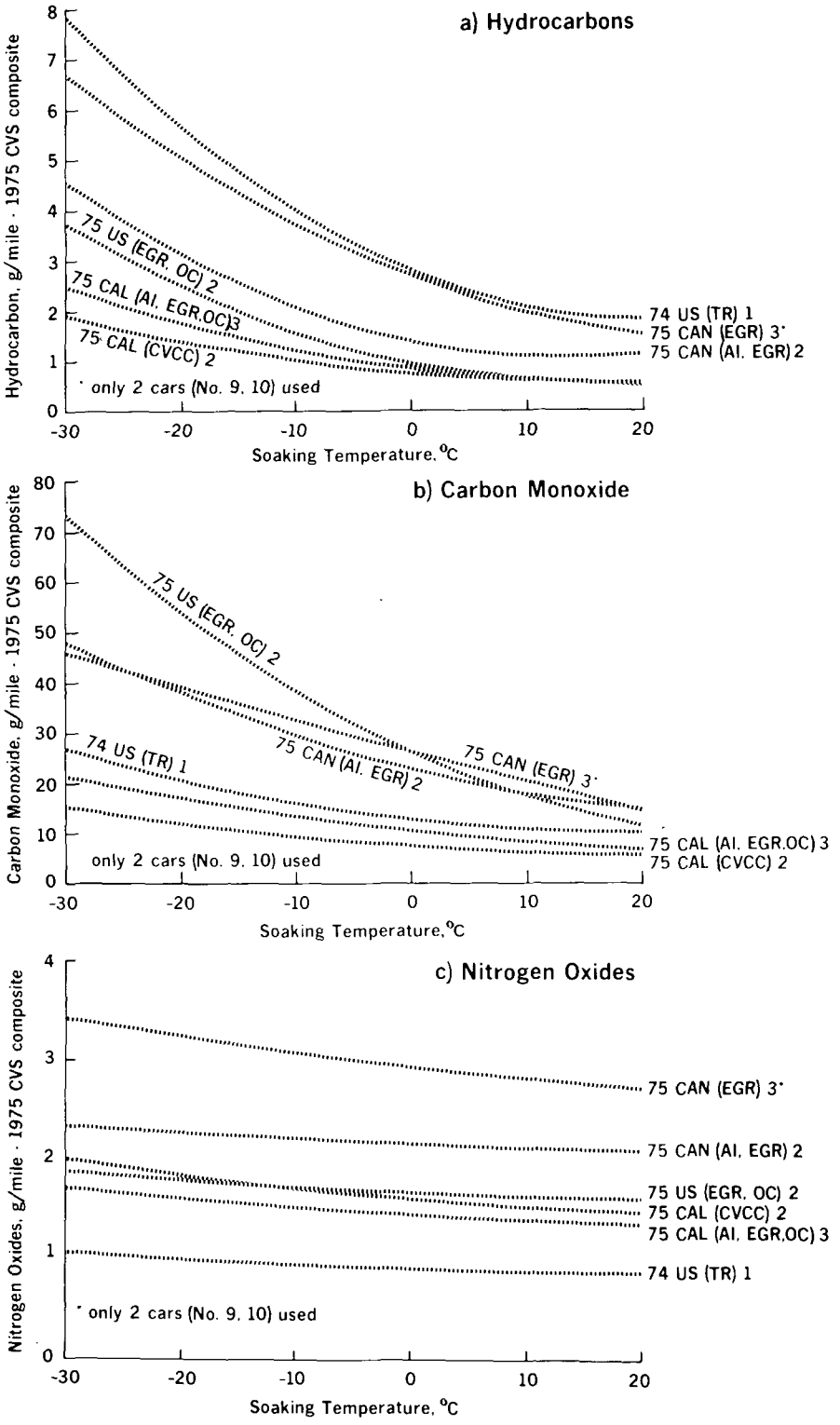

FIGURE 1 Influence of Soaking Temperature on Emissions (averaged for vehicle groups)

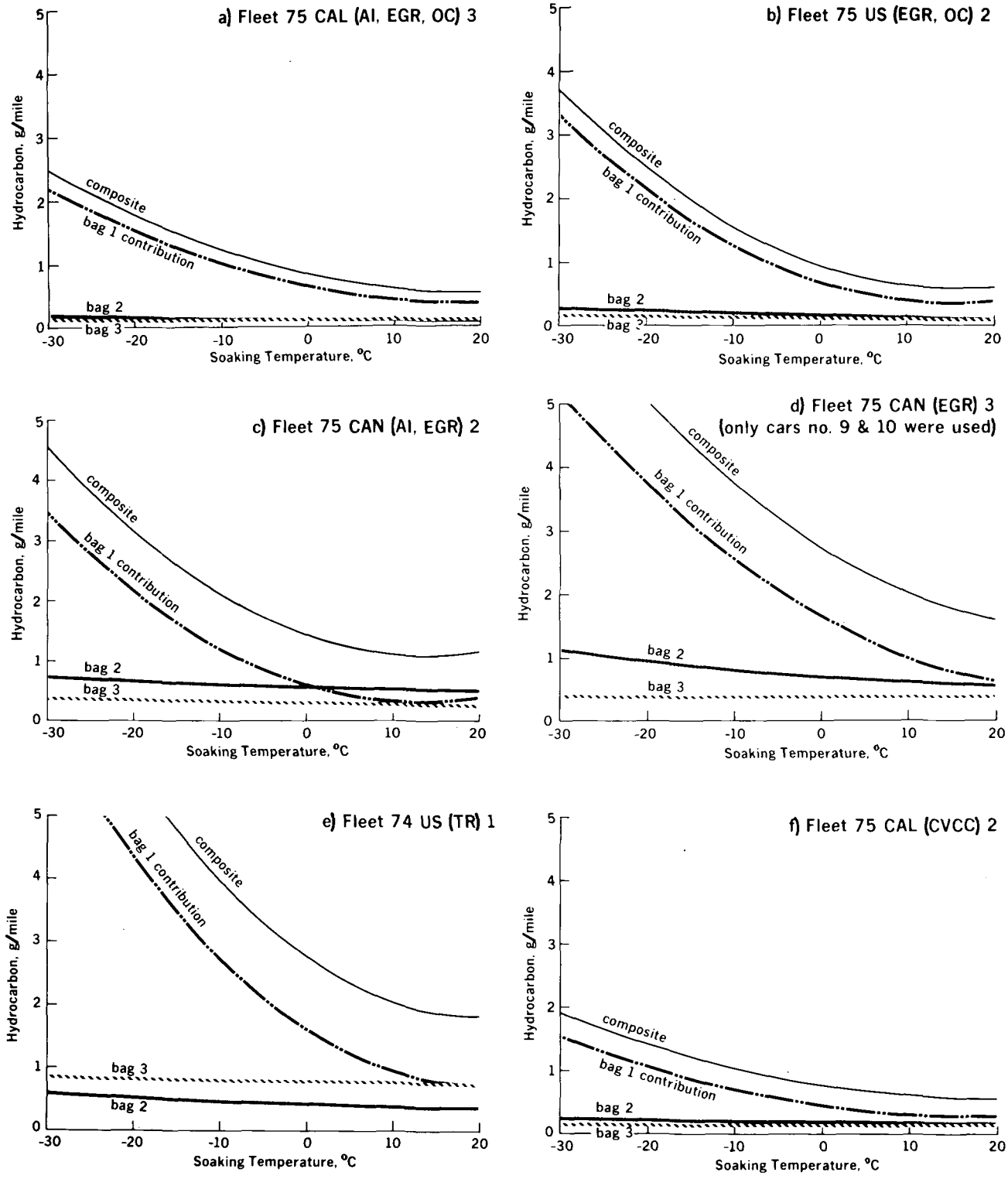

FIGURE 2 Contribution of Test Segments to the Measured Composite Hydrocarbon Emissions at Various Temperatures

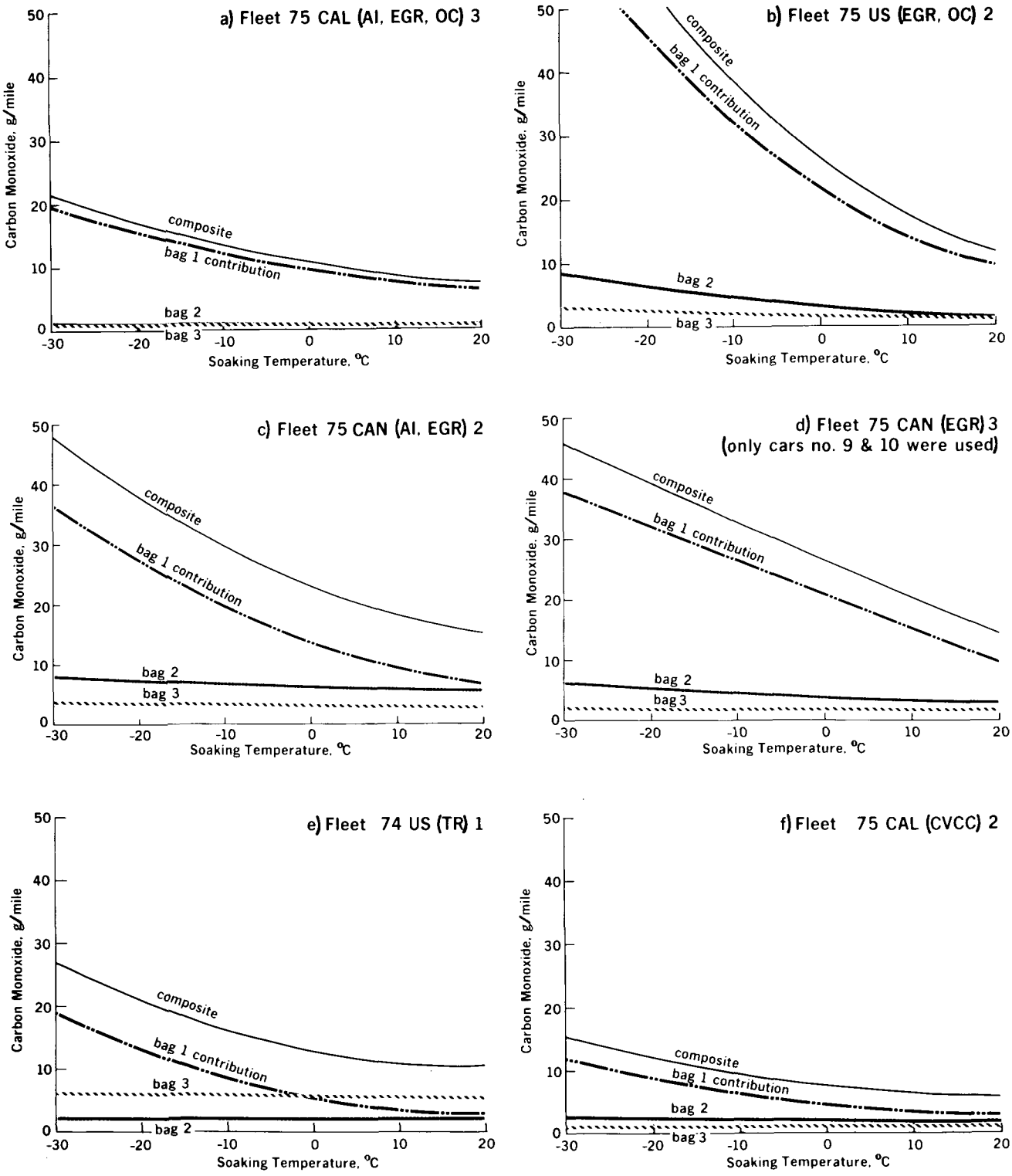

FIGURE 3 Contribution of Test Segments to the Measured Composite Carbon Monoxide Emissions at Various Temperatures

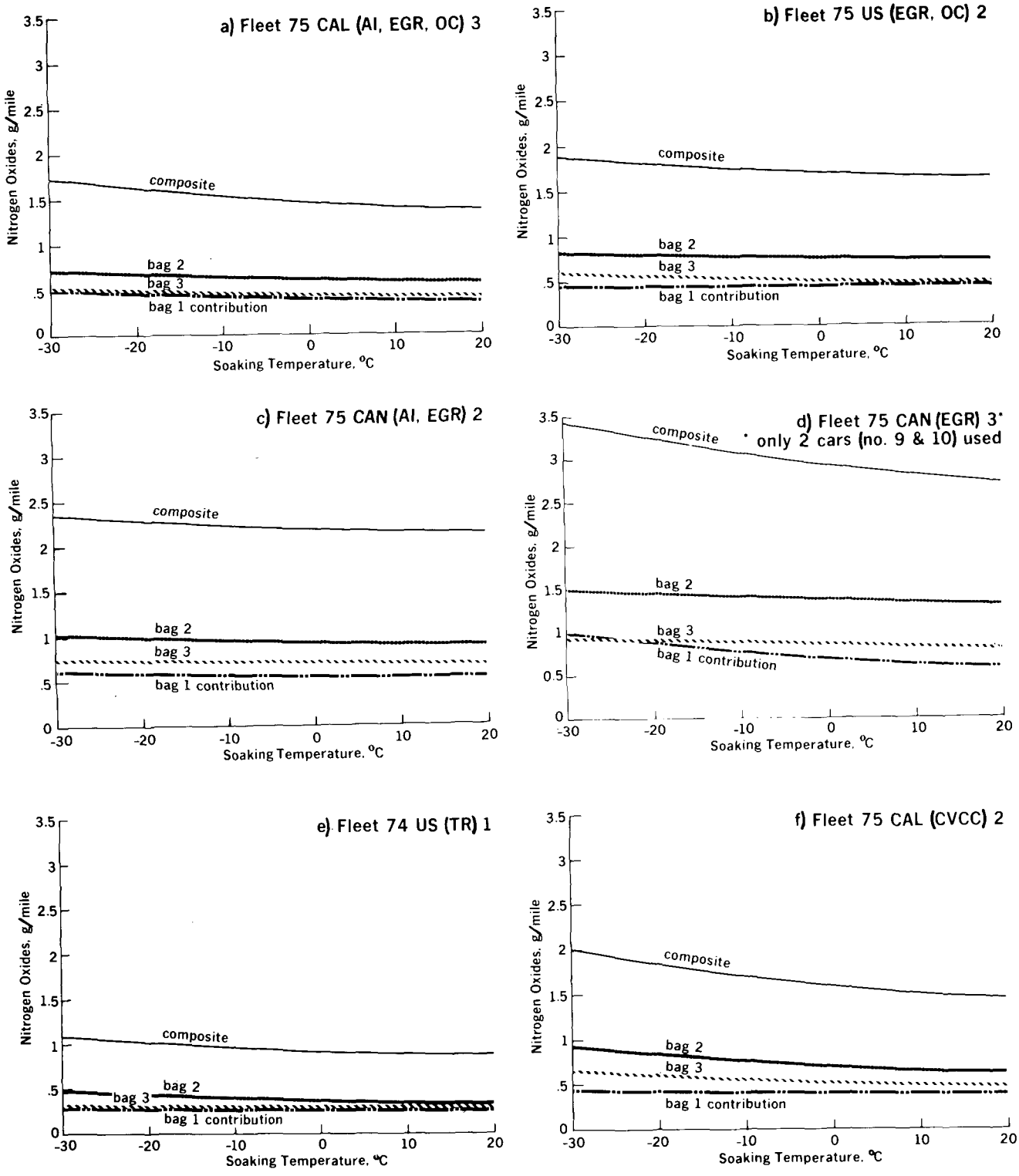

FIGURE 4 Contribution of Test Segments to Measured Composite Emissions of Nitrogen Oxides

The explanation for the marked increase of HC and CO emissions at low ambient temperature may be deduced from the data from the individual phases of the tests. From these data, summarized and illustrated for HC, Figure 2(a) to (f), it is deduced that the effect of greatest magnitude (in moving from a normal ambient temperature within the 20°C to 30°C range) is upon the cold start emissions. A similar effect is noted for carbon monoxide, Figure 3(a) to (f). The explanation is unquestionably related to carburetion of rich mixture during the choking phases of starting and warm-up and to a very low level of activity in normal post combustion oxidation.

For catalyst cars, all the degradation of control at low temperature can be attributed to the cold start contribution to the composite emissions, Figure 2(a), (b) and 3(a), (b). However, because converter bed temperatures increased faster at lower ambients (Figure 8) the initial period of catalyst degradation became shorter. Bags 2 and 3 show almost no degradation. This may explain the much smaller absolute increases in HC and CO emissions experienced with the converter equipped cars.

There are marked differences between the catalyst cars equipped with air injection, Fleet 75CAL(AI, EGR, OC)3, and catalyst cars not equipped with air injection, Fleet 75US(EGR, OC)2.

Emissions of HC and CO from the cars not equipped with air injection are generally higher at lower ambients, Figure 1 (a) and (b). This is due to lack of oxygen to oxidize the CO and HC present under rich choke conditions. Secondary air must therefore be added to provide the necessary oxygen during the cold start phase to maximize the efficiency of an oxidizing catalyst.

In general, from the present study, it seemed that as a practical matter some form of air injection is required for conventional internal combustion engines to achieve the most efficient emission control at lower temperatures.

The explanation for the slight increase in NO_x emissions with lower ambient temperatures is less clear, Figure 1(c). However, again referring to the contributions of individual test phases, Figure 4(a) to (f), the increased NO_x is attributable to the effect on the warmed-up engine. The stabilized phase (Bag 2) of the test is the greatest contributor to this change in NO_x levels.

Two factors are probably contributing to higher NO_x emissions at lower ambient temperature. The first is the EGR thermal vacuum control switch (most of the cars tested), which is only open for coolant temperatures above 40°C to 50°C. Figure 9 shows such coolant temperatures are reached after approximately 1.5 minutes of the driving cycle at an ambient temperature of 22°C, and after more than 3 minutes at an ambient temperature of -20°C. The second is the higher average horsepower requirement over the cycle due to greater friction as ambient temperature decreases. However, lower combustion temperature due to richer mixtures in the cold transient phase cause NO_x to decrease and as a result, NO_x emission is relatively insensitive to ambient temperature.

The Honda CVCC demonstrated the lowest HC and CO emissions throughout the tested ambient temperature range, see Figure 1(a) and (b). The emission levels for these two cars and the effects of soaking temperatures are quite comparable to the emissions averaged for the three California specification catalyst equipped vehicles, Fleet 75CAL(AI, EGR, OC)3. When emissions from Honda CVCC cars, Fleet 75CAL(CVCC)2, are compared with those equipped with EGR only, Fleet 75CAN(EGR)3, reductions shown in Table 2 occurred.

The reduction of about 64% to 59% are seen for HC and CO respectively, at the standard temperature for Honda CVCC, and the CVCC emissions of these pollutants show a lesser sensitivity to the lower temperatures. The relative degree of reduction for NO_x emissions is maintained fairly well across the temperature range.

4.2 Effect of Ambient Temperature and Vehicle Weight on Fuel Economy

There is no simple or inherent relationship between fuel economy, emission control technology and the effect of ambient temperature; therefore the economy data are believed valid only for an indication of general trends to be expected and are not to be construed as indicative of the fuel economy characteristics of any group of vehicles in the test.

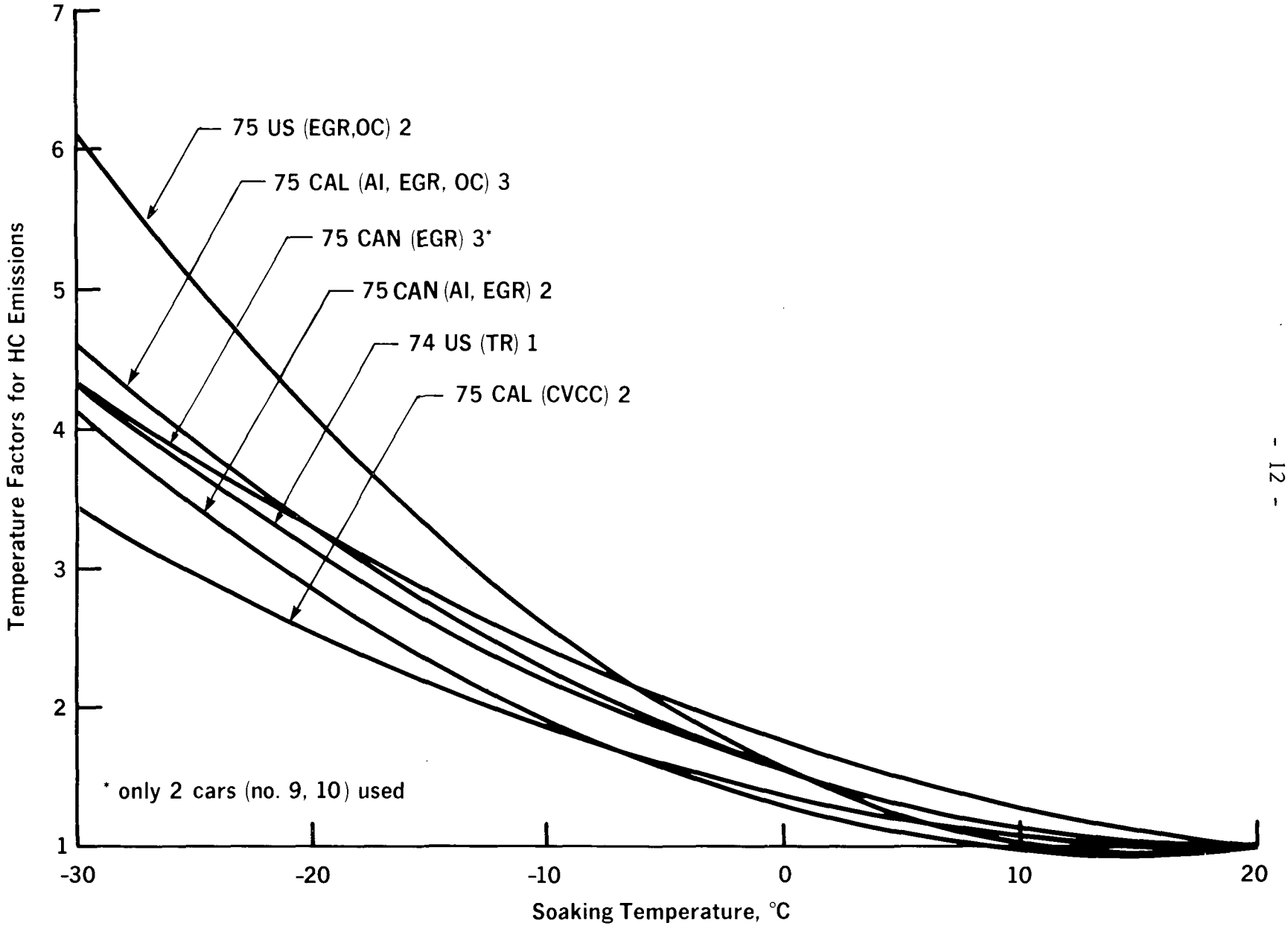

FIGURE 5 Soaking Temperature Factors (normalized against emissions at 20°C) for HC Emissions on the CVS Cycle

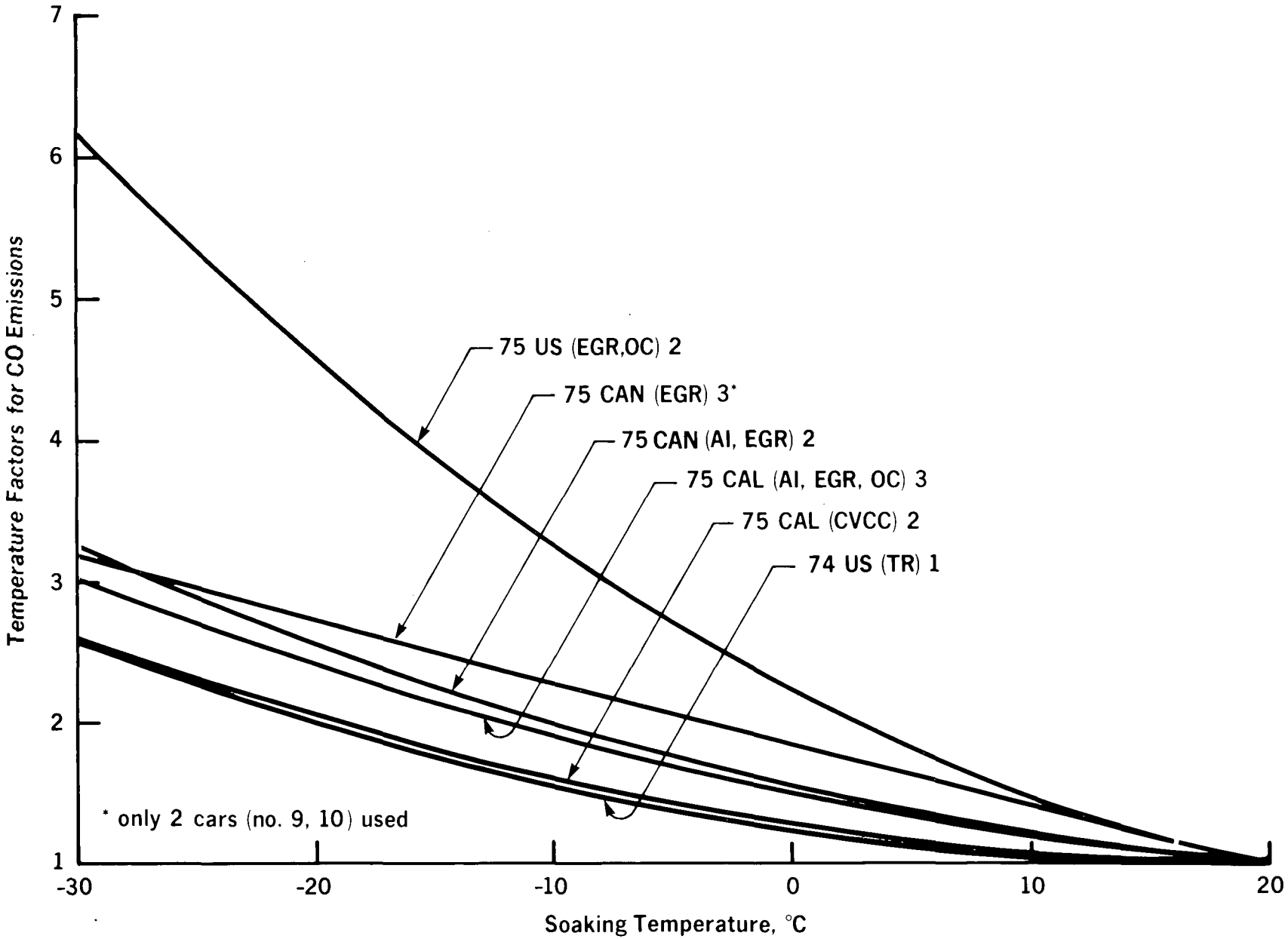

FIGURE 6 Soaking Temperature Factors (normalized against emissions at 20°C) for CO Emissions on the CVS Cycle

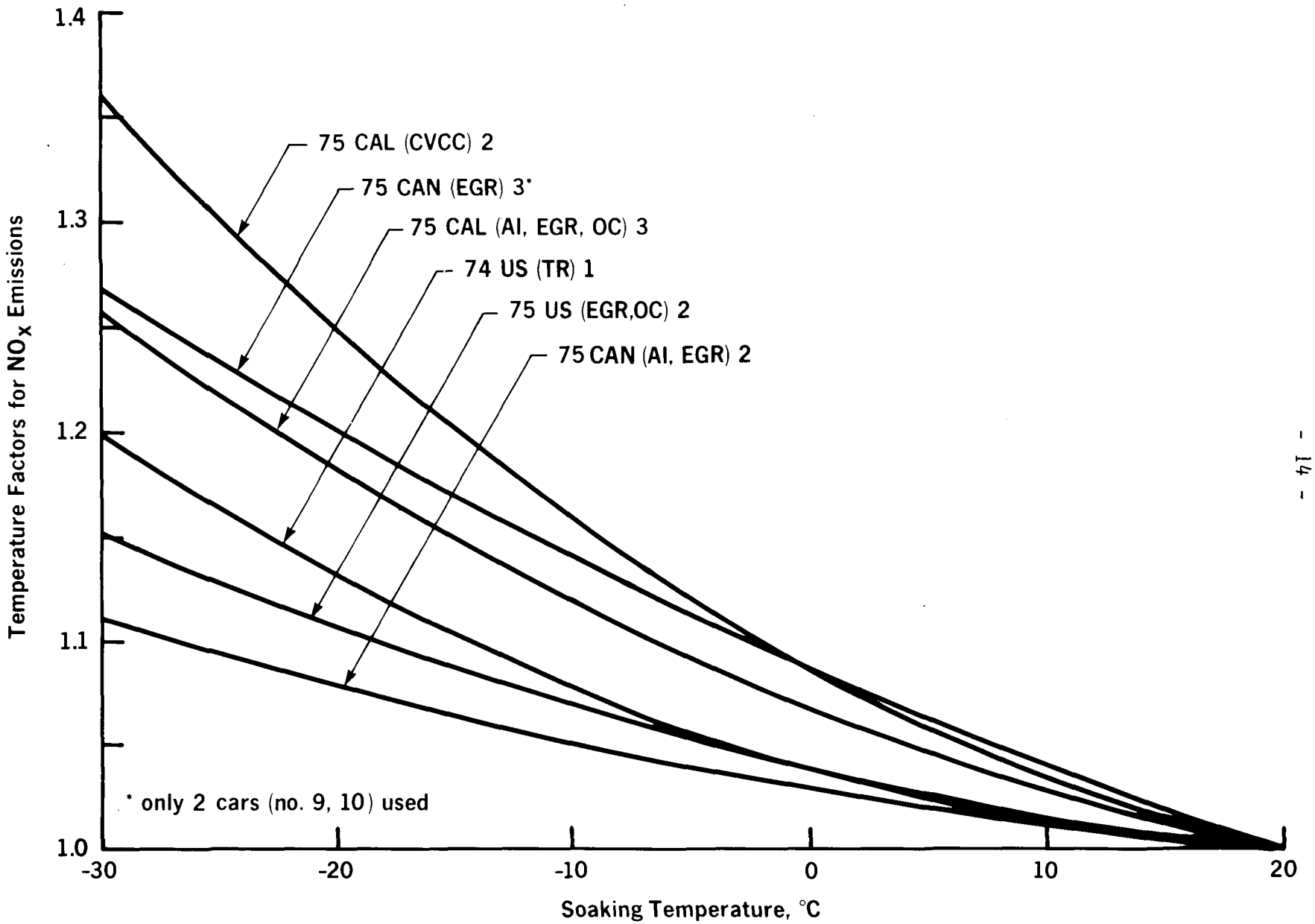

FIGURE 7 Soaking Temperature Factors (normalized against emissions at 20°C) for NO_x Emissions on the CVS Cycle

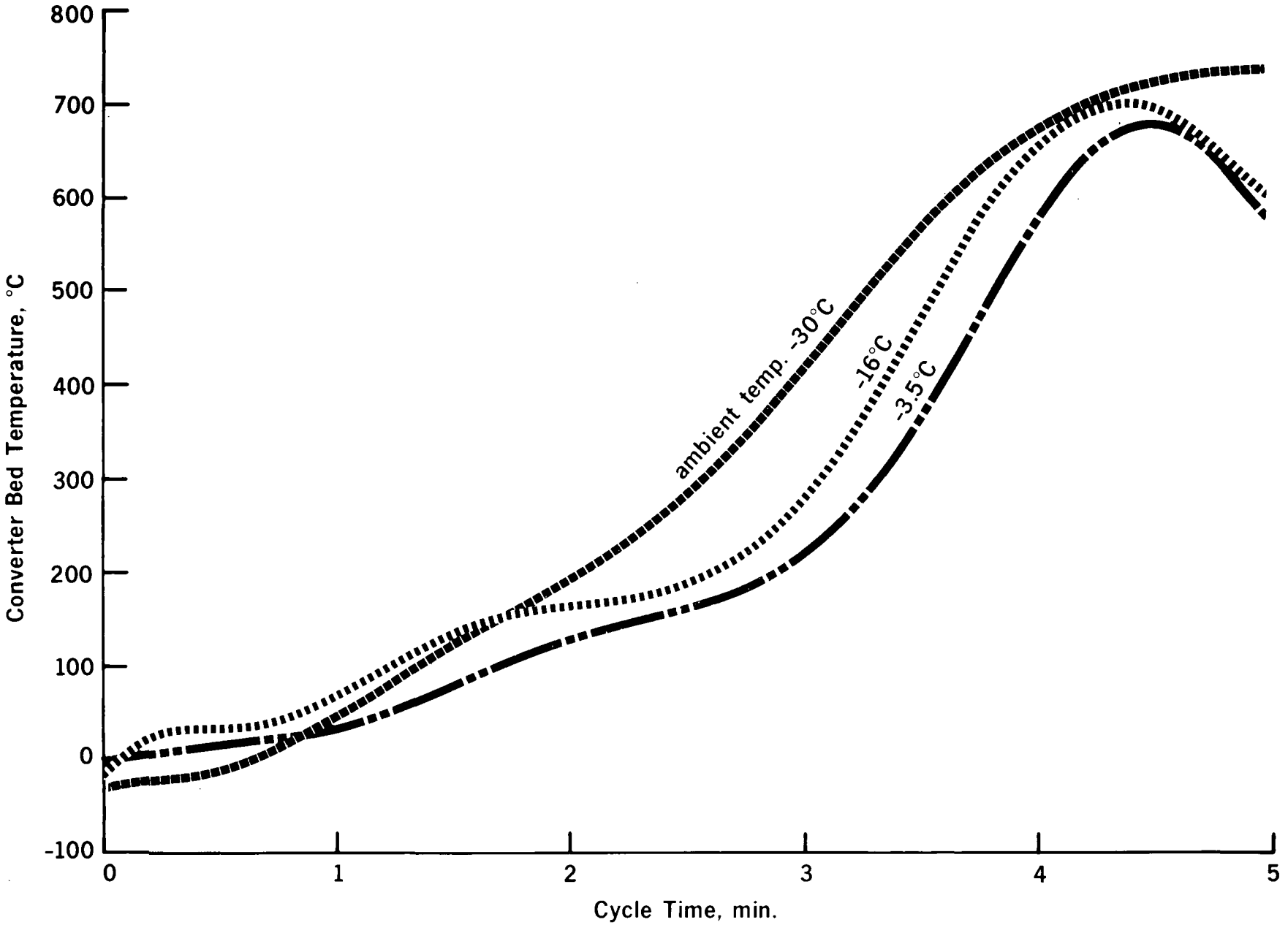

FIGURE 8 Catalytic Converter Bed Temperature Versus Time on the CVS Cycle - Car No. 3

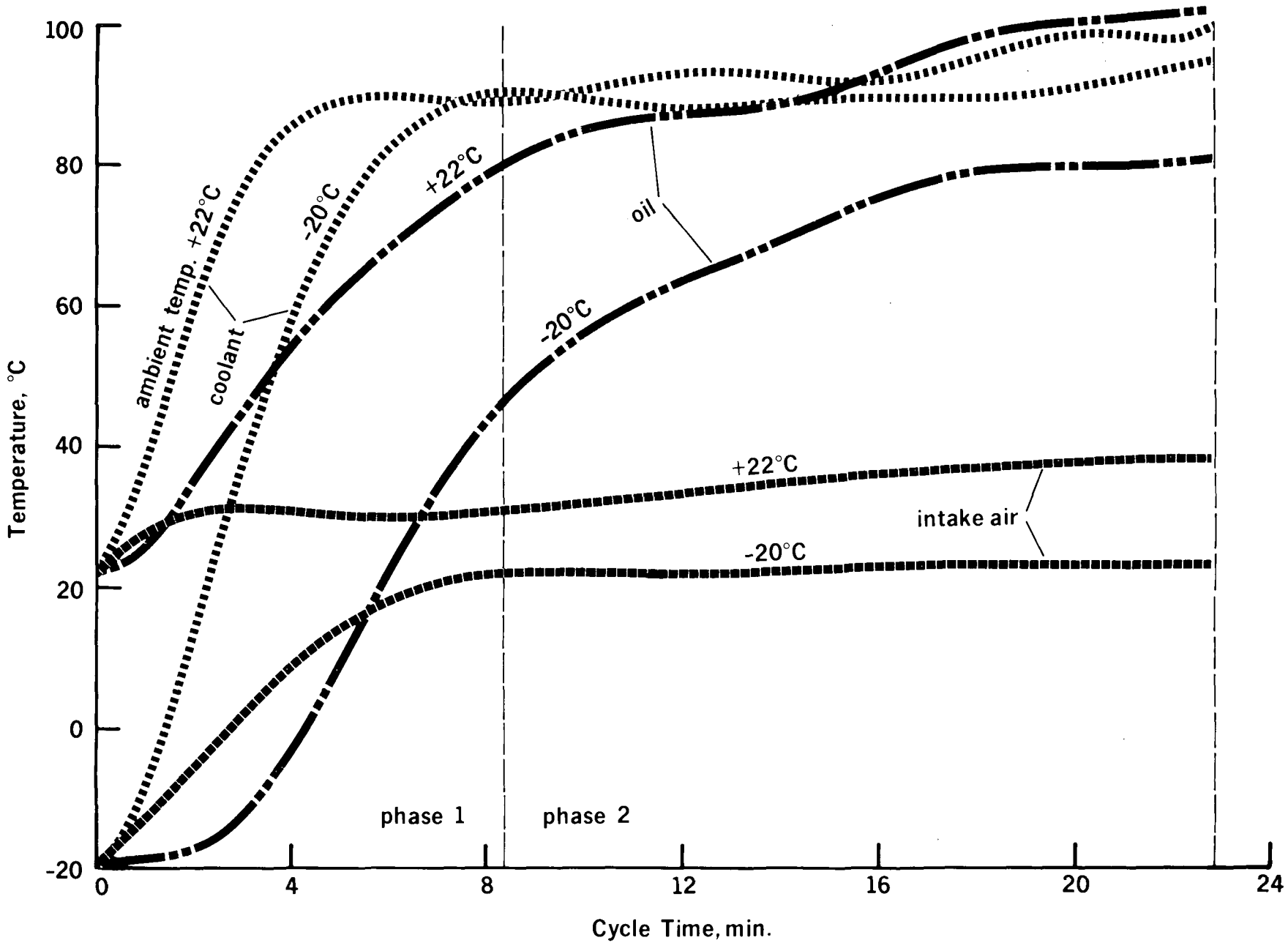

FIGURE 9 Effect of Ambient Temperature on Engine Warm-up on the CVS Cycle - Car No. 4

TABLE 2 EMISSION REDUCTION - HONDA CVCC VERSUS CARS EQUIPPED WITH EGR ONLY, %

Pollutant	Soaking Temperature, °C		
	-30	0	20
Hydrocarbon	72	72	64
Carbon Monoxide	67	72	59
Oxides of Nitrogen	42	45	46

Because vehicle weight is one of the most important factors influencing fuel economy, it has been decided to illustrate the fuel economy as a function of vehicle test weight class and ambient temperature. Vehicles in the same weight class differ: the heavier cars are generally larger, but not all of them use larger engines or the same power-consuming accessories.

Figure 10 shows the average effect of soaking temperatures and vehicle test weight class on fuel economy. The resulting correlation co-efficient of this calculation is very good at about 0.8. The following conclusions can be drawn from Figure 10:

(1) Fuel economy decreases with a decrease in ambient temperature. Reasons for this are: a) the average carburetion gets richer (more choke) as the engine becomes cooler; b) lubricants cool down and friction increases in the engine and transmission; c) more combustion heat is lost to the combustion chamber walls and coolant after they cool down; and d) rolling friction increases as tires cool down and inflation pressures decrease.

(2) The relative decrease in fuel economy gets larger with the lower ambient temperature. This is probably due to the longer period of time needed to warm up the engine.

(3) A higher vehicle weight will naturally give a lower fuel economy, but there is a <u>decreasing</u> effect of ambient temperature as weight increases. The reasons for this are probably relatively lower combustion chamber surface-to-volume ratio and therefore lower heat losses to the walls and coolant, and relatively lower friction losses in the larger engines and drivelines.

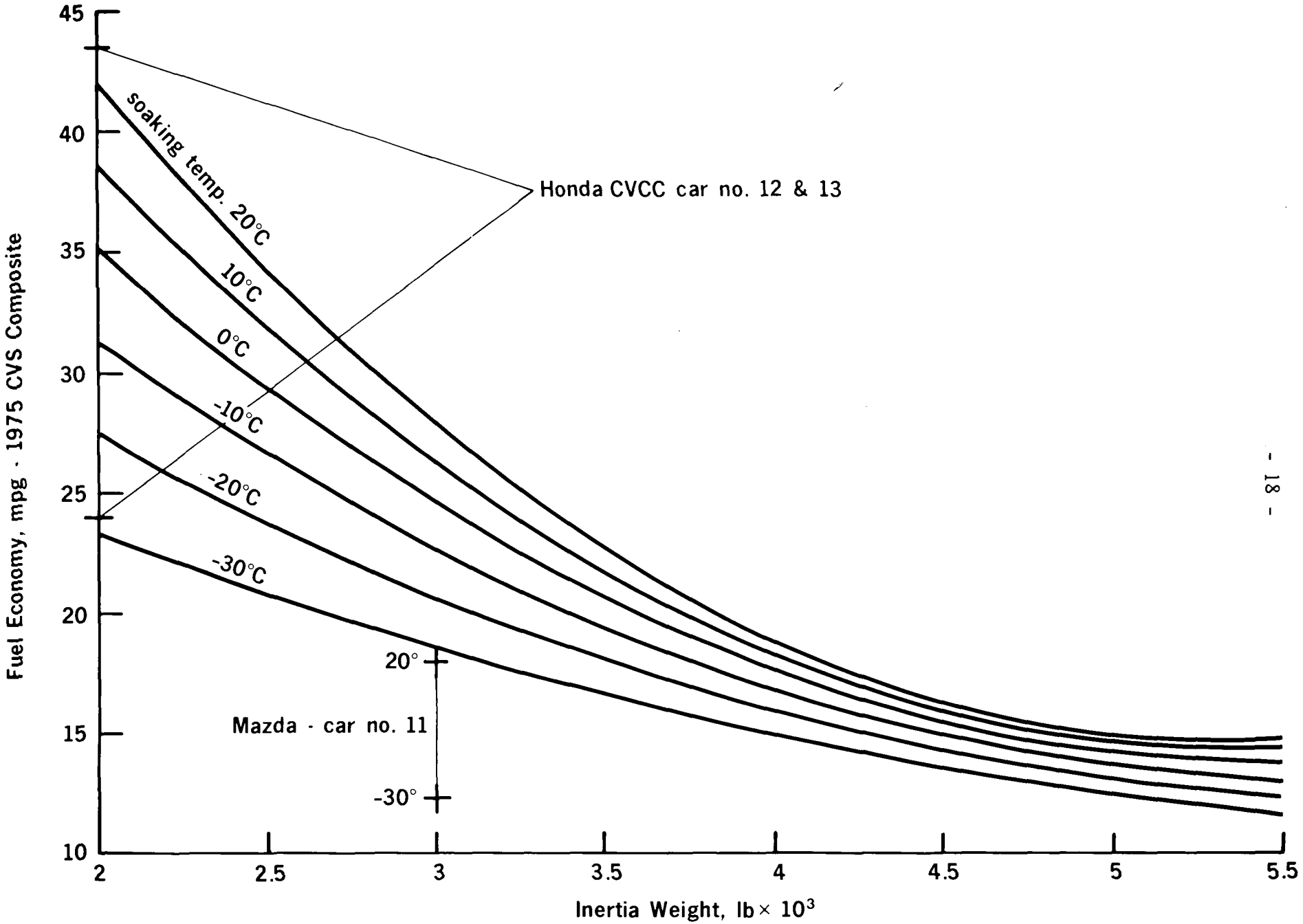

FIGURE 10 Averaged Effect of Soaking Temperature and Vehicle Test Weight Class on Fuel Economy. (All Tested Cars Except Car No. 11)

(4) The decrease in fuel economy between 20°C and -30°C is 15% to 40% depending on vehicle weight and other vehicle characteristics.

The fuel economy of car No. 11 (rotary engine) is also plotted in Figure 10 and indicates that the rotary's fuel economy is the worst despite the low weight of the car. However, the character of the low temperature effect on fuel economy for this car is the same as for conventional engines.

The fuel economy of the Honda Civic (Cars No. 12 and 13) equipped with CVCC is about the same as conventionally powered vehicles of comparable weight.

4.3 Effect of Vehicle Weight on Temperature Sensitivity of HC and CO Emissions

As discussed previously, exhaust emission is determined by many factors. This section will illustrate exhaust emissions of HC and CO as a function of ambient temperature and vehicle weight. This relationship has been examined only for California specification vehicles (Vehicles No. 1, 2, 3, 12, 13) because of the insufficient number of vehicles included in the other two specifications. The resulting correlation coefficient for this relationship is about 0.77. Since a correlation coefficient should be about 0.8 or greater for statistical correlation, this relationship is fairly well demonstrated.

Figures 11 and 12 show the effect of soaking (ambient) temperature and vehicle weight on HC and CO emissions for California specification cars. As indicated, a change to a lower weight of vehicle can give lower HC and CO emissions and a decreasing effect of ambient temperature.

The relative change in nitrogen oxides with variation in ambient temperature and vehicle weight is not shown graphically because of the very small effect.

4.4 Effect of Ambient Temperature on Engine Warm-Up

Figure 9 shows an example of engine warm-up temperatures (coolant, lubricating oil, and intake air) at two ambient temperatures (22°C and -20°C) for car No. 4. The temperatures are plotted for only the first two phases of the driving cycle. Coolant temperature controlled by thermostat reaches its maximum in about 4 minutes of driving at a temperature of 22°C, compared to over 8 minutes at an ambient temperature of -20°C. The engine coolant temperature affects combustion chamber surface temperature and therefore the unburned hydrocarbon emissions by changing

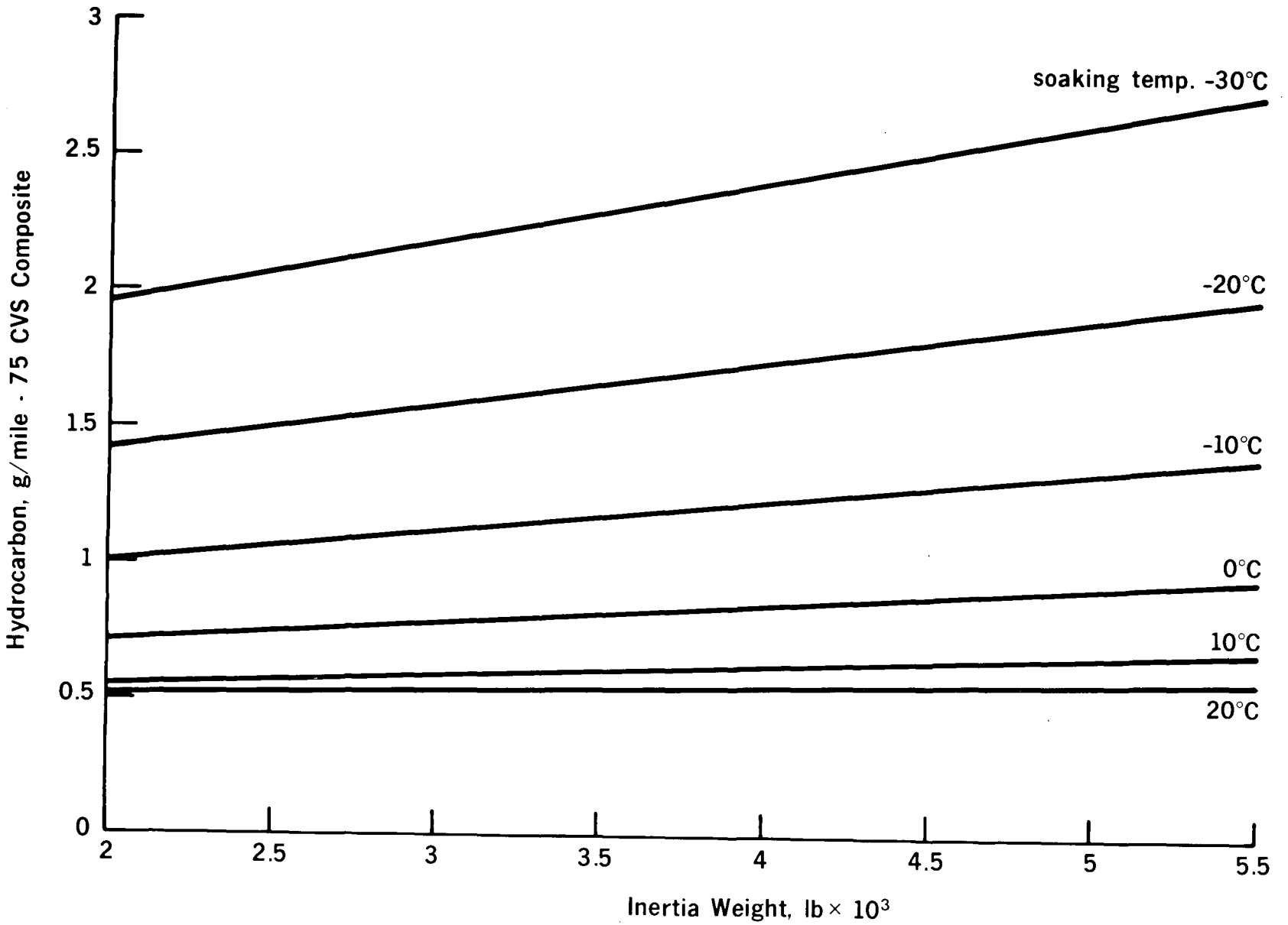

FIGURE 11 Averaged Effect of Soaking Temperature and Vehicle Weight on HC Emissions for California Specification Cars.

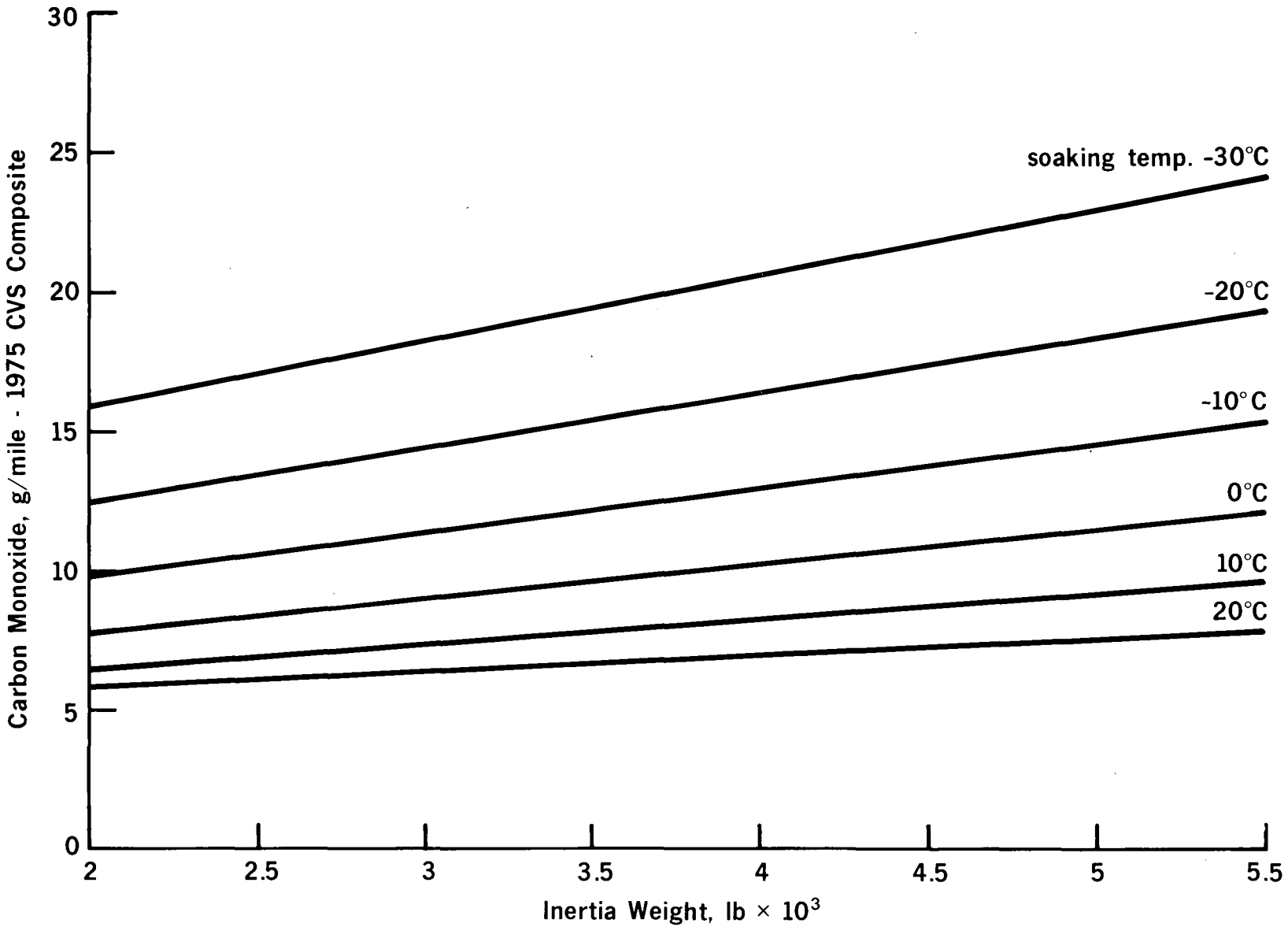

FIGURE 12 Averaged Effect of Soaking Temperature and Vehicle Weight on CO Emissions for California Specification Cars

the thickness of the combustion chamber quench layer and the degree of after-reaction. In addition, low engine temperature affects fuel evaporation and distribution, combustion temperature, and exhaust system temperature causing poorer combustion and higher CO and HC emissions.

Lubricating oil temperature rises more slowly at low ambient temperature and does not reach its maximum even at the end of the second phase of the driving cycle. Lower oil temperature at low ambient temperatures also contributes to higher emissions of HC and CO and to lower fuel economy because of increased friction in the engine and transmission.

Figure 9 shows that intake air temperature is also substantially affected by ambient temperature. The lower intake air temperature affects primarily fuel evaporation and distribution. An earlier conclusion that emissions during the first part of the driving cycle after cold start account for almost all the increase in HC and CO emissions observed at reduced temperatures is confirmed (see Figure 9).

A survey of commuting distance in Canadian urban centres shows that the percentage of the population travelling short distances of 1 to 10 miles is above 70% (7). Thus, the information in this report indicates that a significant amount of travel in Canada is made under very high HC and CO emissions and poor fuel economy.

4.5 Regression Equations for Emissions and Fuel Economy

To provide a tool for researchers engaged in emission modelling or fuel consumption investigations, it was felt advisable to report the regression equations developed during the analysis of the data. Although previously we had to use first power relations (1), this time, with many more data points, the fit was better for second power than for first for all cars (e.g. average R squared for CO is 0.73 for first but 0.78 for second power). Moreover, many of the factors known to affect fuel economy and emissions have power relationships with temperature (e.g. engine warm-up time, lubricant viscosity). Thus, the regression equations for both emissions and fuel economy may be represented as follows:

$$V_{t_1} = V_{t_0} + a_1 + a_2 t_1 + a_3 t_1^2$$

where V = parameter under consideration in grams/mile or miles/gallon,

t_0 = standard testing temperature of 20°C to 30°C,

t_1 = ambient temperature from 20°C to -30°C,

a_1, a_2, a_3 = regression coefficients

Tables B-1 and B-2 in Appendix B show the regression coefficients for vehicles tested in this study. Although these are proved only for the cars tested over the range of variables measured, some extrapolation to similar vehicles and control equipment should be possible for estimations of vehicle emissions and fuel economy in cold weather.

4.6 Conclusions and Recommendations

4.6.1 Conclusions

1. For late model cars, a reduction of the test temperature results in a considerable increase in HC and CO emissions, while the emissions of NO_x are not significantly affected. The increases of emissions at -30°C test temperature compared to those at 20°C are 3.5 to 9.2 times for HC, 2.4 to 6.4 times for CO and 1.1 to 1.4 times for NO_x.
2. The emissions during the first phase of the 75 CVS cycle after a cold start (Bag 1) account for almost all the increase in HC and CO emissions observed at reduced temperatures. The ambient temperature has no significant effect on the emissions from a fully warmed-up engine (Bags 2 and 3).
3. The severity of the change in HC and CO emissions with temperature depends to a large extent on the emission control technology and on the engine characteristics of the car. The absolute increases in HC and CO emissions at lower temperatures are the highest for EGR and catalyst equipped cars without air injection. The lowest absolute increase of HC has been observed in cars equipped with CVCC, and the lowest absolute increase of CO in cars equipped with thermal reactor and CVCC.
4. The effect of ambient temperature on fuel economy also shows that a lowering of ambient temperature results in a loss in fuel economy. A 15% to 43% economy loss has been observed with a change from 20°C to -30°C soaking temperature; however, there seems to be a relatively greater loss with decreasing inertia weight.
5. Vehicle warm-up time (coolant, lubricant, intake air) increases with lower ambient temperature resulting in higher emission rates and lower fuel economy.

6. These significant emission and fuel economy variations can be correlated mathematically in terms of vehicle soaking and operating temperatures and the resulting equations used to correct vehicle emissions and fuel economy to variable overnight temperatures.

4.6.2 Recommendations for Further Study

1. The fact that emissions of fully warmed-up cars are nearly independent of ambient temperature suggests that cars for which the ratio of cold start emissions to hot start emissions is high may also show high emissions with lower ambient temperatures. Further work will be required to establish the correlation between the cold and hot start emissions ratio and the dependency of emissions on temperature.
2. It has been demonstrated (1) that preheating of the engine by an electric block heater eliminates most of the increase in emissions observed at reduced temperatures, but the minimum amount of preheat necessary to result in a significant HC and CO reduction is unknown. Methods to reduce cold start emissions by engine preheating must be examined more closely if reduction of cold start emissions is to become an effective control alternative. Time distribution of coolant temperature, lubricant temperature and intake air temperature against time distribution of emissions rate during the 1975 CVS test will be needed for this kind of analysis.
3. Closer evaluation of catalytic converter performance with and without air injection in cold weather conditions is needed. Time distribution of catalyst bed temperatures and of emission rates during the 1975 CVS test will be needed for this evaluation.
4. Further cold weather testing is required for vehicles equipped with new emission control technology including lean burn and diesel engine powered vehicles.

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APPENDIX A - Individual Vehicle Data (Tables A-1 to A-16)

TABLE A-1 Vehicle Test Fleet

Fleet Code	Car No.	Make & Model	Cyl. No.	Disp. in.^{3}	Vent-uris	Trans.	Inertia Weight lb	No. of Tests
75CAL(AI, EGR, OC)3	1	Chev. Monza	4	140	2	A3	3500	53
	2	Chev. Impala	8	350	4	A3	5000	43
	3	Dodge Dart	8	318	2	A3	4000	59
75US(EGR, OC)2	4	Chev. Biscayne	8	350	2	A3	5000	57
	5	Chev. Nova	6	250	1	A3	4000	60
75CAN(AI, EGR)2	6	Ford Custom	8	351	2	A3	5000	51
	7	Ford Maverick	6	250	1	A3	3500	44
75CAN(EGR)3	8	AMC Hornet	6	258	1	A3	3000	40
	9	Dodge Dart	6	225	1	A3	4000	53
	10	Dodge Monaco S/W	8	440	4	A3	5500	40
74US(TR)1	11	Mazda RX4	2R	80	4	M4	3000	51
75CAL(CVCC)2	12	Honda Civic	4	90.8	3	M4	2000	48
	13	Honda Civic	4	90.8	3	M4	2000	52

Fleet Codes

75, 74 - model year
CAL - California specific
US - 49 state specific
CAN - Canada specific
AI - manifold air injection
EGR - exhaust gas recirculation
OC - oxidizing catalytic converter
TR - thermal reactor
CVCC - compound vortex controlled combustion
1, 2, 3 - no. of cars used in the fleet

TABLE A-2 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 1

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	11.09	7.39	4.60	2.72	1.74	1.67
Carbon monoxide, g/mile	86.89	69.53	55.10	43.61	35.04	29.41
Oxides of nitrogen, g/mile	2.66	2.57	2.50	2.44	2.40	2.38
Carbon dioxide, g/mile	680.5	626.3	581.2	545.3	518.5	500.9
Fuel economy, mpg	12.42	14.14	15.68	17.06	18.26	19.27
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	0.29	0.24	0.19	0.16	0.13	0.12
Carbon monoxide, g/mile	1.61	1.34	1.12	0.94	0.80	0.71
Oxides of nitrogen, g/mile	1.69	1.59	1.50	1.42	1.37	1.33
Carbon dioxide, g/mile	570.5	517.2	472.9	437.6	411.3	394.0
Fuel economy, mpg	18.48	20.59	22.49	24.18	25.66	26.94
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	0.40	0.37	0.34	0.32	0.31	0.30
Carbon monoxide, g/mile	1.86	1.53	1.25	1.03	0.87	0.76
Oxides of nitrogen, g/mile	2.71	2.47	2.26	2.10	1.98	1.90
Carbon dioxide, g/mile	503.9	478.5	457.4	440.5	428.0	419.7
Fuel economy, mpg	20.94	22.14	23.17	24.03	24.73	25.26
1975 CVS Composite						
Hydrocarbon, g/mile	2.55	1.75	1.15	0.73	0.51	0.48
Carbon monoxide, g/mile	19.29	15.47	12.30	9.77	7.89	6.65
Oxides of nitrogen, g/mile	2.17	2.03	1.91	1.82	1.75	1.70
Carbon dioxide, g/mile	575.0	529.1	491.0	460.6	438.0	423.1
Fuel economy, mpg	17.38	19.15	20.79	22.23	23.47	24.50

TABLE A-3 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 2

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	10.41	7.75	5.60	3.97	2.85	2.24
Carbon monoxide, g/mile	91.27	74.20	60.01	48.70	40.26	34.70
Oxides of nitrogen, g/mile	1.85	1.81	1.78	1.75	1.73	1.72
Carbon dioxide, g/mile	851.59	815.88	786.19	762.52	744.87	733.23
Fuel economy, mpg	10.34	11.16	11.88	12.49	13.00	13.41
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	0.44	0.35	0.28	0.24	0.21	0.21
Carbon monoxide, g/mile	0.78	0.60	0.46	0.34	0.26	0.20
Oxides of nitrogen, g/mile	1.45	1.34	1.26	1.19	1.13	1.10
Carbon dioxide, g/mile	855.86	812.02	775.58	746.53	724.86	710.58
Fuel economy, mpg	12.42	13.09	13.72	14.25	14.68	14.98
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	0.41	0.41	0.41	0.41	0.41	0.41*
Carbon monoxide, g/mile	3.74	2.99	2.37	1.87	1.50	1.25
Oxides of nitrogen, g/mile	1.95	1.87	1.81	1.75	1.71	1.69
Carbon dioxide, g/mile	713.0	711.7	710.6	709.7	709.1	708.7
Fuel economy, mpg	14.80	14.85	14.90	14.93	14.96	14.97
1975 CVS Composite						
Hydrocarbon, g/mile	2.48	1.89	1.42	1.05	0.80	0.66
Carbon monoxide, g/mile	20.25	16.43	13.26	10.73	8.85	7.62
Oxides of nitrogen, g/mile	1.67	1.59	1.52	1.46	1.42	1.39
Carbon dioxide, g/mile	815.7	785.2	759.9	739.7	724.6	714.7
Fuel economy, mpg	12.45	13.06	13.58	14.02	14.37	14.63

*Negative trend was observed.

TABLE A-4 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 3

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	10.42	7.01	4.42	2.66	1.71	1.60
Carbon monoxide, g/mile	106.78	82.18	61.72	45.43	33.29	25.30
Oxides of nitrogen, g/mile	2.57	2.15	1.81	1.53	1.32	1.18
Carbon dioxide, g/mile	809.1	799.1	790.8	784.2	779.3	776.1
Fuel economy, mpg	10.54	11.23	11.83	12.32	12.71	12.99
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	0.34	0.27	0.21	0.16	0.13	0.11
Carbon monoxide, g/mile	3.95	3.45	3.03	2.70	2.46	2.29
Oxides of nitrogen, g/mile	0.97	0.97	0.97	0.97	0.97	0.97
Carbon dioxide, g/mile	866.3	822.9	786.9	758.3	736.9	722.8
Fuel economy, mpg	12.18	12.87	13.46	13.96	14.36	14.67
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	0.46	0.42	0.39	0.37	0.35	0.34
Carbon monoxide, g/mile	3.16	2.93	2.73	2.57	2.44	2.35
Oxides of nitrogen, g/mile	1.06	1.03	1.01	0.99	0.98	0.97
Carbon dioxide, g/mile	764.0	744.8	728.8	716.0	706.5	700.3
Fuel economy, mpg	13.83	14.20	14.52	14.77	14.97	15.11
1975 CVS Composite						
Hydrocarbon, g/mile	2.45	1.70	1.13	0.73	0.51	0.47
Carbon monoxide, g/mile	24.94	19.55	15.06	11.48	8.82	7.06
Oxides of nitrogen, g/mile	1.32	1.23	1.15	1.09	1.05	1.02
Carbon dioxide, g/mile	826.5	796.6	771.8	752.1	737.3	727.7
Fuel economy, mpg	12.19	12.82	13.35	13.79	14.14	14.40

TABLE A-5 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 4

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	23.75	14.49	7.67	3.28	1.34	1.83
Carbon monoxide, g/mile	380.07	281.78	200.10	135.01	86.53	54.64
Oxides of nitrogen, g/mile	1.96	1.96	1.96	1.96	1.96	1.96*
Carbon dioxide, g/mile	656.2	656.2	656.2	656.2	656.2	656.2
Fuel economy, mpg	7.93	9.41	10.79	12.05	13.20	14.24
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	0.36	0.31	0.27	0.23	0.21	0.20
Carbon monoxide, g/mile	7.82	6.46	5.34	4.44	3.77	3.33
Oxides of nitrogen, g/mile	1.45	1.37	1.30	1.24	1.20	1.18
Carbon dioxide, g/mile	777.8	746.9	721.2	700.7	685.5	675.4
Fuel economy, mpg	13.46	14.07	14.60	15.04	15.39	15.65
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	0.46	0.43	0.40	0.38	0.36	0.35
Carbon monoxide, g/mile	8.97	7.48	6.24	5.26	4.52	4.04
Oxides of nitrogen, g/mile	1.85	1.80	1.75	1.71	1.69	1.67
Carbon dioxide, g/mile	668.6	651.4	637.1	625.7	617.2	611.7
Fuel economy, mpg	15.58	16.05	16.45	16.78	17.03	17.22
1975 CVS Composite						
Hydrocarbon, g/mile	5.22	3.27	1.83	0.90	0.48	0.57
Carbon monoxide, g/mile	84.96	63.57	45.78	31.62	21.06	14.11
Oxides of nitrogen, g/mile	1.66	1.61	1.56	1.52	1.49	1.48
Carbon dioxide, g/mile	722.8	702.0	684.8	671.0	660.7	654.0
Fuel economy, mpg	12.18	13.16	14.00	14.71	15.28	15.73

*Negative trend was observed.

TABLE A-6 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 5

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	8.26	6.29	4.69	3.46	2.60	2.11
Carbon monoxide, g/mile	217.34	159.79	112.95	76.85	51.47	36.81
Oxides of nitrogen, g/mile	2.45	2.36	2.28	2.22	2.18	2.17
Carbon dioxide, g/mile	539.0	524.7	512.8	503.3	496.2	491.6
Fuel economy, mpg	11.65	13.51	15.19	16.70	18.02	19.17
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	0.68	0.54	0.42	0.33	0.26	0.22
Carbon monoxide, g/mile	24.39	17.74	12.22	7.82	4.54	2.39
Oxides of nitrogen, g/mile	1.71	1.68	1.65	1.63	1.61	1.60
Carbon dioxide, g/mile	251.7	523.2	499.5	480.7	466.6	457.3
Fuel economy, mpg	17.96	19.33	20.52	21.55	22.40	23.08
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	0.62	0.55	0.49	0.44	0.40	0.38
Carbon monoxide, g/mile	13.23	9.99	7.30	5.15	3.55	2.50
Oxides of nitrogen, g/mile	2.56	2.33	2.15	2.00	1.89	1.82
Carbon dioxide, g/mile	497.4	477.7	461.4	448.4	438.7	432.3
Fuel economy, mpg	20.47	21.55	22.48	23.26	23.89	24.37
1975 CVS Composite						
Hydrocarbon, g/mile	2.23	1.73	1.32	1.00	0.78	0.65
Carbon monoxide, g/mile	61.15	44.93	31.66	21.34	13.96	9.52
Oxides of nitrogen, g/mile	2.09	2.00	1.92	1.85	1.81	1.78
Carbon dioxide, g/mile	534.3	511.1	491.8	476.5	465.1	457.6
Fuel economy, mpg	16.66	18.21	19.57	20.72	21.69	22.46

TABLE A-7 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 6

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	18.41	11.33	6.17	2.91	1.57	2.14
Carbon monoxide, g/mile	194.90	146.06	105.47	73.13	49.03	33.19
Oxides of nitrogen, g/mile	2.08	2.08	2.08	2.08	2.08	2.08*
Carbon dioxide, g/mile	745.7	745.7	745.7	745.7	745.7	745.7
Fuel economy, mpg	9.56	10.59	11.47	12.21	12.81	13.26
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	1.66	1.54	1.44	1.36	1.30	1.27
Carbon monoxide, g/mile	10.52	10.50	10.48	10.47	10.46	10.46
Oxides of nitrogen, g/mile	1.63	1.53	1.44	1.37	1.32	1.29
Carbon dioxide, g/mile	828.0	794.1	766.0	743.5	726.8	715.8
Fuel economy, mpg	12.53	13.08	13.55	13.94	14.25	14.47
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	1.89	1.67	1.48	1.33	1.22	1.15
Carbon monoxide, g/mile	12.26	12.12	12.01	11.92	11.85	11.81
Oxides of nitrogen, g/mile	2.27	2.18	2.10	2.04	1.99	1.96
Carbon dioxide, g/mile	661.9	647.2	635.0	625.3	618.1	613.4
Fuel economy, mpg	15.51	15.88	16.18	16.44	16.63	16.77
1975 CVS Composite						
Hydrocarbon, g/mile	5.18	3.60	2.43	1.67	1.33	1.41
Carbon monoxide, g/mile	49.03	38.92	30.51	23.80	18.81	15.51
Oxides of nitrogen, g/mile	1.90	1.82	1.75	1.70	1.66	1.64
Carbon dioxide, g/mile	765.6	743.9	726.0	711.6	701.0	694.0
Fuel economy, mpg	12.39	13.07	13.64	14.12	14.48	14.75

*Negative trend was observed.

TABLE A-8 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 7

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	15.14	9.61	5.49	2.79	1.51	1.63
Carbon monoxide, g/mile	156.85	117.96	85.65	59.90	40.72	28.10
Oxides of nitrogen, g/mile	3.69	3.52	3.37	3.26	3.17	3.11
Carbon dioxide, g/mile	617.9	605.5	595.2	587.0	580.8	576.8
Fuel economy, mpg	11.62	13.05	14.31	15.39	16.29	17.02
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	1.09	0.97	0.87	0.78	0.72	0.68
Carbon monoxide, g/mile	20.35	17.62	15.35	13.54	12.20	11.31
Oxides of nitrogen, g/mile	2.29	2.24	2.19	2.16	2.13	2.12
Carbon dioxide, g/mile	589.2	566.1	546.8	531.5	520.1	512.6
Fuel economy, mpg	17.05	17.88	18.59	19.18	19.66	20.02
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	0.79	0.73	0.69	0.65	0.62	0.61
Carbon monoxide, g/mile	14.40	12.68	11.25	10.12	9.27	8.71
Oxides of nitrogen, g/mile	3.10	3.08	3.06	3.05	3.04	3.03
Carbon dioxide, g/mile	554.6	546.3	539.4	533.9	529.7	527.0
Fuel economy, mpg	18.38	18.75	19.06	19.31	19.51	19.64
1975 CVS Composite						
Hydrocarbon, g/mile	3.91	2.69	1.77	1.16	0.86	0.86
Carbon monoxide, g/mile	46.89	36.98	28.73	22.17	17.28	14.06
Oxides of nitrogen, g/mile	2.80	2.73	2.68	2.63	2.60	2.58
Carbon dioxide, g/mile	585.7	568.8	554.8	543.6	535.3	529.8
Fuel economy, mpg	15.85	16.80	17.61	18.29	18.83	19.22

TABLE A-9 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 8

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	6.33	4.55	3.15	2.15	1.53	1.30
Carbon monoxide, g/mile	86.14	70.20	55.52	42.12	30.00	19.13
Oxides of nitrogen, g/mile	3.28	3.15	3.03	2.90	2.78	2.66
Carbon dioxide, g/mile	721.5	629.0	555.8	501.8	467.0	451.4
Fuel economy, mpg	12.16	14.14	16.32	18.54	20.54	21.94
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	0.91	0.90	0.89	0.87	0.86	0.85
Carbon monoxide, g/mile	5.30	4.71	4.12	3.54	2.95	2.36
Oxides of nitrogen, g/mile	2.14	2.09	2.05	2.00	1.96	1.92
Carbon dioxide, g/mile	589.2	555.6	522.1	488.6	455.0	421.5
Fuel economy, mpg	17.75	18.84	20.06	21.45	23.05	24.91
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	0.89	0.89	0.89	0.89	0.89	0.89*
Carbon monoxide, g/mile	6.17	5.59	5.01	4.42	3.84	3.26
Oxides of nitrogen, g/mile	2.48	2.38	2.28	2.19	2.09	1.99
Carbon dioxide, g/mile	502.0	479.0	456.0	433.0	410.0	386.9
Fuel economy, mpg	20.72	21.73	22.84	24.07	25.45	27.00
1975 CVS Composite						
Hydrocarbon, g/mile	2.02	1.65	1.36	1.14	1.01	0.95
Carbon monoxide, g/mile	22.22	18.47	14.97	11.74	8.78	6.07
Oxides of nitrogen, g/mile	2.47	2.39	2.32	2.24	2.16	2.09
Carbon dioxide, g/mile	592.7	549.8	511.0	476.1	445.16	418.2
Fuel economy, mpg	16.81	18.25	19.78	21.40	23.06	24.75

*Negative trend was observed.

TABLE A-10 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 9

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	16.92	11.96	8.02	5.11	3.22	2.35
Carbon monoxide, g/mile	123.12	105.71	88.30	70.89	53.48	36.06
Oxides of nitrogen, g/mile	5.97	4.97	4.16	3.54	3.10	2.84
Carbon dioxide, g/mile	594.9	534.5	488.6	457.4	440.8	438.7
Fuel economy, mpg	12.66	14.43	16.33	18.22	19.92	21.20
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	2.12	1.91	1.72	1.54	1.38	1.23
Carbon monoxide, g/mile	15.14	12.19	9.87	8.19	7.14	6.73
Oxides of nitrogen, g/mile	2.72	2.70	2.69	2.68	2.66	2.65
Carbon dioxide, g/mile	503.0	488.5	474.0	459.5	444.9	430.4
Fuel economy, mpg	19.98	20.75	21.53	22.33	23.15	23.96
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	1.52	1.49	1.45	1.42	1.39	1.35
Carbon monoxide, g/mile	7.80	7.47	7.14	6.82	6.49	6.16
Oxides of nitrogen, g/mile	2.99	2.95	2.92	2.88	2.85	2.81
Carbon dioxide, g/mile	464.2	450.6	437.1	423.5	410.0	396.4
Fuel economy, mpg	22.15	22.82	23.53	24.30	25.10	25.98
1975 CVS Composite						
Hydrocarbon, g/mile	5.00	3.87	2.94	2.24	1.76	1.49
Carbon monoxide, g/mile	35.37	30.16	25.28	20.73	16.51	12.62
Oxides of nitrogen, g/mile	3.46	3.24	3.06	2.91	2.80	2.73
Carbon dioxide, g/mile	511.30	487.6	466.9	449.2	434.5	422.8
Fuel economy, mpg	18.29	19.48	20.66	21.80	22.87	23.83

TABLE A-11 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 10

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	33.30	24.35	16.92	10.99	6.58	3.67
Carbon monoxide, g/mile	241.52	204.80	168.08	131.36	94.64	57.92
Oxides of nitrogen, g/mile	3.67	3.51	3.34	3.18	3.02	2.85
Carbon dioxide, g/mile	838.8	771.7	727.9	707.3	710.0	735.0
Fuel economy, mpg	8.05	9.10	10.19	11.24	12.12	12.71
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	2.14	1.71	1.38	1.13	0.98	0.93
Carbon monoxide, g/mile	8.82	7.98	7.14	6.30	5.46	4.61
Oxides of nitrogen, g/mile	2.99	2.87	2.75	2.62	2.50	2.37
Carbon dioxide, g/mile	851.1	838.1	825.2	812.2	799.3	786.3
Fuel economy, mpg	12.23	12.45	12.68	12.91	13.14	13.38
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	1.28	1.28	1.28	1.28	1.28	1.28*
Carbon monoxide, g/mile	6.21	6.21	6.20	6.20	6.19	6.19
Oxides of nitrogen, g/mile	3.86	3.70	3.55	3.39	3.23	3.07
Carbon dioxide, g/mile	770.8	757.0	743.1	729.3	715.5	701.6
Fuel economy, mpg	13.59	13.83	14.08	14.34	14.64	14.90
1975 CVS Composite						
Hydrocarbon, g/mile	8.34	6.27	4.56	3.21	2.22	1.59
Carbon monoxide, g/mile	56.14	48.12	40.10	32.09	24.07	16.05
Oxides of nitrogen, g/mile	3.37	3.23	3.09	2.95	2.81	2.66
Carbon dioxide, g/mile	826.6	802.2	782.7	767.9	757.9	752.7
Fuel economy, mpg	11.32	11.87	12.39	12.87	13.28	13.61

*Negative trend was observed.

TABLE A-12 Effect of Soaking Temperature on Emissions and Fuel Economy, Car No. 11

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	31.10	21.01	13.26	7.83	4.74	3.9
Carbon monoxide, g/mile	91.64	63.23	41.31	25.90	17.00	14.5
Oxides of nitrogen, g/mile	1.39	1.33	1.29	1.25	1.22	1.2
Carbon dioxide, g/mile	781.0	721.8	672.6	633.3	604.1	584.9
Fuel economy, mpg	10.30	12.14	13.74	15.12	16.27	17.2
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	1.10	0.98	0.88	0.80	0.74	0.7
Carbon monoxide, g/mile	3.77	3.77	3.77	3.77	3.77	3.7
Oxides of nitrogen, g/mile	0.91	0.83	0.77	0.72	0.68	0.6
Carbon dioxide, g/mile	885.8	811.2	749.3	699.9	663.1	638.9
Fuel economy, mpg	11.86	13.04	14.09	15.02	15.81	16.4
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	3.12	2.98	2.86	2.77	2.70	2.6
Carbon monoxide, g/mile	22.30	21.63	21.07	20.62	20.29	20.0
Oxides of nitrogen, g/mile	1.12	1.11	1.10	1.09	1.09	1.0
Carbon dioxide, g/mile	632.0	569.2	516.9	475.2	444.2	423.8
Fuel economy, mpg	15.66	17.48	19.12	20.58	21.87	22.9
1975 CVS Composite						
Hydrocarbon, g/mile	7.85	5.66	3.98	2.79	2.10	1.8
Carbon monoxide, g/mile	26.97	20.93	16.25	12.95	11.02	10.4
Oxides of nitrogen, g/mile	1.07	1.01	0.96	0.93	0.90	0.8
Carbon dioxide, g/mile	794.7	726.5	669.9	624.7	591.1	568.9
Fuel economy, mpg	12.37	13.71	15.05	16.30	17.33	18.0

* Negative trend was observed.

TABLE A-13 Effect of Soaking Temperature on Emissions and Fuel Economy, Car Nos. 12 & 13

	Soaking Temperature, °C					
	-30	-20	-10	0	10	20
Cold Transient Phase (Bag 1)						
Hydrocarbon, g/mile	7.39	5.15	3.43	2.22	1.52	1.35
Carbon monoxide, g/mile	56.82	41.94	30.26	21.77	16.48	14.38
Oxides of nitrogen, g/mile	2.10	2.02	1.96	1.90	1.86	1.84
Carbon dioxide, g/mile	423.1	378.0	340.6	310.7	288.5	273.8
Fuel economy, mpg	19.64	23.43	26.90	30.06	32.91	35.44
Stabilized Phase (Bag 2)						
Hydrocarbon, g/mile	0.45	0.40	0.36	0.33	0.31	0.29
Carbon monoxide, g/mile	4.90	4.55	4.25	4.01	3.83	3.72
Oxides of nitrogen, g/mile	1.76	1.59	1.44	1.33	1.25	1.19
Carbon dioxide, g/mile	426.8	366.5	316.4	276.5	246.7	227.2
Fuel economy, mpg	24.14	28.71	33.13	37.40	41.51	45.47
Hot Transient Phase (Bag 3)						
Hydrocarbon, g/mile	0.48	0.48	0.48	0.48	0.48	0.48
Carbon monoxide, g/mile	3.49	3.49	3.49	3.49	3.49	3.49*
Oxides of nitrogen, g/mile	2.39	2.19	2.02	1.89	1.79	1.72
Carbon dioxide, g/mile	368.3	321.2	282.5	252.2	230.3	216.8
Fuel economy, mpg	28.42	32.85	36.98	40.83	44.38	47.64
1975 CVS Composite						
Hydrocarbon, g/mile	1.89	1.40	1.03	0.76	0.60	0.55
Carbon monoxide, g/mile	15.23	11.97	9.41	7.53	6.34	5.85
Oxides of nitrogen, g/mile	2.00	1.84	1.71	1.60	1.47	1.45
Carbon dioxide, g/mile	409.0	356.1	312.2	277.1	251.0	233.9
Fuel economy, mpg	24.28	28.1	32.28	36.59	40.55	43.54

*Negative trend was observed.

TABLE A-14 Hydrocarbon Emission Averaged for Vehicle Groups, g/mile

Fleet Code	Car No.	Vehicle Group	Control	Test Phase	Soaking Temperature, °C -30	-20	-10	0	10	20
75CAL	1	Chev. Monza	AI,	Bag 1	10.64	7.38	4.87	3.12	2.10	1.84
(AI,	2	Chev. Impala	EGR,	Bag 2	0.36	0.29	0.23	0.19	0.16	0.15
EGR,	3	Dodge Dart	OC	Bag 3	0.42	0.40	0.38	0.37	0.36	0.35
OC)3				Composite	2.49	1.78	1.23	0.84	0.61	0.54
75US			EGR,	Bag 1	16.01	10.39	6.18	3.37	1.97	1.97
(EGR,	4	Chev. Biscayne	OC	Bag 2	0.52	0.43	0.35	0.28	0.24	0.21
OC)2	5	Chev. Nova		Bag 3	0.54	0.49	0.45	0.41	0.38	0.37
				Composite	3.73	2.50	1.58	0.95	0.63	0.61
75CAN			AI,	Bag 1	16.78	10.47	5.83	2.85	1.54	1.89
(AI,	6	Ford Custom	EGR	Bag 2	1.38	1.26	1.16	1.07	1.01	0.98
EGR)	7	Ford Maverick		Bag 3	1.34	1.20	1.09	0.99	0.92	0.88
2				Composite	4.55	3.15	2.10	1.42	1.10	1.14
75CAN			EGR	Bag 1	25.11	18.16	12.47	8.05	4.90	3.01
(EGR)	9	Dodge Dart		Bag 2	2.13	1.81	1.55	1.34	1.18	1.08
3*	10	Dodge Monaco		Bag 3	1.40	1.39	1.37	1.35	1.34	1.32
				Composite	6.67	5.07	3.75	2.73	1.99	1.54
74US			TR	Bag 1	31.10	21.01	13.26	7.83	4.74	3.97
(TR)	11	Mazda RX4		Bag 2	1.10	0.98	0.88	0.80	0.74	0.70
1				Bag 3	3.12	2.98	2.86	2.77	2.70	2.66
				Composite	7.85	5.66	3.98	2.79	2.10	1.81
75CAL			CVCC	Bag 1	7.39	5.15	3.43	2.22	1.52	1.35
(CVCC)	12	Honda Civic		Bag 2	0.45	0.40	0.36	0.33	0.31	0.29
2	13	Honda Civic		Bag 3	0.48	0.48	0.48	0.48	0.48	0.48
				Composite	1.89	1.40	1.03	0.76	0.60	0.55

* Only 2 cars (Nos. 9 and 10) used.

TABLE A-15 Carbon Monoxide Emission Averaged for Vehicle Groups, g/mile

Fleet Code	Car No.	Vehicle Group	Control	Test Phase	Soaking Temperature, °C -30	-20	-10	0	10	20
75CAL	1	Chev. Monza	AI,	Bag 1	94.98	75.30	58.94	45.91	36.20	29.80
(AI,	2	Chev. Impala	EGR,	Bag 2	2.11	1.80	1.54	1.33	1.17	1.07
EGR,	3	Dodge Dart	OC	Bag 3	2.92	2.48	2.12	1.82	1.60	1.45
OC)3				Composite	21.49	17.15	13.54	10.66	8.52	7.11
75US			EGR,	Bag 1	298.71	220.79	156.53	105.93	69.00	45.73
(EGR,	4	Chev. Biscayne	OC	Bag 2	16.11	12.10	8.78	6.13	4.16	2.86
OC)	5	Chev. Nova		Bag 3	11.10	8.74	6.77	5.21	4.04	3.27
2				Composite	73.06	54.25	38.72	26.48	17.51	11.82
75CAN			AI,	Bag 1	175.88	132.01	95.56	66.52	44.88	30.65
(AI,	6	Ford Custom	EGR	Bag 2	15.44	14.06	12.92	12.01	11.33	10.89
EGR)	7	Ford Maverick		Bag 3	13.33	12.40	11.63	11.02	10.56	10.26
2				Composite	47.96	37.95	29.63	22.99	18.05	14.79
75CAN			EGR	Bag 1	182.32	155.26	128.19	101.13	74.06	46.99
(EGR)	9	Dodge Dart		Bag 2	11.98	10.09	8.51	7.25	6.30	5.67
3*	10	Dodge Monaco		Bag 3	7.01	6.84	6.67	6.51	6.34	6.18
				Composite	45.76	39.14	32.69	26.41	20.29	14.34
74US			TR	Bag 1	91.64	63.23	41.31	25.90	17.00	14.59
(TR)	11	Mazda RX4		Bag 2	3.77	3.77	3.77	3.77	3.77	3.77
1				Bag 3	22.30	21.63	21.07	20.62	20.29	20.08
				Composite	26.97	20.93	16.25	12.95	11.02	10.47
75CAL			CVCC	Bag 1	56.82	41.94	30.26	21.77	16.48	14.38
(CVCC)	12	Honda Civic		Bag 2	4.90	4.55	4.25	4.01	3.83	3.72
2	13	Honda Civic		Bag 3	3.49	3.49	3.49	3.49	3.49	3.49
				Composite	15.23	11.97	9.41	7.53	6.34	5.85

* Only 2 cars (Nos. 9 and 10) used.

TABLE A-16 Nitrogen Oxides Emission Averaged for Vehicle Groups, g/mile

Fleet Code	Car No.	Vehicle Group	Control	Test Phase	Soaking Temperature, °C -30	-20	-10	0	10	20
75CAL	1	Chev. Monza	AI,	Bag 1	2.36	2.18	2.03	1.91	1.82	1.76
(AI,	2	Chev. Impala	EGR,	Bag 2	1.37	1.30	1.24	1.19	1.16	1.13
EGR,	3	Dodge Dart	OC	Bag 3	1.91	1.79	1.69	1.61	1.56	1.52
OC)3				Composite	1.72	1.62	1.53	1.46	1.41	1.37
75US			EGR,	Bag 1	2.21	2.16	2.12	2.09	2.07	2.07
(EGR,	4	Chev. Biscayne	OC	Bag 2	1.58	1.53	1.48	1.44	1.41	1.39
OC)	5	Chev. Nova		Bag 3	2.21	2.02	1.95	1.86	1.79	1.75
2				Composite	1.88	1.81	1.74	1.69	1.65	1.63
75CAN			AI,	Bag 1	2.89	2.80	2.73	2.67	2.63	2.60
(AI,	6	Ford Custom	EGR	Bag 2	1.96	1.89	1.82	1.77	1.73	1.71
EGR)	7	Ford Maverick		Bag 3	2.69	2.63	2.58	2.55	2.52	2.50
2				Composite	2.35	2.28	2.22	2.17	2.13	2.11
75CAN			EGR	Bag 1	4.82	4.24	3.75	3.36	3.06	2.85
(EGR)	9	Dodge Dart		Bag 2	2.86	2.79	2.72	2.65	2.58	2.51
3*	10	Dodge Monaco		Bag 3	3.43	3.33	3.24	3.14	3.04	2.94
				Composite	3.42	3.24	3.08	2.93	2.81	2.70
74US			TR	Bag 1	1.39	1.33	1.29	1.25	1.22	1.21
(TR)	11	Mazda RX4		Bag 2	0.91	0.83	0.77	0.72	0.68	0.66
1				Bag 3	1.12	1.11	1.10	1.09	1.09	1.09
				Composite	1.07	1.01	0.96	0.93	0.90	0.89
75CAL			CVCC	Bag 1	2.10	2.02	1.96	1.90	1.86	1.84
(CVCC)	12	Honda Civic		Bag 2	1.76	1.59	1.44	1.33	1.25	1.19
2	13	Honda Civic		Bag 3	2.39	2.19	2.02	1.89	1.79	1.72
				Composite	2.00	1.84	1.71	1.60	1.52	1.47

* Only 2 cars (Nos. 9 and 10) used.

APPENDIX B - Regression Coefficients (Tables B-1 and B-2)

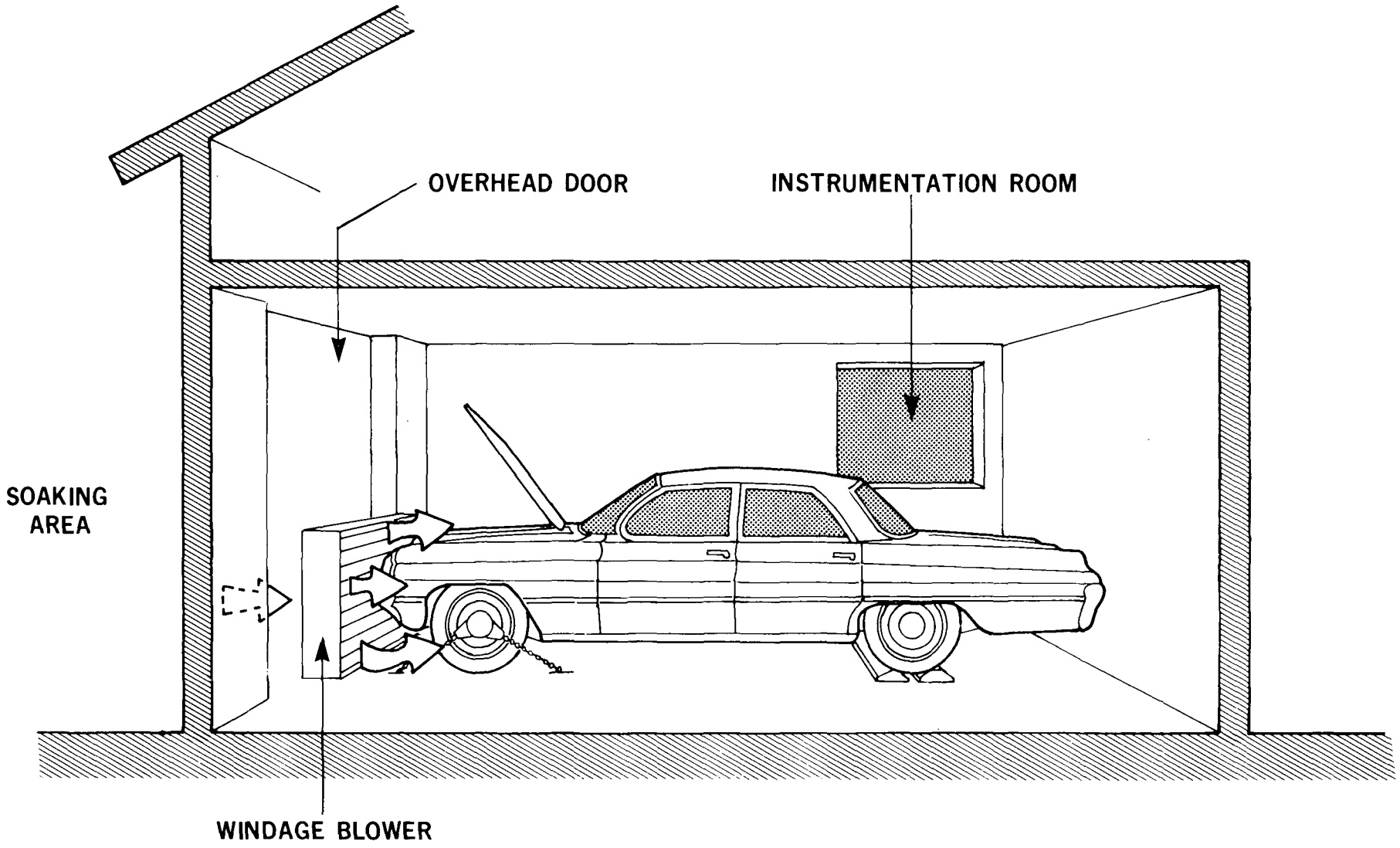
TABLE B-1 Regression Coefficients for Emissions

Pollutant	Fleet Code (see Table A-1)	a_1	a_2	a_3
	75CAL(AI, EGR, OC)3	0.30	-0.0310	0.0008
	75US(EGR, OC)2	0.34	-0.0473	0.0015
Hydrocarbon	75CAN(AI, EGR)2	0.28	-0.0502	0.0018
	75CAN(EGR)3*	1.14	-0.0870	0.0015
	74US(TR)1	0.98	-0.0962	0.0024
	75CAL(CVCC)2	0.21	-0.0213	0.0005
	75CAL(AI, EGR, OC)3	3.55	-0.2510	0.0037
	75US(EGR, OC)2	14.66	-1.0607	0.0164
Carbon	75CAN(AI, EGR)2	8.20	-0.5790	0.0084
Monoxide	75CAN(EGR)3*	12.07	-0.6200	0.0008
	74US(TR)1	2.48	-0.2614	0.0069
	75CAL(CVCC)2	1.68	-0.1531	0.0034
	75CAL(AI, EGR, OC)3	0.09	-0.0062	0.0001
	75US(EGR, OC)2	0.06	-0.0044	0.0001
Nitrogen	75CAN(AI, EGR)2	0.06	-0.0044	0.0001
Oxides	75CAN(EGR)3*	0.23	-0.0135	0.0001
	74US(TR)1	0.04	-0.0030	0.0001
	75CAL(CVCC)2	0.13	-0.0093	0.0001

* Only 2 cars (Nos. 9 and 10) used.

TABLE B-2 Regression Coefficients for Fuel Economy

Vehicle No. (see Table A-1)	a_1	a_2	a_3
1	-2.28	0.1334	-0.0009
2	-0.51	0.0393	-0.0004
3	-0.61	0.0396	-0.0005
4	-1.02	0.0643	-0.0007
5	-1.74	0.1062	-0.0010
6	-0.63	0.0420	-0.0005
7	-0.93	0.0606	-0.0007
9	-2.03	0.1086	-0.0003
10	-0.74	0.0434	-0.0003
11	-1.73	0.1075	-0.0008
12, 13	-7.11	0.3852	-0.0009



Appendix C. Cold Weather Testing Cell