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Summary Report of Several Ambient Carbon Monoxide Studies

by

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The Federal Clean Air Act assigns to the United States Environmental Protection Agency (EPA) the responsibility to promulgate National Ambient Air Quality Standards (NAAQS) regarding carbon monoxide (CO). On August 8, 1980 EPA proposed CO standards of 25 parts per million (ppm) maximum allowable one hour expected concentration level and 9 ppm maximum allowable expected eight hour average concentration level (Reference 1). In an effort to achieve these standards the Clean Air Act also assigns to EPA the responsibility to promulgate regulations regarding the amount of CO new highway vehicles may emit from the tailpipe.

To properly fulfill this second mandate, it is necessary to understand the conditions associated with high ambient CO concentrations. The EPA Office of Mobile Source Air Pollution Control (OMSAPC) has conducted several studies concerning ambient CO concentrations and the relationship between those concentrations and motor vehicle emissions. The purpose of this report is to provide a single concise summary of several such studies. Four of the included studies were conducted by OMSAPC. Another related study, sponsored by EPA Region X, is included in this summary report for completeness.

The five studies summarized in this report provide information on recent CO emission inventory estimates, the meteorological conditions associated with high ambient CO concentrations, the distribution of CO concentrations within selected cities, the effects on CO concentration levels of both meteorological conditions and traffic characteristics at typical hot spot locations and the estimated amount that in-use vehicle emissions must be reduced to achieve the NAAQS for CO.

This report presents a synopsis of how each study was conducted, the questions addressed by the studies and the major results from each study.

Synopsis of Studies

The first study is summarized in the Mobile Source Emission Inventory Report (Reference 2). That study focuses on the development of emission inventory estimates for a variety of mobile pollution sources. The purpose of the study was to evaluate the contributions of various mobile sources to the total emission burden. The study was performed to provide one input into the OMSAPC Program Assessment Group's evaluation and direction of mobile source control programs. Both current and future year (up to 2005) carbon monoxide county inventories were estimated and presented in this report. The estimates were based on the 1978 Mobile Source Emission Factors document (Reference 3) and the 1977 National Emissions Data Systems (Reference 4). Eighteen different types of mobile sources were considered. The contribution of unregulated as well as presently regulated mobile sources were included. Inventories for non-methane hydrocarbons and oxides of nitrogen were also estimated. The sensitivity of the emission inventory estimates to low ambient temperatures, different stationary source control and retirement rate assumptions, different driving modes and different mobile and stationary source growth rate assumptions were considered. Finally, the results were interpreted in terms of their likely air quality effect.

The purpose of the second study (Reference 5) was to determine the temporal and meteorological characteristics that are associated with deteriorated air quality. The study used meteorological observations obtained from the National Weather Service (NWS) for 60 U.S. cities in calendar year 1975-1977. Corresponding ambient concentration data were provided by the EPA Storage and Retrieval of Aerometric Data (SAROAD) system (Reference 6). In general, sites were ranked and chosen according to the number of times the NAAQS was exceeded in the 1975-1977 period.* The parameters studied included:

1. Month of the year
2. Hour of the day
3. Observation temperature
4. Rush hour temperature
5. Pre-rush hour temperature
6. Absolute humidity
7. Barometric pressure
8. Wind speed
9. Insolation
10. Atmospheric stability

Ambient CO concentration levels were related to each of these temporal and meteorological parameters.

EPA Region X sponsored the third set of studies in Seattle, Washington and Boise, Idaho (References 7 and 8) to find out how high CO concentrations were distributed in those two cities. The Seattle study involved monitoring CO concentrations at 36 outdoor sites, five indoor sites and two pedestrian walking routes. Data were collected for twenty days in the fourth quarter of 1977. The fourth quarter corresponds to the season when high carbon monoxide levels frequently occur. A similar study methodology was established for Boise. The purpose of these studies was to determine the magnitude and spatial extent of the carbon monoxide problem and the representativeness of the central business districts' permanent monitors. Although this set of studies was not sponsored by OMSAPC, they have been included in the report because of their relevance.

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*CO 10 mg/m^3 (8 hour average)
Ozone 160 ug/m^3 (1 hour average)

An exceedence of one of these levels is not necessarily a violation of the standard. The standard may, for example, recognize only one violation per day. If the concentration level was higher than the standard for an entire day, then while there would be only one violation, there would be 24 exceedences.

EPA also collected data in the vicinity of congested intersections - hot spots - in another study to find out more about the meteorological, traffic and CO background conditions in specific areas that have a history of high CO concentrations (Reference 9). One intersection was chosen in each of the four cities: San Jose, Phoenix, Seattle and Chicago. Vehicle and traffic characteristics, as well as meteorological parameters and ambient concentration levels, were measured. Several techniques were used to collect these data. Postcard survey and driver interviews were used to collect vehicle characteristics information. A traffic analyzer and instrumented pace car were used to collect traffic speed and volume data. Ten CO sampling devices were placed in the vicinity of each intersection, some in close proximity to the intersection to measure the effects of local traffic and some further away to measure urban background concentration levels. Each of the vehicle and meteorological variables were related to the ambient CO level. Further, an attempt was made to ascertain the degree to which vehicles operating in the immediate vicinity of the study intersection were responsible for the observed ambient concentrations.

Another study was performed to estimate the amount in-use vehicle emissions must be reduced to achieve the NAAQS for CO. This work is described in a memorandum entitled "Percent Reduction Needed in Mobile Source Emissions" memorandum (Reference 10). Data from over 50 of the worst CO problem cities in the U.S. for the three year period 1975-1977 were included in the analysis. Ambient CO concentration data from the SAROAD system were combined with meteorological data from the National Weather Service and the 1980 draft mobile source emission factor data from EPA. These data are the same as those that were used in the second study of this series. Cities were chosen on the basis of the number of hourly concentration values in one year that exceeded 10 mg/m^3. In general, the cities with the greatest number of exceedences were included. The percent reduction required from mobile sources to achieve the NAAQS was calculated as function of ambient temperature. This required percent reduction was estimated for each calendar year from 1978 through 1995. In the years that the expected percent reduction needed became zero, no violations of the CO standard were predicted.

Each of these studies was designed to address a different aspect of the high CO concentration problem. Together, they attempt to answer the following questions:

1. How are CO emissions distributed throughout the country?

2. What is the mobile source proportion of total CO emissions?

3. During what seasons and times of day are CO concentrations highest?

4. What meteorological conditions are associated with high CO concentrations?

5. What vehicle and traffic conditions are associated with high ambient CO concentrations?

6. To what extent are high CO concentrations related to activity within a few hundred meters of the CO monitoring instruments?

7. How does the degree of emission reduction required from mobile sources to meet the NAAQS change over time?

8. How does the degree of emission reduction required from mobile sources change with temperature?

The following five sections of this report present the study results as they pertain to these questions. One section is devoted to each study.

Mobile Source Emission Inventory Report

To answer the first two questions, the Mobile Source Emission Inventory Report focused on the development of emission inventory estimates for a variety of mobile pollution sources. In 1977, the latest year for which data were available at the time the report was written, CO emissions from all sources totaled 113,715,311 tons. On average, 36 thousand tons were emitted in each of the nations's approximately 3200 counties. In most counties, however, fewer than 12 thousand tons were emitted (Figure 1). Obviously, the total amount of CO emitted is only one aspect of the CO inventory. The distribution of emissions within counties is also important. If emissions are uniformly distributed within counties and if meteorological conditions are the same for all counties, then emission densities would be better predictors of ambient concentration differences among counties than would total tonnage. (The density of CO for a county is the total amount of CO emitted annually divided by the county area.)

Like the total annual CO emission levels shown in Figure 1, Figure 2 shows that emission density in most counties is comparatively low. For the majority of counties CO density is less than 19 tons per square mile. However, in five percent of counties CO density is greater than 230 tons per square mile. Since the distribution of CO emissions within counties is not uniform and meteorological conditions across counties are not constant, it is also important to relate CO concentrations to population density. Most CO emissions are caused by motor vehicles and tend to be concentrated in urbanized areas. This assertion is supported by Figure 3. The high emission density counties are also the high population density (urbanized) counties. The relationship is significant for two reasons. First, it indicates that a large portion of the population may be exposed to harmful CO levels. Second, since most stationary CO sources are in rural areas, it supports the hypothesis that the CO emissions of greatest concern are caused primarily by mobile sources.

Of the 113 million tons of CO emitted in 1977, transportation sources accounted for approximately 85 percent. Figure 4 shows the relative contribution of mobile source emissions to total county emissions for each county. The horizontal axis indicates the percent of total emissions contributed by mobile sources. (The percent of emissions contributed by stationary sources can be computed as 100 percent minus this number.) The vertical axis indicates the number of counties at each mobile source contribution level. As Figure 4 indicates, mobile sources account for a relatively large portion of CO emissions in most counties. In 5 percent of counties, mobile sources contribute more than 98 percent of all the CO emitted. The median contribution is 92 percent. However, as the portion of the curve at the left hand end of the horizontal axis indicates, there are a few counties in which mobile sources contribute a small percentage of county emissions. In most of these counties the dominant emissions sources are forest wild fires and forest managed burning. This is particularly true in Alaska, Idaho, Montana and Puerto Rico. However, there are a few counties in the southwest in which chemical manufacturing is the dominant CO source. These counties often contain carbon black manufacturing plants, which, when uncontrolled, emit large amounts of CO.

In order to narrow the focus to the counties with a CO problem, 143 counties showing violations of the eight hour average NAAQS were analyzed. (At the time the report was written the primary CO standard was 10 mg/m^3. Also, the National Emission Data System data for Connecticut was erroneous, so that state's data were excluded.) Most of the 143 counties include a large urban area. Figure 5 shows the distribution of total CO emissions for these counties. As would be expected, total average annual CO emission levels tend to be greater among these counties than among all the nation's counties. Similarly, emission densities in these 143 counties also tend to be higher (Figure 6). Further, as can be seen from Figure 7, the general association of high emission densities with high population densities also prevails among the counties showing NAAQS violations. Finally, as Figure 8 shows, most county CO is emitted by mobile pollution sources. The general shape of Figure 8 follows that of Figure 4. However, while in Figure 4 several counties are represented in which mobile sources contributed a negligible portion of total CO, among 143 counties of Figure 8 which represent areas with ambient CO violations, mobile sources contributed at least 37 percent of total county CO. The median CO contribution was 95 percent.

To summarize, three conclusions can be drawn from these figures: 1) the highest CO emissions levels are found in the nation's urban centers; 2) in these areas mobile source emissions predominate; and 3) large segments of the population are exposed to high CO emission levels.

Identification of Meteorological Conditions

The second study summarized in this report focused on the temporal and meteorological characteristics that are associated with deteriorated CO air quality. This study addresses the third and fourth questions that were previously listed. Figure 9 shows the relationship between CO emission rates and ambient temperature developed for the draft 1980 mobile source emission factor document. The specific curves shown represent the 1975-1977 calendar year period. Since mobile source CO emissions tend to increase as temperature decreases, the absolute CO ambient concentration levels in the nation's urban centers also increase during cold weather months. In Figure 10 the total number of CO eight hour moving averages greater than the 10 mg/m^3 NAAQS are displayed for each month of the year. As indicated, most exceedences of the standard occur during the winter months. Figure 11 shows the number of NAAQS exceedences as a function of pre-rush hour temperature. Pre-rush hour temperature was arbitrarily defined as the average temperature during the three hours preceeding the rush hour associated with the exceedence. For many vehicles the temperature during this period is the temperature during the time the vehicle was parked. It is this temperature that is related to CO emissions. For a given length of parked time, CO emissions tend to increase as ambient temperature decreases. Therefore, one would expect that an increased number of exceedences would occur at colder temperatures. This would skew Figure 11 to the left. Instead, the distribution in Figure 11 is more or less centered around 50°F. The confounding factor is that there are comparatively few eight hour periods anywhere in the country during which the average temperature is below 0°F. Normalizing the data for the total number of hours in each temperature interval, Figure 12 presents the fraction of time that the ambient CO concentration level exceeded the NAAQS, given that the ambient temperature was within the range indicated. Thus, within a given temperature interval, the likelihood of a high ambient CO concentration is greater at low temperatures than at high temperatures.

The likelihood of high ambient CO concentrations is also greater at low wind speeds and stable* atmospheric conditions (Figures 13 and 14). These are conditions under which the CO generated from motor vehicle operation is not readily dispersed. The low wind speeds and stable conditions occur most frequently during the late Fall than during the February - March winter months. That is why more standard violations occur during the fourth quarter of the year than occur during the first quarter. The average temperature difference between the two quarters is not great. However, there is a difference in the prevalence of unstable atmospheric conditions.

Collectively, Figures 10-14 indicate that CO violations occur most frequently during the October - January season and that, in general, the colder the temperature during low wind speed and stable atmospheric conditons, the greater will be the likelihood of a NAAQS violation.

The frequency of CO violations also changes during the day. This variation is associated with both traffic and meteorological patterns. As Figure 15 shows, the likelihood of a NAAQS CO violation increases from a minimum at 6:00 hours (6 a.m.) to a maximum at 17:00 hours (5 p.m.). The hour indicated in the figure is the ending hour of the eight hour moving average. Thus, a 5 p.m. ending hour represents the 10 a.m. - 5 p.m. eight hour average. Traffic volume generally follows a bi-modal pattern with peaks during both the morning and evening rush hour period. Since in most localities the morning rush hour is over by 10 a.m., one hypothesis that may explain the pattern of exceedence frequencies given in Figure 15 is that the emissions from the morning traffic rush mix with emissions from vehicles operating during the day. That hypothesis would explain the increased frequency of a NAAQS exceedence in the 1 - 2 p.m. period. The same sort of hypothesis can be set forth for the relatively

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*Stability classes range from unstable (A) to stable (G).

high likelihood of an exceedence during the late evening hours. High levels of CO seem to disperse slowly, over a period of three or more hours. For example, if this hypothesis is correct, then emissions from vehicles operating after the evening rush hour (8 p.m.) would contribute to the eight hour average ending at 6 a.m. the next morning. (The 8 p.m. emissions would contribute to the 11 p.m. ambient one hour CO concentration level and that level would then be averaged with the levels from the subsequent seven hour period, thus forming the eight hour average ending at 6 a.m. the next morning.) If CO emissions dispersed immediately, then one would expect the eight hour average CO concentration level to fall to its minimum value eight hours after the close of the evening rush hour, about 2 a.m.

A second hypothesis that can be supported by Figure 15 is that the citywide distribution of high CO concentrations may be more widespread than is sometimes thought. If this hypothesis is correct, the high CO emission levels orginating at one congested intersection have time to mix with high CO emissions originating at other congested intersections. If, indeed, high ambient CO levels are widely distributed over an urban area, then all segments of the urban population are exposed to high CO levels and not just those segments located in a one or two block radius of a few congested intersections.

<u>Seattle, Washington and Boise, Idaho Carbon Monoxide Studies</u>

Evidence supporting the proposition that high ambient CO levels are widely distributed over an urban area was collected in Seattle, Washington and Boise, Idaho. The study results indicate that the carbon monoxide problem is widespread and not restricted to the downtown commercial district. Figure 16 shows the locations of the study monitoring sites within Boise and the maximum 8-hour values over the entire sampling period. The bar heights are proportional to those maximum values. The central business district is detailed in the cutout section of Figure 16. At several sites within the central business district the maximum 8-hour value exceeded 9 ppm CO. (The 9 ppm level is approximately equivalent to the 10 mg/m^3 NAAQS in the effect at the time the study was conducted.) However, as Figure 16 shows, the NAAQS exceedences were not restricted to the district. In several outlying areas the maximum 8-hour values also exceed the NAAQS.

To paraphrase the report, the spatial extent of the Boise CO problem encompasses not only the downtown commercial district but also locations along traffic corridors outside the core area. When higher concentrations were observed in the core area, elevated CO levels also occurred elsewhere. Altogether about 70 percent of the study sites experienced one or more days when the eight-hour average exceeded 9.0 ppm.

The study also found that pedestrians were, at times, exposed to eight-hour average CO concentration levels exceeding the standard. This is inferred from the fact that for nearly sequential sampling periods totaling seven or more hours, the average exposure was equal to or above 9.0 ppm on four days. Also, for sampling periods between two to four hours, pedestrians were on one occasion exposed to 14 ppm.

This study, conducted by EPA Region X, also measured CO concentrations at indoor sites such as large department stores and office buildings. Changes in the level of CO concentrations at indoor sites often coincided with changes in CO concentrations at outdoor sites. At several sites, late afternoon increases in indoor CO were observed, suggesting an influence from the afternoon traffic peak. On one or more days the eight-hour average CO concentration exceeded 9.0 ppm at four of the indoor sites.

Finally, although the state monitor in Boise is located in the central business district, the magnitude of Boise carbon monoxide levels measured as part of the study was somewhat greater than indicated by the state monitor. On 19 of the 20 study days the eight-hour standard was exceeded at one or more sites. Exceedences at the state site occurred on only 9 days. Further, at other locations, eight-hour concentrations above the standard were up to three times greater than those measured at the permanent monitor. Since control strategies for an area are based, in part, upon the levels of CO measured by that area's permanent monitoring network, it is important that the network accurately reflect the levels of CO concentration to which the population is exposed. If the measurements made by the permanent monitor are too high, then expensive control measures may be undertaken unnecessarily. On the other hand, if the measurements are too low, then the area's population may be exposed to a significant health risk.

CO Hot Spot Study

The CO hot spot study was designed to characterize the meteorological and traffic conditions at congested intersections. At each of the four study sites, ambient CO concentrations were measured in the immediate vicinity of an intersection. CO monitors were also placed on roof tops, alley ways and parks away from the intersection in an attempt to measure background concentration levels. The meteorological parameters were measured within a few blocks of the study intersection. These parameters included ambient temperature, barometric pressure, humidity, windspeed and direction and insolation. (Insolation is a measure of sunlight intensity.) A traffic counter was placed on the roadway leading into the intersection while an instrumented pace car monitored traffic speed. As vehicles stopped for the red light at the intersection itself, drivers were asked a series of questions pertaining to their vehicles and the length of time they had been driving.

Since ten concurrent CO measurements were made for each sampling period, and since at least a few of the measurements were made away from the traffic flow, the minimum of those ten measurements was used as an indicator of the background CO level for the sampling period. The difference between the maximum and minimum values was used as an indicator of the CO concentration attributable to traffic at the intersection. The difference was then divided by the maximum value to express the local contribution as a percentage. Thus, a high local contribution indicates that vehicles at the study intersection are responsible for most of the measured CO. Conversely, a low local contribution level indicates that vehicles operating throughout the urban area are responsible. If vehicles removed from the intersection contribute significantly to the CO concentrations at the intersection, then CO is a mesoscale, not a microscale, problem.

In San Jose the eight-hour average CO NAAQS was exceeded 10 times during the study week. On all 10 occasions the sampler recording the highest CO level was directly downwind of the intersection. Average wind speed was 4 knots; traffic volume was high. The local contribution during these periods - as we have defined it - ranged from 62 to 98 percent and averaged 80 percent.

The local contribution during the NAAQS exceedences in Seattle ranged from 36 to 76 percent and averaged 60 percent. Average wind speed was 2.8 knots. Twice in Seattle high CO concentrations were recorded by all of the sampling devices in the immediate vicinity of the intersection and by the "background" devices situated away from the intersection. In these cases it is probable that the high CO concentrations were not representative of a typical "hot spot" situation but were widespread and not restricted to the immediate study area. These particular violations were likely to be the result of traffic throughout a fairly wide area. Three other exceedences in Seattle were associated with high local contributions and followed the pattern seen in San Jose.

Four exceedences of the NAAQS occurred during the test week spent in Phoenix. High CO concentrations were recorded simultaneously by many sampling devices there, including those positioned to measure background concentrations. Since the NAAQS exceedences occurred during eight hour periods that ended between 1 and 3 a.m., the local contribution averaged only 35 percent. Thus, the Phoenix location can not be described as a true hot spot, at least during the study period.

In Chicago there were two eight-hour NAAQS exceedences during the study week. They occurred after periods of heavy traffic and were associated with relatively high local contributions - from 79 to 97 percent.

The study findings indicate that the local CO contribution varies directly with wind speed and insolation and varies inversely with barometric pressure. It seems that high wind and insolation, and low barometric pressure are conducive to higher CO dispersion rates. And a high rate of CO dispersion means that CO from adjacent traffic corridors tends to be diluted before it reaches the study intersection.

Traffic conditions also influence the local contribution level. The level varies directly with the proportion of vehicles that are started after having been parked for several hours. It also varies directly with the total number of vehicles passing through the intersection and with the age of those vehicles. Under each of these conditions, vehicle emissions tend to increase so that the greater the total emission level, the greater will be the local contribution. This is a typical CO hot spot situation.

High CO concentrations, at times, were also recorded at all monitoring locations. This phenomenon was observed most frequently in Phoenix and Seattle. On several occasions when the highest CO concentration recorded was greater than 10 mg/m^3, the local contribution was between 15 and 40 percent. Such a low local contribution indicates that several segments of the urban area experienced high concentration levels simultaneously.

On such occasions, the CO problem is not strictly a hot spot problem but is a mesoscale problem affecting the entire urban area.

Percent Reduction Needed in Mobile Source Emissions

The purpose of each of the studies discussed so far has been to gather information about the conditions associated with high ambient CO concentrations in an attempt to determine the level of emissions reduction needed to meet the CO National Ambient Air Quality Standard. Currently, many areas of the country do not attain the NAAQS. With the principal exception of the inspection and maintenance strategy, the Federal Motor Vehicle Control Program has been applied to new vehicles. Thus, as older, generally dirtier vehicles leave the vehicle pool, the average level of emissions has declined. As emission rates continue to decline, so will ambient CO concentration levels. However, the reduction in average emissions and the resulting improvement in air quality will take time.

In the final study being summarized the concept of a percent reduction needed from mobile source emissions was constructed to estimate when and how many of the nation's counties will meet the NAAQS. The percent reduction needed is defined in this work as the amount by which mobile source emissions must be reduced in order to eliminate NAAQS exceedences. As an example, reducing a 40 mg/m^3 ambient concentration to 10 mg/m^3 requires a 75 percent emission reduction. If the maximum CO concentration measured anywhere in the country is 40 mg/m^3, then reducing emissions throughout the country by 75 percent would eliminate all exceedences. Reducing emissions by less than 75 percent would eliminate only a portion of the exceedences.

Figure 17 shows the percent by which the highest eight hour average ambient CO levels must be reduced in order to meet the CO NAAQS in each calendar year. Figure 17 assumes that FTP conditions prevail, that no inspection maintenance program is instituted and that VMT growth is two percent. Data from over 50 cities with the highest 1975-1977 CO concentrations were included in the analysis. The dotted line indicates the level at which 100 percent of ambient CO standard exceedences will be eliminated. The solid line indicates the level at which only 90 percent of exceedences will be eliminated. For example, to eliminate 99 percent of the total number of eight hour periods that presently exceed the CO NAAQS, each eight hour average would need to be reduced by 51 percent in 1982 and by 32 percent by 1987.

Several assumptions concerning vehicle miles traveled and stationary source impact underlie the construction of Figure 17. Vehicle miles traveled by mobile sources are expected to grow at a two percent annual compound rate. Stationary source emissions are assumed not to influence urban concentrations, but to completely disperse before reaching urban centers. The CO emission factors for the entire highway vehicle fleet without inspection maintenance are derived from MOBILE2 (Reference 11).

Two points should be made with respect to Figure 17. First, it appears that 90 percent of NAAQS CO exceedences will be eliminated around 1985. (The logic here is that if no further reduction is needed to meet the standard, then the standard must have been met.) Elimination of 90 percent of the CO exceedences is a major achievement. However, eliminating 90 percent of the standard exceedences still leaves many eight hour periods each year during which the public is exposed to unhealthy levels of carbon monoxide. The remaining 10 percent of exceedences would generally occur in large urban areas where a significant segment of the population would be exposed. Second, Figure 17 suggests that at least one percent of the exceedences will never be eliminated, since the 99 percent line begins to turn upward in 1995. (Inspection maintenance or other control programs not currently in place would have the effect of lowering each of the curves in Figure 17.)

It should be remembered while interpreting Figure 17 that it represents only one set of conditions. Other sets of conditions would result in different curves. Specifically, as we found out in previous studies, both emissions and ambient concentrations tend to increase at lower temperatures. Changing the assumptions concerning stationary source influence, vehicle miles traveled, vehicle control programs and driving conditions would also result in different curves. (Temperature was of prime concern in these studies because CO emission rates are very sensitive to temperature changes.)

The 70 - 75°F temperature interval was used to construct Figure 17. Figure 18 displays the percent reduction needed from mobile sources as a function of temperature. Individual vehicle emissions increase at colder temperatures. At extremely cold temperatures, however, other factors, such as increased wind speed and decreased atmospheric stability, disperse the greater per vehicle emissions. As a result, a smaller percentage reduction in mobile source CO emissions is required at temperatures below 0°F than at 0°F. (At the temperature extremes comparatively few data points determine the position of the curves. Fairbanks, Alaska, for example, accounts for most of the very low temperatures. Caution should therefore be used before making any inferences from these sections of the Figure 18 curves.)

Both the 90 and 95 percent curves of Figure 18 show that the greatest level of control is needed in the 0 - 5°F temperature interval. A decreasing level of control is needed over the 0 - 30°F interval. From 30 - 75°F an increasing level of control is needed. Finally, from 75 - 100°F a decreasing level of control is needed. The required levels of control are summarized in Table 1.

The initial 70 - 75°F interval was chosen as one aspect of study in this analysis to be consistent with the Federal Test Procedure. Motor vehicles are tested in that program at a temperature within the 68 - 86°F range. However, since the likelihood of a standard exceedence increases as temperature decreases and since the percent reduction required from motor vehicles is greater at colder temperatures, Figure 19 was constructed with the zero to five degree temperature range. In this colder range, the elimination of 90 percent of the NAAQS exceedences will not be achieved under the study assumptions. Around 1995 growth in the number of vehicles increases total emissions more than the reduction in emissions from each individual vehicle decreases total emissions. Beyond 1995 sufficiently more vehicles enter the vehicle pool to more than compensate for the reduced emissions from each of them.

Conclusion

Each of these studies has addressed a different aspect of the high ambient CO concentration problem. The National Emission Inventory report showed that the highest CO concentration levels are found in the nation's urban centers, that in these areas mobile source emissions predominate and that large segments of the population are exposed to high CO emission levels. The meteorological study showed that the likelihood of a CO National Ambient Air Quality Standard exceedence tends to increase at low temperatures, low wind speeds and stable atmospheric conditions. These conditions are most prevalent during the late fall months. Within any season, the likelihood of an exceedence also changes during the day, reaching a maximum during the evening rush hours. Evidence from the EPA Region X Seattle, Washington and Boise, Idaho studies indicates that the citywide distribution of high CO concentrations may be more uniform than has sometimes been thought. The study results indicate that the carbon monoxide problem is widespread and not restricted to downtown commercial districts. Further, both pedestrians and those individuals indoors are at times exposed to eight hour average CO concentrations exceeding the standard. The "hot spot" study characterized the meteorological and traffic conditions at congested intersections. Under conditions conducive to high dispersion rates, the local contribution to CO concentration levels tends to be high. Under conditions conducive to low dispersion rates, the local contribution tends to be low. At low dispersion rates, the CO problem may be more of an areawide than a hot spot problem. The percent reduction needed study focused on when and how many of the nation's counties will meet the NAAQS. That study indicated that 90 percent of warm weather standard exceedences would be eliminated by 1985. However, during cold weather, when the likelihood of an exceedence is greater, an additional 20 percent emissions reduction from mobile sources <u>beyond that which is already</u> accounted for by current control measures will be required to eliminate even 90 percent of current exceedences.

Distribution of CO Emissions For All Counties

FIGURE 1

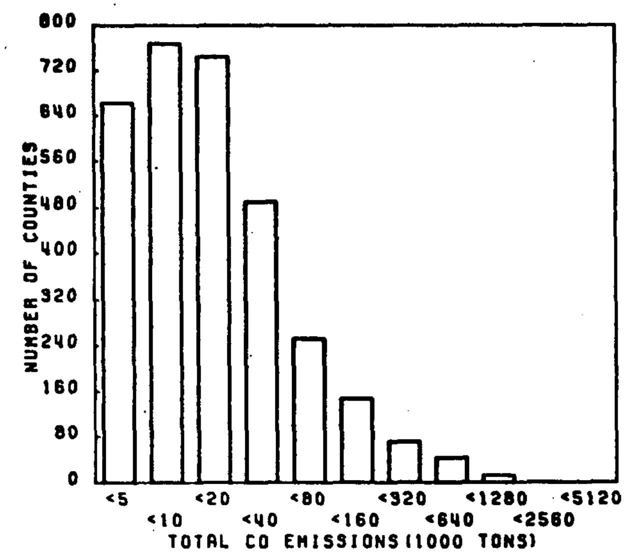


FIGURE 2

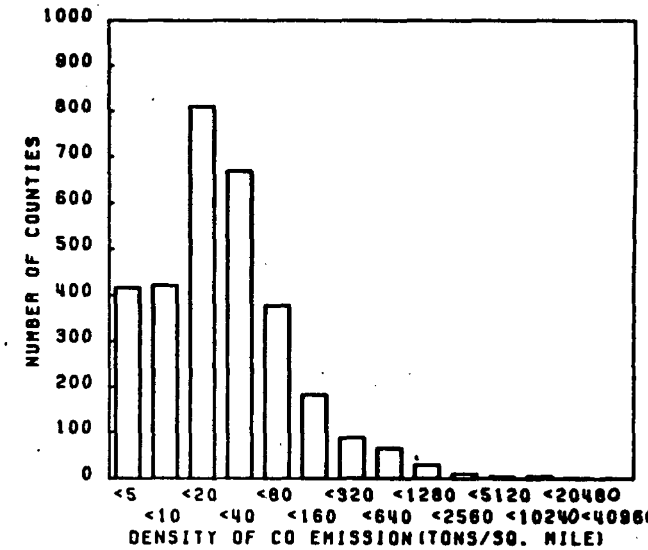


FIGURE 3

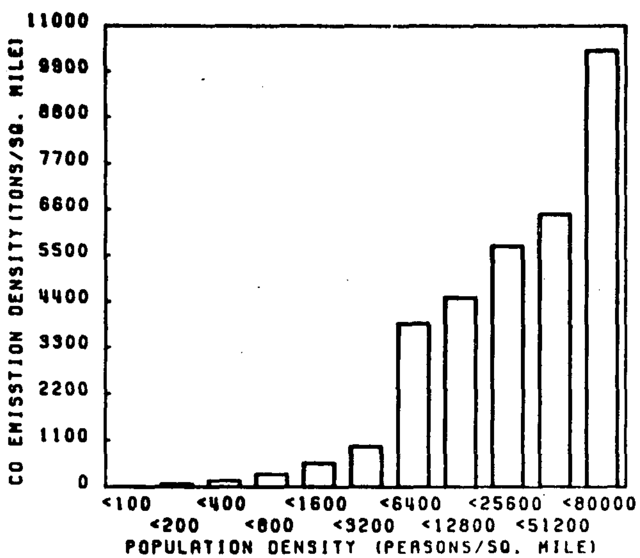
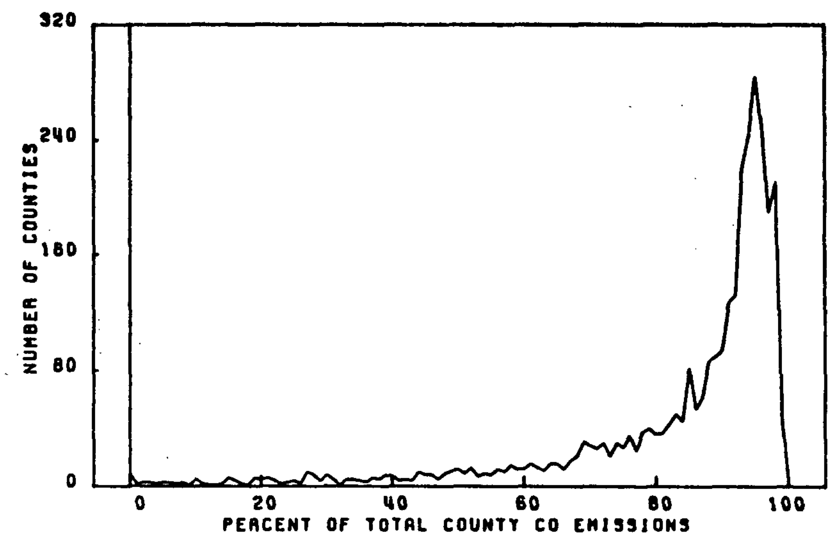


FIGURE 4



Distribution of CO Emissions For Worst Counties

FIGURE 5

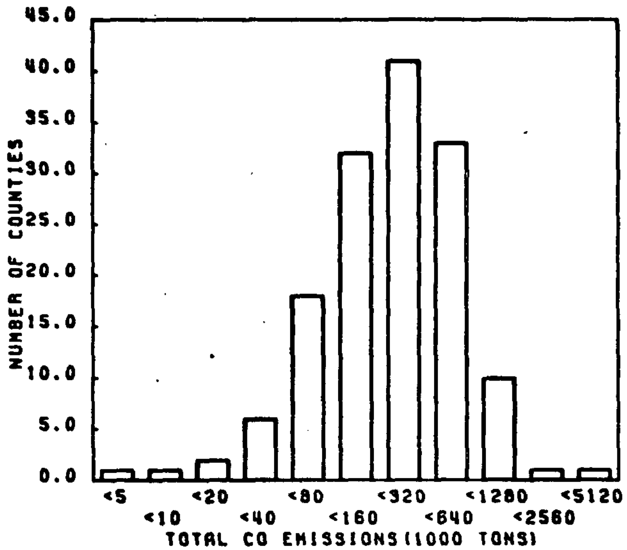


FIGURE 6

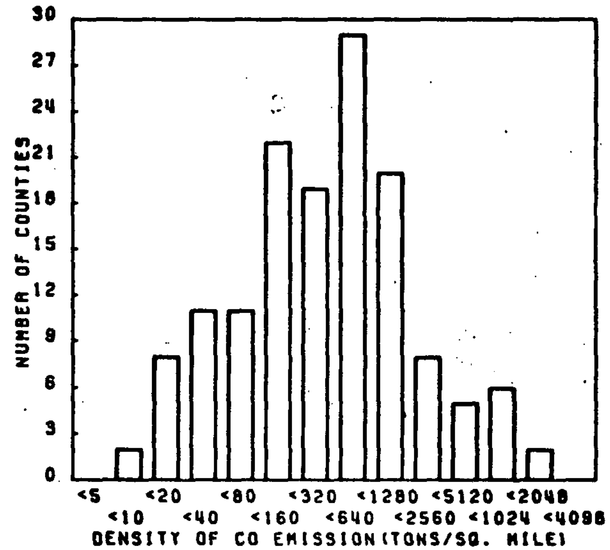


FIGURE 7

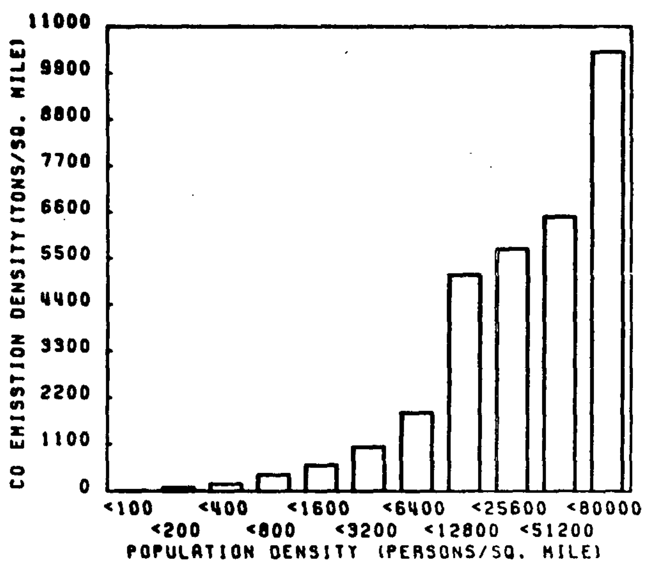


FIGURE 8

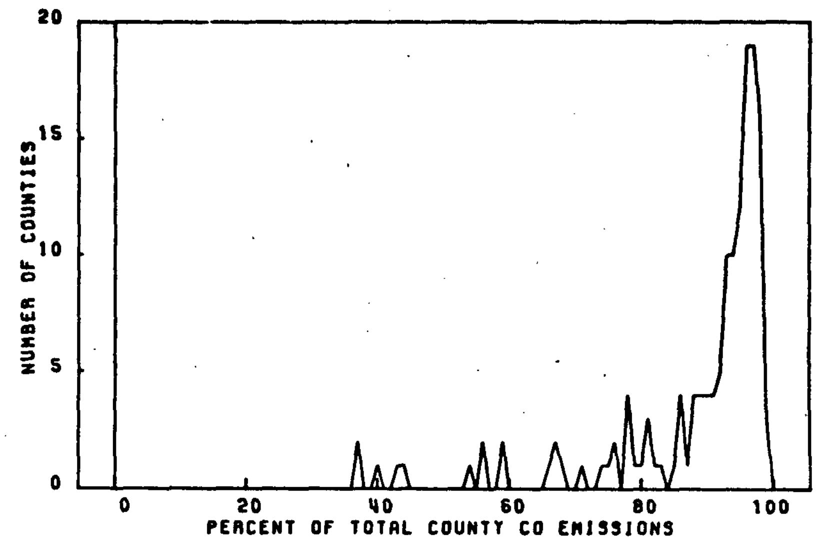


FIGURE 9 MOTOR VEHICLE EMISSION TEMPERATURE EFFECTS

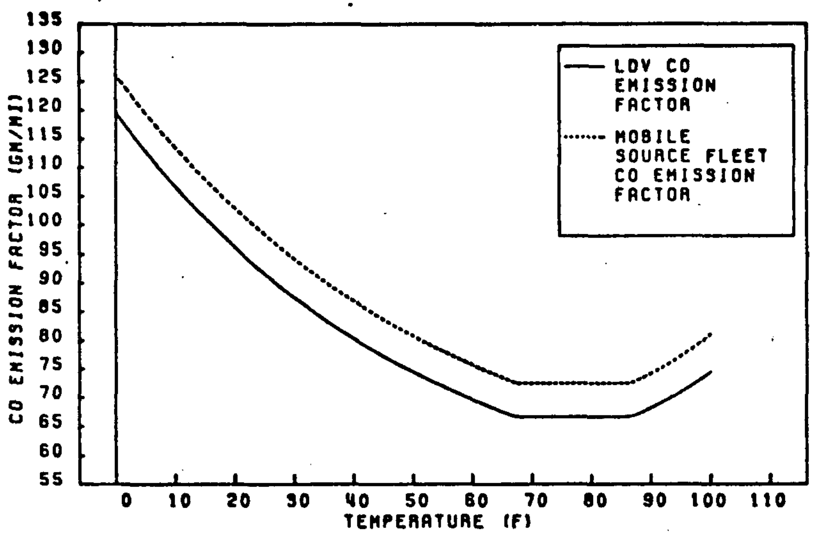


FIGURE 10 EXCEEDENCES OF THE 8 HOUR CO NAAQS

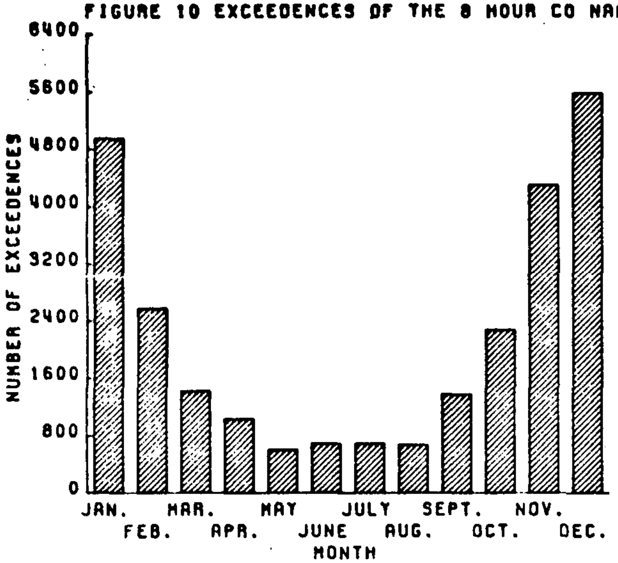
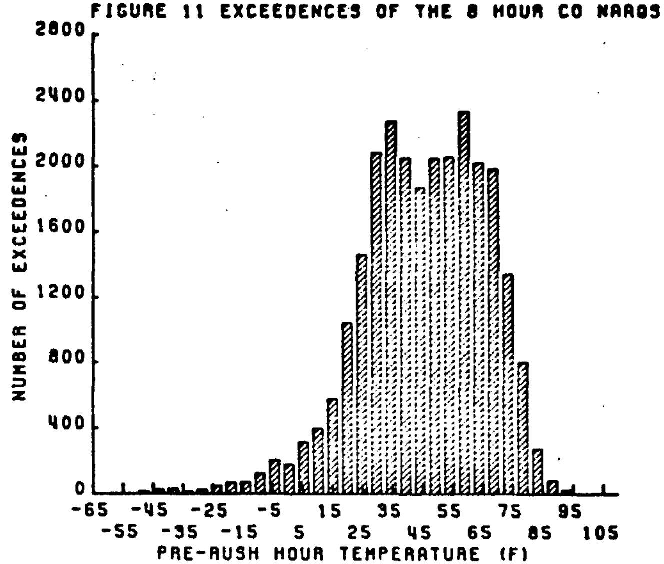


FIGURE 11 EXCEEDENCES OF THE 8 HOUR CO NAAQS



Likelihood of a 8 hour CO NAAQS Exceedence

FIGURE 12

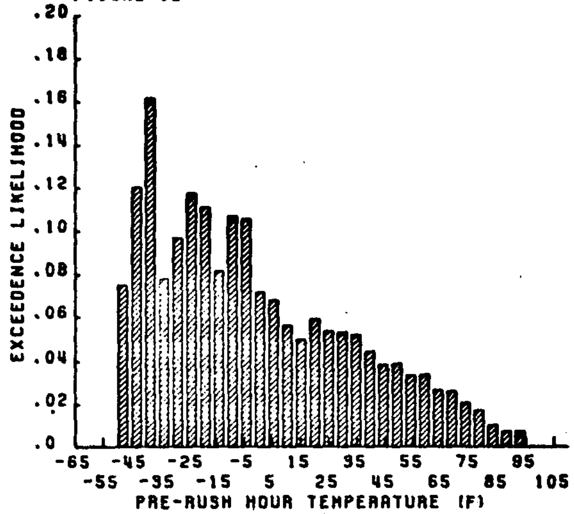


FIGURE 13

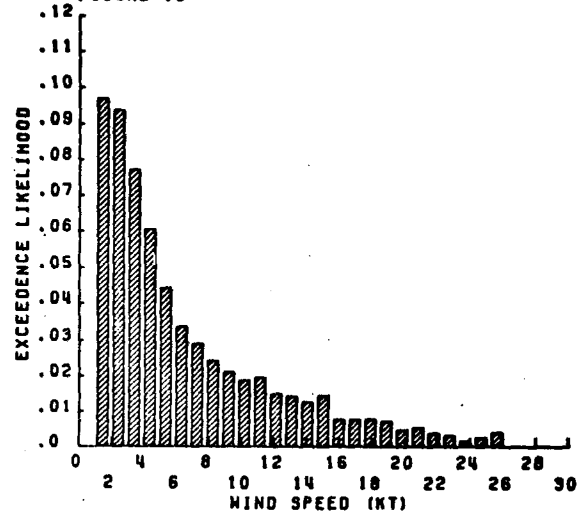


FIGURE 14

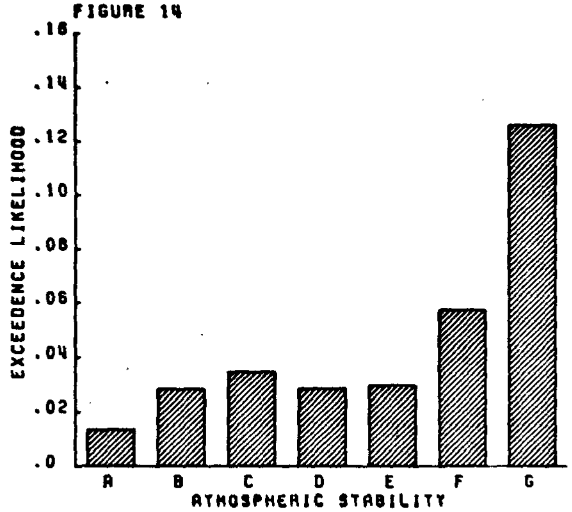


FIGURE 15

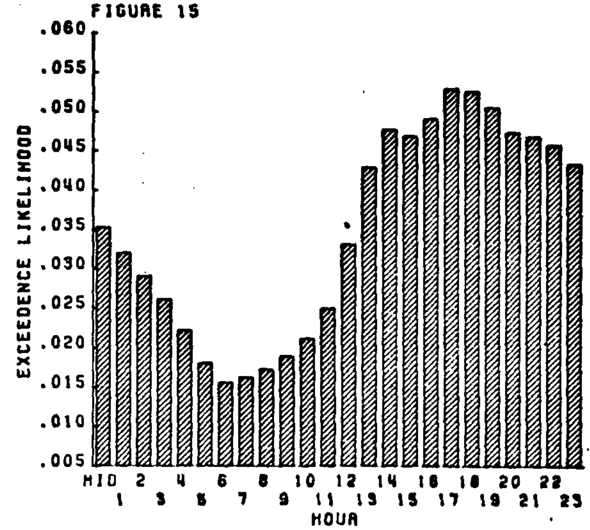
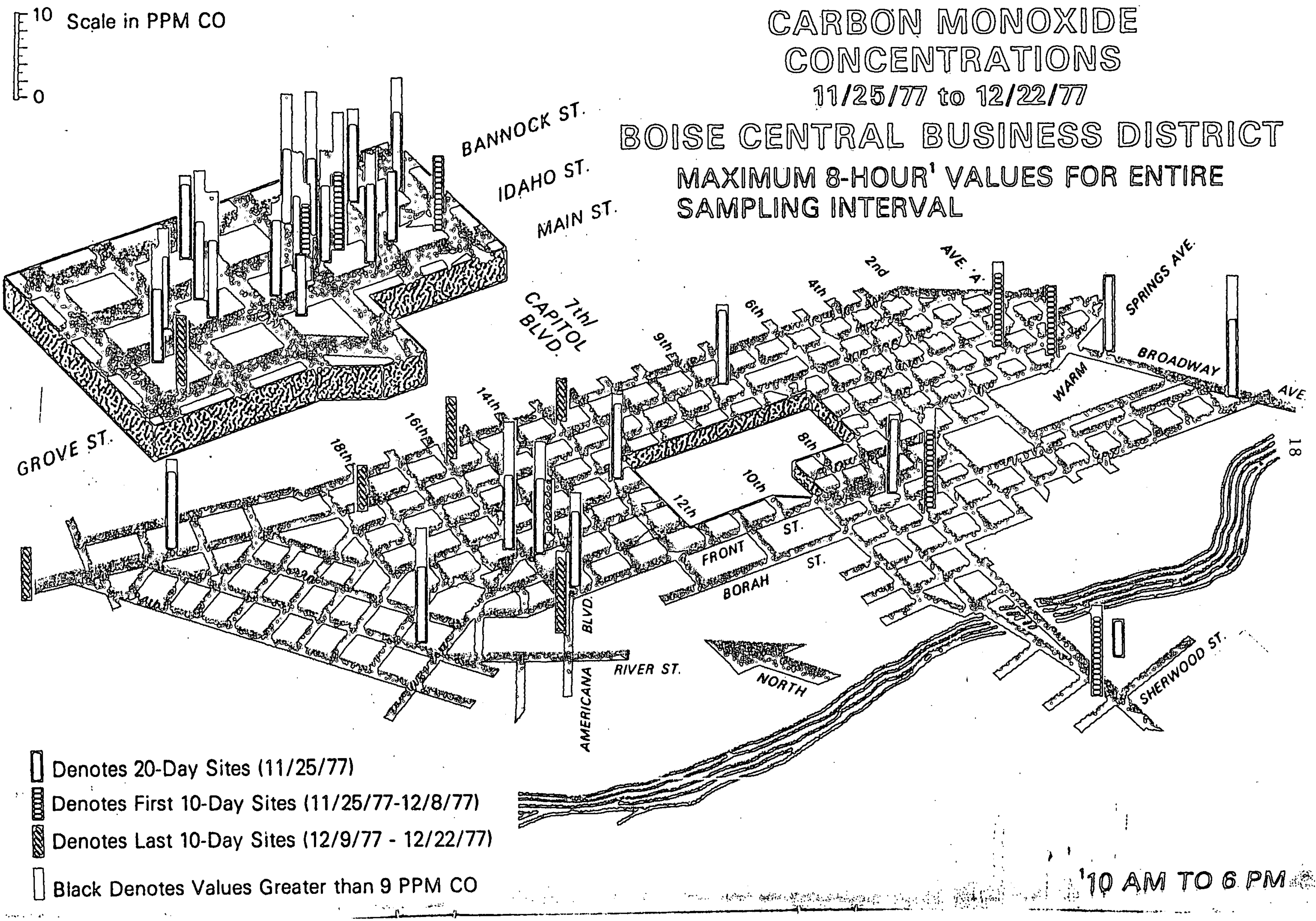


Figure 16



10 Scale in PPM CO
0
CARBON MONOXIDE
CONCENTRATIONS
11/25/77 to 12/22/77
BOISE CENTRAL BUSINESS DISTRICT
MAXIMUM 8-HOUR¹ VALUES FOR ENTIRE
SAMPLING INTERVAL
BANNOCK ST.
IDAHO ST.
MAIN ST.
GROVE ST.
7th/
CAPITOL
BLVD.
2nd
AVE. 'A'
SPRINGS AVE.
4th
6th
9th
14th
16th
18th
8th
10th
12th
WARM
BROADWAY
AVE.
FRONT
ST.
BORAH
ST.
BLVD.
AMERICANA
RIVER ST.
NORTH
SHERWOOD ST.
Denotes 20-Day Sites (11/25/77)
Denotes First 10-Day Sites (11/25/77-12/8/77)
Denotes Last 10-Day Sites (12/9/77 - 12/22/77)
Black Denotes Values Greater than 9 PPM CO
¹10 AM TO 6 PM

Reduction Needed In Mobile Source CO Emissions

FIGURE 17

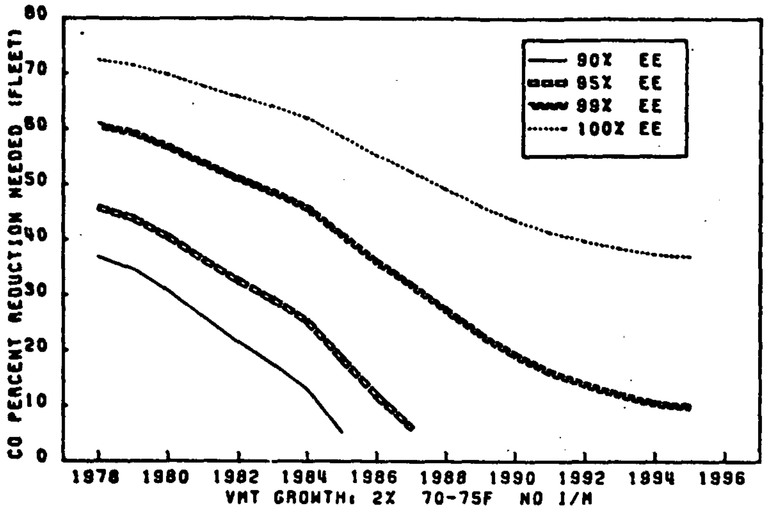


FIGURE 18

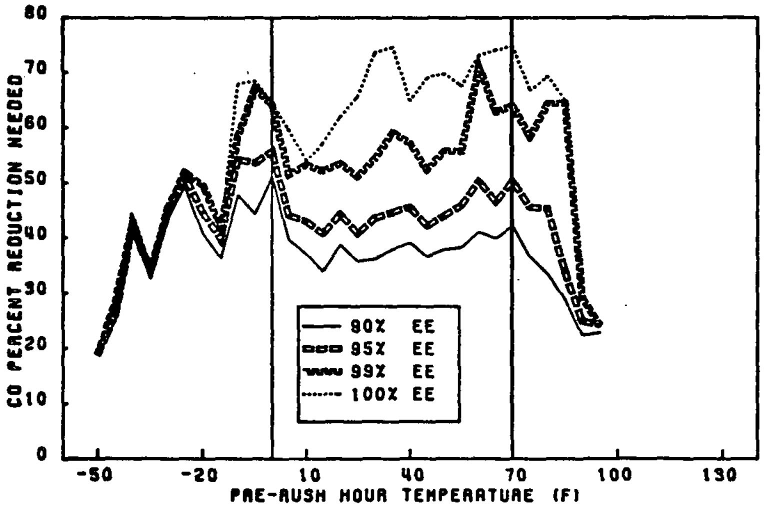


FIGURE 19

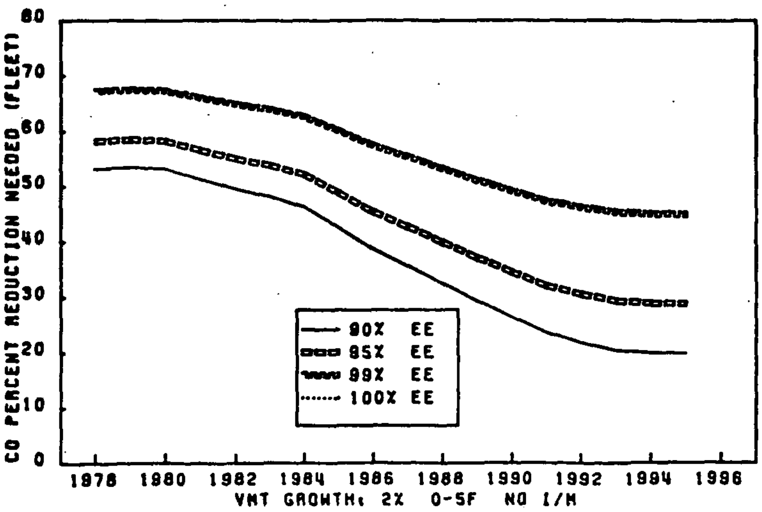


Table 1

Level of Control Required to Meet CO NAAQS

Temperature Range (F)	Exceedences of CO NAAQS Eliminated 90%	95%	99%
0-5	51(a)	56	64
25-30	36	41	51
70-75	42	50	64
95-100	23	24	24

(a) Percent reduction in ambient CO concentrations required to eliminate 90% of NAAQS exceedences in the 0-5°F temperature range. This is a reduction from the emissions levels observed in the 1975-1977 vehicle fleet.

Source: Reference 10

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5. Identification of Meteorological Conditions During Oxidant, CO and Nitroge Dioxide Ambient Violation Conditions, U.S. Environmental Protection Agency, Discussion Draft, April, 1979.

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8. Carbon Monoxide Study, Boise, Idaho, EPA 910/9-78-055, U.S. Environmental Protection Agency, Region X, Seattle, Washington, December, 1978.

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11. MOBILE2 is a highway mobile source emissions computer model based on data released in November, 1980.