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Carbon Monoxide Hot Spot Guidelines

Volume II: Rationale

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Carbon Monoxide Hot Spot Guidelines

Volume II: Rationale

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ABSTRACT

This report presents the rationale used in developing the analytical techniques for the carbon monoxide hot spot guidelines.

Discussed in this report are the technical aspects of the guidelines, including the assumptions used in developing hot spot procedures. Since the guidelines were based largely on EPA's Indirect Source Guidelines, these are discussed in some detail, as well.

PREFACE

This document is the first in a series comprising the Carbon Monoxide Hot Spot Guidelines. The purpose of this series is to provide state and local agencies with a relatively simple yet accurate procedure for assessing carbon monoxide hot spot potential on urban street networks. Included in the Hot Spot Guideline series are:

Volume I: Techniques
Volume II: Rationale
Volume III: Summary Workbook
Volume IV: Documentation of Computer Programs to Generate Volume I Curves and Tables
Volume V: Intersection-Midblock Model User's Manual
Volume VI: Modified ISMAP User's Manual
Volume VII: Example Applications at Waltham/Providence/Washington, D.C.

Hot spots are defined as locations where ambient carbon monoxide concentrations exceed the national ambient air quality standards (NAAQS). For both the 1-hour and 8-hour averaging times the assumption is made throughout these guidelines that a CO hot spot is primarily affected by local vehicle emissions, rather than areawide emissions. Studies have shown that for the 1-hour CO concentration, local sources are the dominant factor. Accordingly, representative urban worst-case meteorological, traffic, and background concentration conditions are selected as those corresponding to the period of maximum local emissions — usually the period of peak traffic. For 8-hour concentrations evidence indicates that neither the local nor the areawide contributions can be assumed to be dominant in every case. However, for the purpose of analysis discussed in these guidelines, local source domination of CO hot spots is assumed for 8-hour averages. This allows some consistency between assumptions in relating the 1-hour and 8-hour CO estimates.

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ACKNOWLEDGMENTS

We wish to acknowledge the significant contributions made early in the development of the Hot Spot Guidelines by previous GCA/Technology Division staff members, including Dr. Robert Patterson, Messrs. David Bryant, Alan Castaline, and Walter Stanley. We are especially indebted to the EPA Project Officer, Mr. George J. Schewe of the Source Receptor Analysis Branch, who provided overall project direction and performed extensive technical and editorial review of the final reports.

SECTION I

INTRODUCTION

INTRODUCTION

This volume, Volume II, is part of a seven-volume report providing guidelines for identifying and analyzing carbon monoxide "hot spots"-locations with the potential for experiencing violations of the National Ambient Air Quality Standards (NAAQS) for CO. These guidelines are intended for engineers, planners, and others who must consider the air quality effects of traffic management decisions and who are responsible for traffic planning to control CO hot spots.

The guidelines present two levels for screening potential hot spots. One is a screening procedure to identify potential carbon monoxide hot spots using only data on automobile traffic volumes, thus obviating time-consuming and costly monitoring of air quality at potential hot spots. The other is a hot spot verification procedure that uses more detailed input data. This procedure provides the capability of accounting for a number of additional conditions beyond those assumed in the screening procedure, and it provides a worst case quantitative estimate of hot spot potential.

Volume I[1] discusses in detail the concepts of hot spot screening and verification as well as providing analytical techniques and procedures. Two companion volumes, this volume and Volume III, present the technical rationale behind the guidelines and a workbook. Volumes IV, V and VI provide documentation respectively on an intersection midblock traffic and dispersion model, the IMM; a traffic assignment and dispersion model, the modified ISMAP model; and the computer programs used to generate the curves and tables in Volume I. Volume VII presents the results of several application studies. The remainder of this volume describes the background and techniques in Volume I.

Section II provided a discussion of the rationale for developing the verification procedures described in Volume I. Also provides are discussions of the technical aspects of the guidelines including traffic, emission, and dispersion used and the basis for the assumptions. The emphasis is on how the various nomographs and tables were constructed rather than on how to apply the procedure. A similar discussion is provided in Section III concerning development of the screening procedures.

SECTION II

DEVELOPMENT AND ASSUMPTIONS OF THE VERIFICATION PROCEDURE

INTRODUCTION

The verification process in Volume I is a followup to the initial screening of an urban area. The intent is to perform a more thorough evaluation of the hot spot potential of a street section or intersection using a technique that permits input of parameters specific to that location rather than assumed parameters. While the initial screening process focused on identifying potential hot spot locations anywhere within a city or town (thus requiring a very general approach), the verification process involves analysis of specific locations, and a more detailed analysis of each location is feasible. Since the screening curves are developed from the same methodology as the verification procedure, using a more detailed set of assumptions, the development of the verification procedure is discussed first.

During an earlier project,[3,4] analysis of CO hot spots was initially envisioned as a two-step process: screening and detailed dispersion modeling. Development of the hot spot screening guidelines, originally intended to be the only hot spot guidelines, involved many assumptions and generalizations in order to achieve the simplicity that was desired. In these original guidelines the assumptions were such that the screening was thought to be overly conservative and thus limit their utility. Therefore, the test cases in Waltham, Massachusetts of the Hot Spot Guidelines were reanalyzed utilizing the Indirect Source Guidelines,[5] ISG (1975) to check the degree of conservativeness.

The application of the Indirect Source Guidelines to the Waltham study locations led to the following conclusions:

- The hot spot screening guidelines are not overly conservative, as demonstrated by the fact that the screening guidelines identified only a few more potential hot spots in the Waltham case study than did the application of the more detailed Indirect Source Guidelines.

- The Indirect Source Guidelines are a workable method for analysis of potential hot spots, and allow the use of more data specific to conditions at individual locations. Results are quantitative, rather than qualitative.

- The Indirect Source Guidelines can, in some cases, be used for assessment of alternative improvement measures, in lieu of detailed computer modeling.

These conclusions led to a recommendation for using the Indirect Source Guidelines as the foundation for a second, verification stage of hot spot potential. However, the Indirect Source Guidelines have been revised[2] and they (the original Guidelines[5]) are no longer suitable for the level of analysis desired for hot spot verification. The Revised Indirect Source Guidelines[2] allow much more latitude in the selection of values of input variables than did the original Guidelines, and their application is similarly much more complex. In developing revised verification procedures based on the Revised Indirect Source Guidelines, the intent was to deep the requirements on the user at about the same level as in the old verification method.

The remainder of this section discusses how the new verification procedures were derived using the Revised Indirect Source Guidelines, the Automobile Exhaust Emission Modal Analysis Model,[12] and the Compilation of Air Pollutant Emission Factors (AP-42).[6] In particular, three specific

Assumptions

Before we begin a detailed discussion of the derivation of the normalized concentration curves, used in Volumes I and III, we list a number of the more important assumptions upon which these curves are based. The rationale for these assumptions are presented in the following sections.

- Queue lengths for each of the four approaches to the intersection are assumed to be equal to the queue length on the approach adjacent to the receptor (designated as approach 1). Criteria for the selection of a given intersection approach for the placement of a receptor are presented in Volume I. It must be remembered that lane volumes are used in the calculation of queue lengths, but approach volumes are used to calculate excess or free flow emissions.
- Each of the two intersecting streets are 10 meters wide.
- The distance from the receptor to the centerline of approach 1 is 10 meters.
- Consistent with worst case urban conditions, the atmospheric stability is chosen to be category D, windspeed is assumed to be 1 m/sec, and the initial vertical dispersion (σ_{ZO}) is assumed to be 5 meters.
- The optimum wind angle and location of the receptor along approach 1 (at a perpendicular distance of 10 m from the approach centerline) will depend upon the queue length calculated for this approach. The resultant wind angle and receptor location is then used for the calculation of normalized concentration contributions for excess emissions from the three remaining queues and the free flow emissions from all four approaches.

Intersections - Queueing Vehicles

The main technical problem in deriving the hot spot verification procedures was to develop curves relating traffic parameters to normalized CO concentrations at the critical receptor location for the interrupted flow, or intersection, case. The location of the point of maximum concentration varies along a line parallel to the roadway depending on the queue length and the wind angle.

Figure 1 shows the intersection configuration for the determination of the receptor location and wind angle (θ). For the discussion that follows, all measurements in the direction of the approach in question will be taken from a reference plane located 20 m behind the receptor. For a wind perpendicular to the road, the reference plane establishes the extent of the line source emissions that significantly affect the concentration at the most distant receptor considered. Its use will become apparent in the following discussion. As shown in Figure 1 the distances from the reference plane to the downwind and upwind boundaries of the queue are Yd and Yu respectively, so that:

$$Yu = Yd + Le$$

where Le = queue length (m).

Figure 2 depicts the normalized[*] concentration (χ_e^*) contribution from approach 1 as a function of effective queue length, Le, on that approach. It is assumed that all lanes comprising approach 1 develop queues of equal length. The CO concentration at the receptor site is maximized when the wind angle θ is such that the contribution from the nearest lane is maximized. Figure 2 was developed from Figure 3 which is taken from the Revised Indirect Source Guidelines[2] (σ_{ZO} = 5m, stability class D). Figure 3 is based on sequential runs of HIWAY[12] and treats queuing vehicles as finite line sources. χ_e^* is a function of the distance from the receptor to the emission source(x), the roadway/wind angle (θ), the length Yu, and the length Yd. χ_e^* equals $\left(\chi_e^*(Yu) - \chi_e^*(Yd)\right)$ and Yu equals (Le + Yd) where Le is the effective queue length. For a given queue length Le and distance x, χ_e^* is maximized when the following condition is satisfied:

$$\frac{d\chi_e^*}{d\theta} = 0$$

that is, when χ_e^* is at a peak value in the curves in Figure 3.

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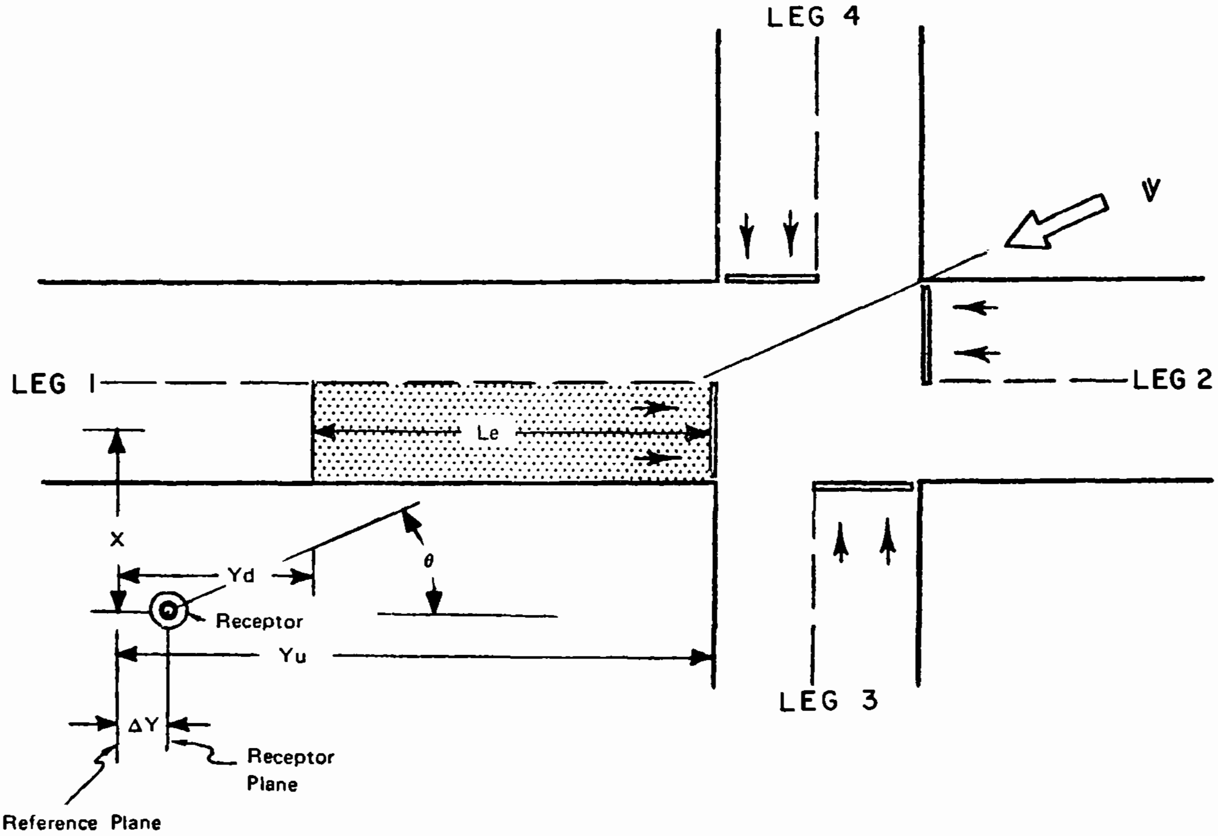
[*] Normalized with respect to wind speed and emissions, such that $\chi_e^* = \frac{\chi_e U}{Q}$



Yu = Distance from reference plane to upwind end of queue (m)

Yd = Distance from reference plane to downwind end of queue (>0)
(Distance is denoted positive to windward) (m)

ΔY = Distance between receptor and reference plane (20m)

Le = Effective excess emissions length (m)

V = Wind vector

θ = Wind/roadway angle (acute)

x = 10m

Figure 1. Intersection geometry

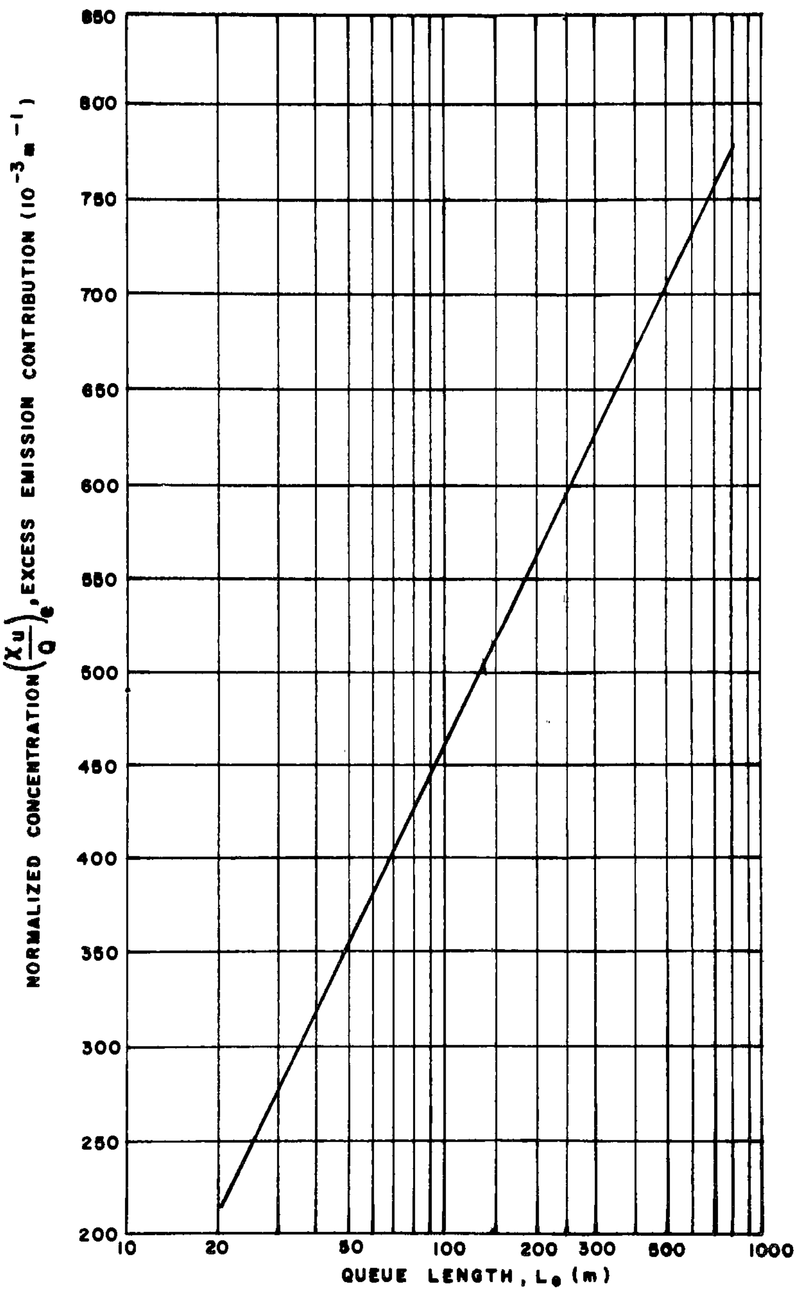


Figure 2. Normalized CO concentration contribution from excess emissions on approach 1

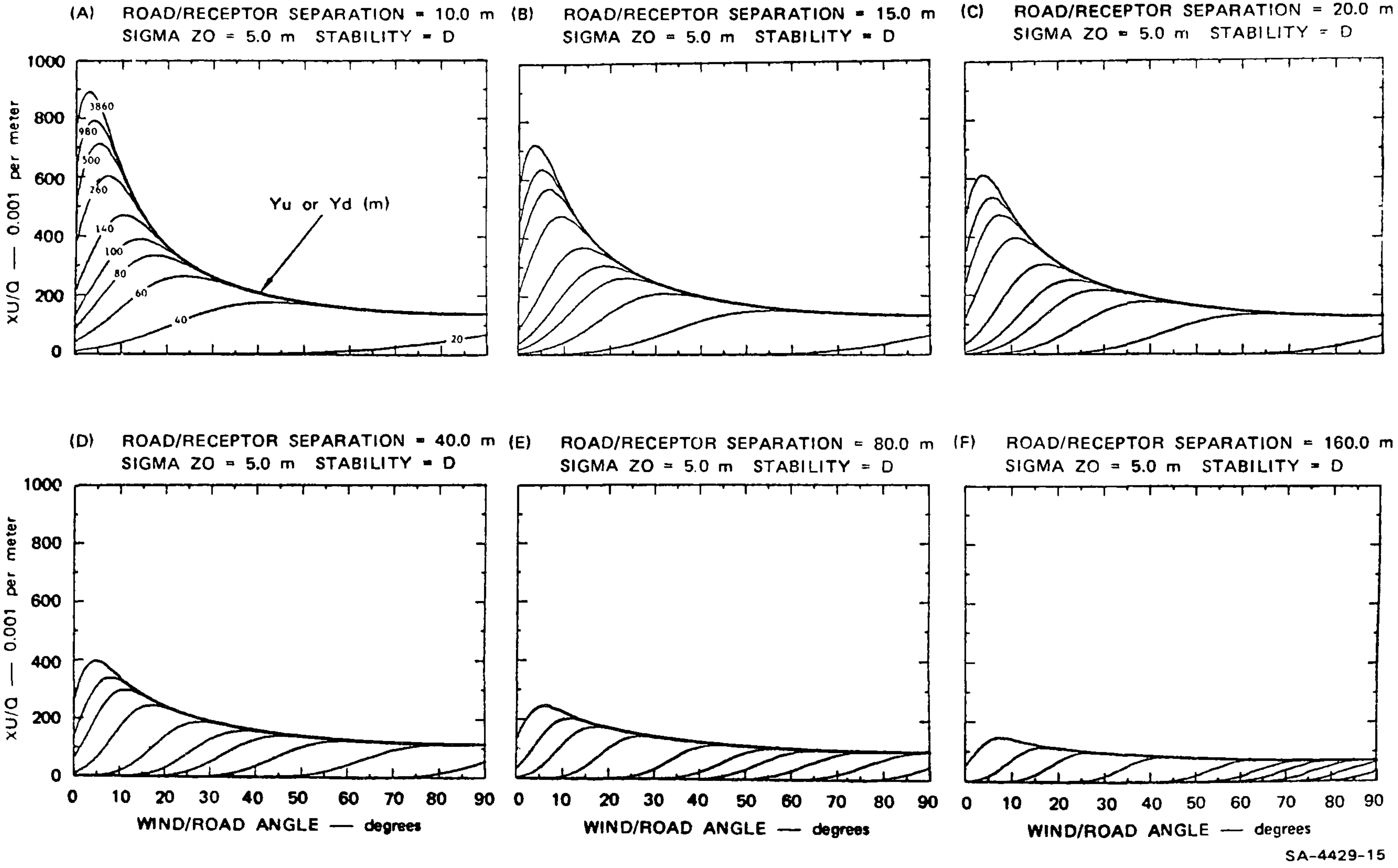


Figure 3. Variation of the normalized CO concentration with roadway length, road/receptor separation, stability, wind/road angle

In terms of Figure 3a, one would move the receptor downwind of the queue (subject to the constraint of a 10 m road receptor separation), thereby decreasing the wind/road angle and increasing both Yu and Yd. This maximization procedure is actually a two-step process in which the distance Yd and therefore Yu are first selected and then the wind angle which maximizes $(\chi_e^*(Yu) - \chi_e^*(Yd))$ is determined. A larger value of Yd is then obtained. In practice, a value of Yd of approximately 20 m was found to maximize χ_e^* in most cases.

Figure 4 is used to determine the χ_e^* contributions from legs 2, 3, and 4 of the intersection. This graph was also developed from Figure 3. This curve was formulated by assuming the road center/receptor seperation, x of the leg 2 approach is 15 m and $Yu_{\text{approach 2}} = Yu_{\text{approach 1}} + Le + 10$ m. Inherent in the latter assumption is the fact that the queue which develops on approach 2 is the same length as that which develoos on approach 1 (Le). $Yd_{\text{approach 2}} = Yu_{\text{approach 2}} - Le$, and θ is the same as determined previously for approach 1, at the corresponding Le. Hence, all variables are specified and χ_e^* for approach 2 can be derived from Figure 3(B).

The procedure is slightly different for determining the excess emissions from the crossroad, approaches 3 and 4. The reference plane must be rotated 90^o to yield the intersection geometry depicted in Figure 5.

The actual receptor location (where the contribution from approach 1 is maximized) remains unchanged, as does the wind direction. However, the roadway/wind angle θ' is $90^o - \theta$. Yu = 27.5 m and Yd = 0 for approach 3. The roadway/receptor separation distance $x = Yu_{\text{approach 1}} - 12.5$ m. Thus, x varies as Le changes on approach 1.

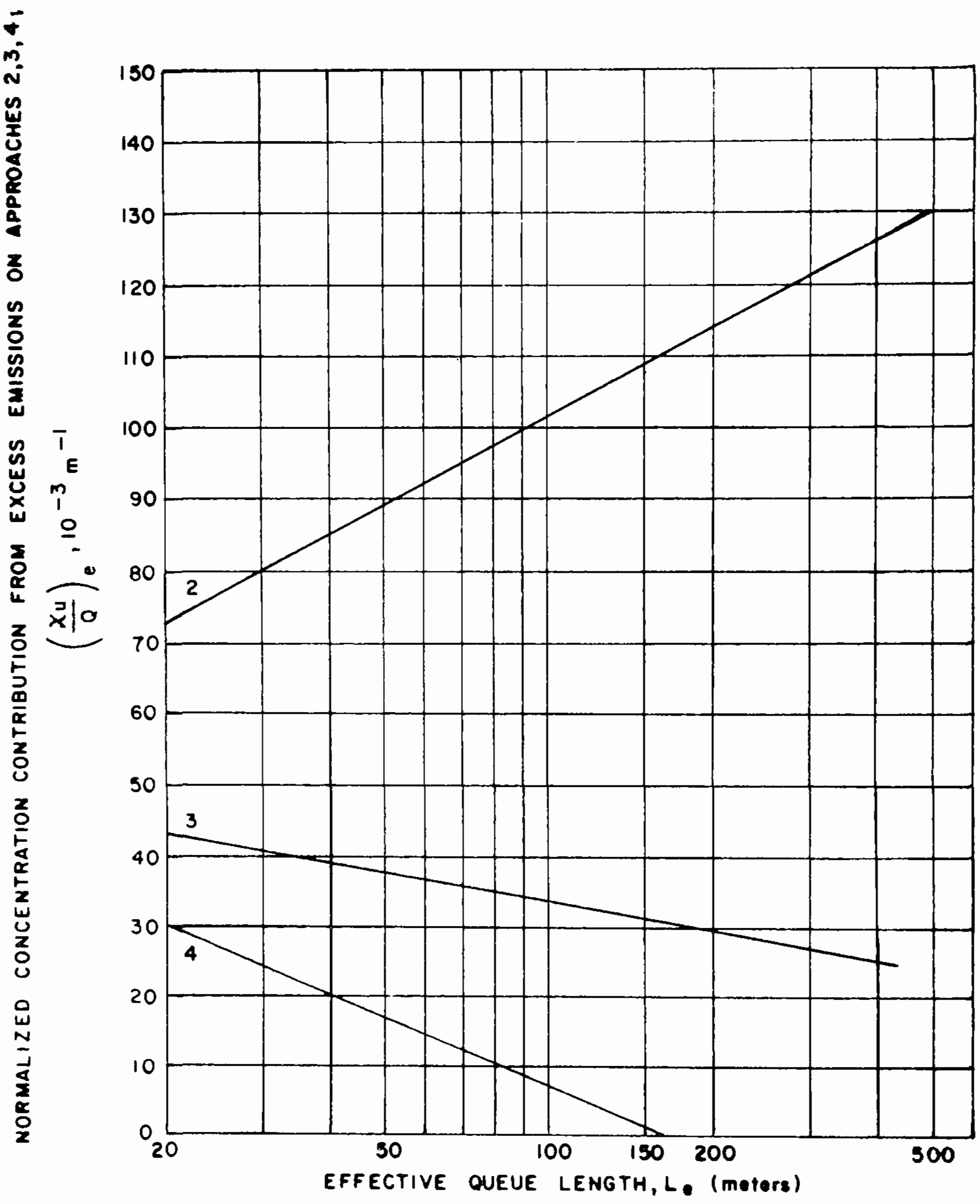
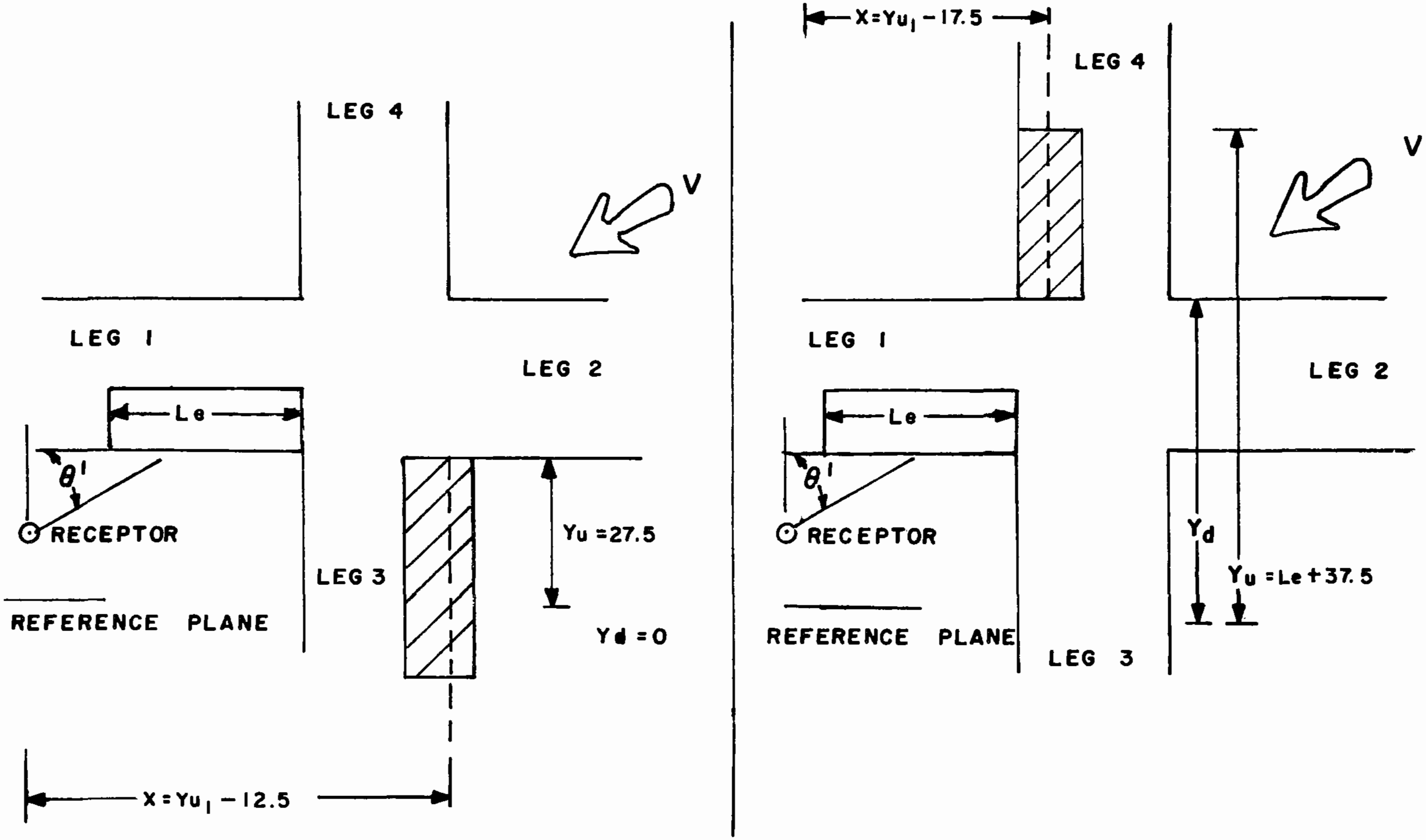


Figure 4. Normalized CO concentration contributions from excess emissions on approaches 2, 3, and 4



(a) APPROACH 3 CONTRIBUTION

(b) APPROACH 4 CONTRIBUTION

Figure 5. Intersection geometry - crossroad

For approach 4, χ_e^* is calculated at $\theta' = 90^\circ - \theta$, $Yu = Le + 37.5$ m, $Yd = 37.5$ m, and $x = Yu_{\text{approach 1}} - 17.5$ m. Note that slight errors will result for crossroad flow configurations and lane widths which would yield values of x that differ from that of the estimated values. However, this error will be extremely small since the χ_e^* value at large θ changes very slowly with changes in x; i.e., $\frac{d\chi_e^*(\theta)}{dx} \approx 0$ at $\theta > 45^\circ$.

Figure 6 gives the distance correction factors (Cxe) for the χ_e^* terms previously determined. These curves were derived by calculating the χ_e^* values in the HIWAY model at road/receptor separation distances other than 10 m, thus at different optimum wind angles. The ratio of these χ_e^* values to χ_e^* at $x = 10$ was plotted. The curves are given for queue lengths only up to 180 m, since longer queue lengths produce curves that vary only slightly from the 180 m queue length curve.

Intersections - Through Vehicles (Free-Flow)

In making CO concentration estimates at a receptor near an intersection, the contribution from free-flowing vehicles, that is, those that do not stop, on each leg must also be considered.

Figure 7 from the Volume 1 procedures depicts the normalized concentration contribution from free-flowing traffic, χ_f^*, as a function of queue length Le. Actually χ_f^* is a function of the θ which maximizes the excess emission contribution, χ_e^*, at that Le. Excess emissions contributions are generally higher than free-flow, hence the use of the θ and Le that maximizes χ_e^*. Figure 8, from the Revised ISG, was used in generating the curves by taking a given Le and the associated roadway/wind angle, θ, as determined previously in constructing Figure 3, and finding χ_f^*. Curves are plotted for both the main road and crossroad at each intersection.

Distance correction factors similar to those derived in Figure 6 are shown for free-flow traffic contributions at intersections in Figure 9.

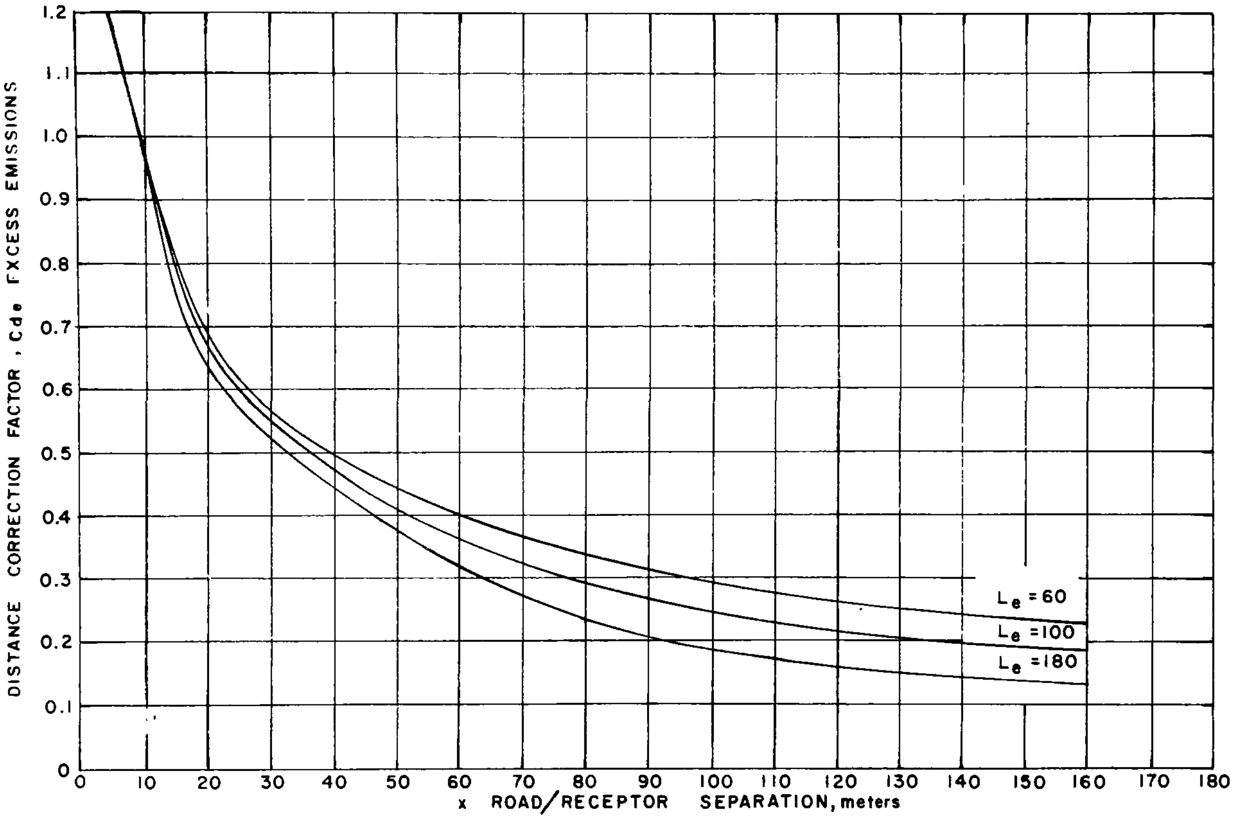


Figure 6. Distance correction factor for excess emission contributions at intersections

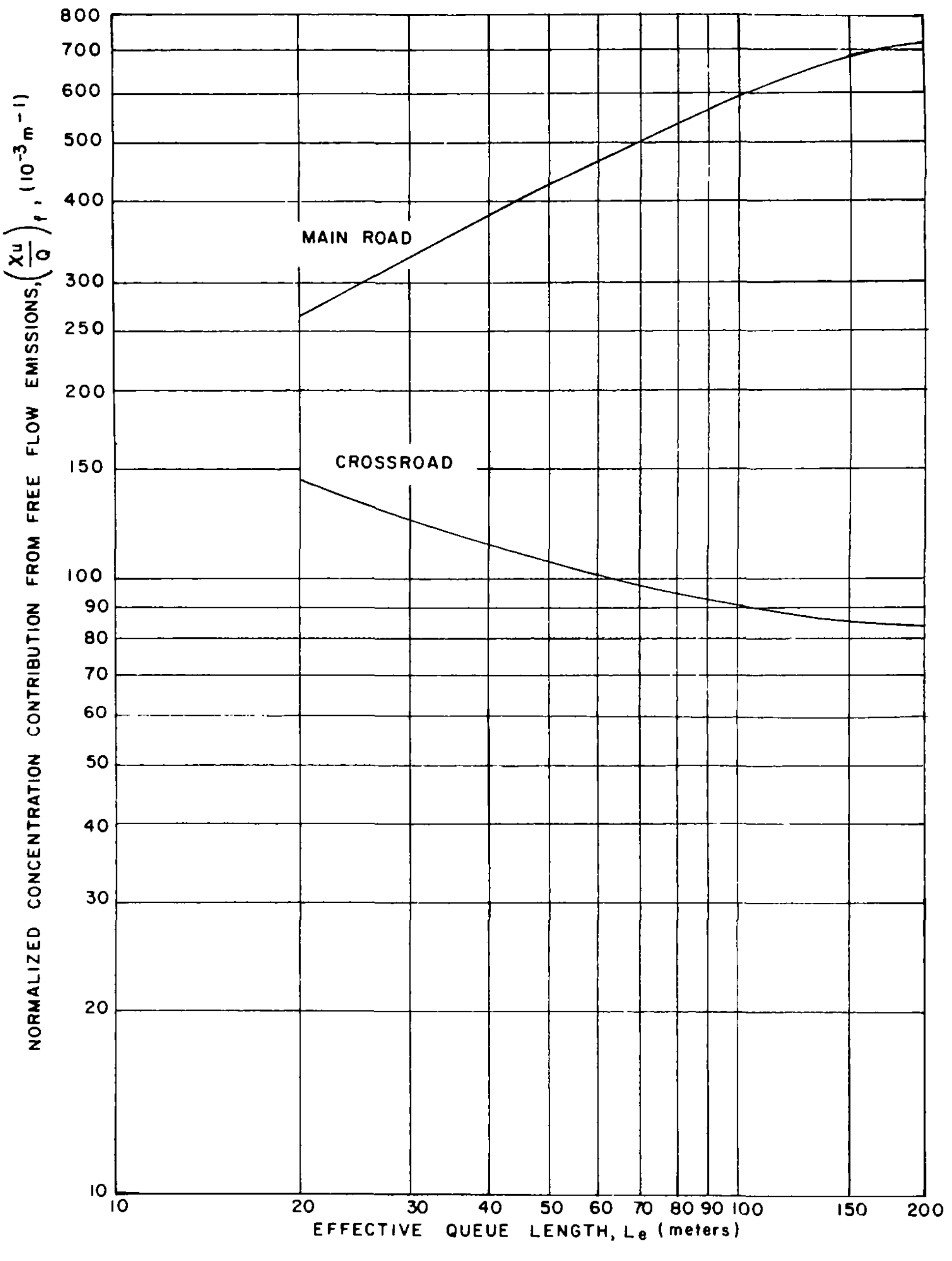


Figure 7. Normalized CO concentration contributions from free-flow emissions on each lane of roadways at intersections

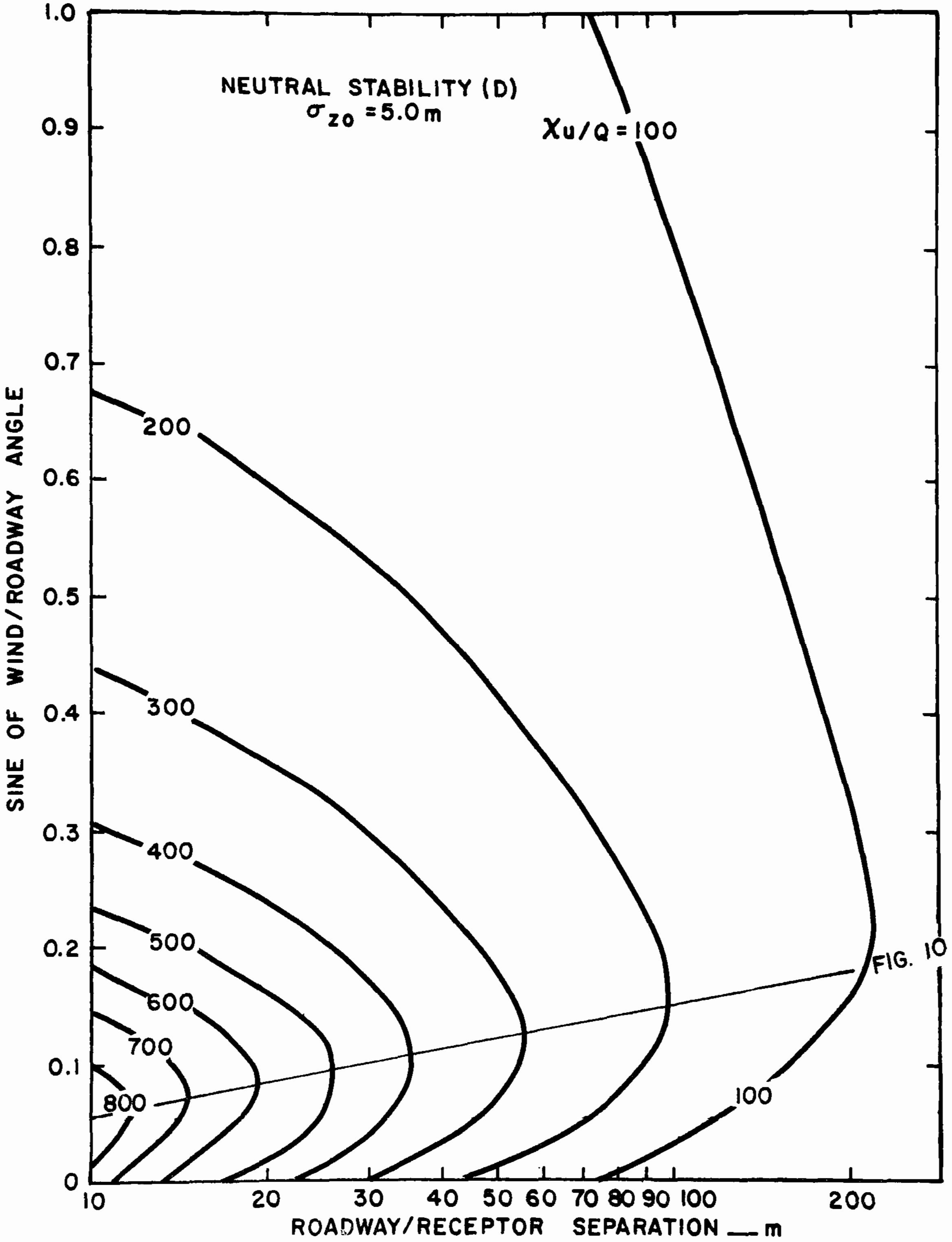


Figure 8. Values of $\chi u/Q$ ($10^{-3}m^{-1}$) for various roadway/receptor separations and wind/roadway angles; infinite line source

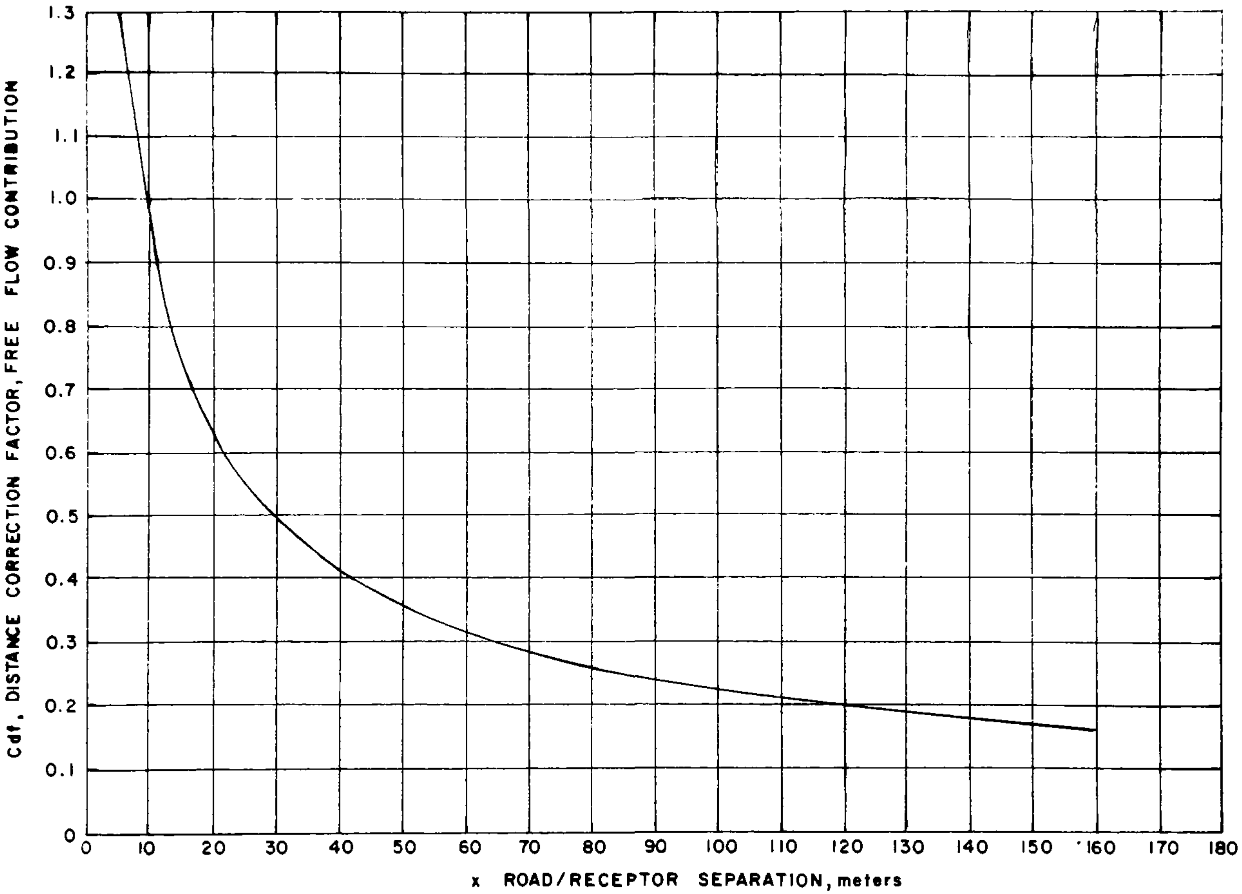


Figure 9. Distance correction factor for free-flow emission contributions at intersection locations

Uninterrupted Flow

Curves for concentration estimates from uninterrupted flow roadways (expressways, midblock locations, etc.) in Volume I are derived similarly to the above from the infinite line source curves (Figure 8) in the Revised Indirect Source Guidelines.[2] Figure 10 gives the normalized concentration contributions from each traffic stream. In this case χ_f^* is a function of the road/receptor distance, x, and the road/wind angle, θ, and are taken from the maximum concentration estimates in Figure 8. Because χ_f^* is a function of x no further distance correction is needed.

Further Comments on Curves

The procedure just described is based upon a number of limiting assumptions. The most important of these is that the position of the critical receptor location at an intersection is determined by the queue length on approach 1. Ideally, the receptor should be located so as to maximize the joint contributions from the free flow emissions and the queue emissions on all approaches but this approach would be quite difficult to implement on a graphical basis. Using the queue on approach 1 to locate the critical receptor is a reasonable approximation for the following reasons:

- The relative concentrations of approaches 2, 3 and 4 are small with respect to approach 1. For example, a queue length of 60 meters (approach 1) will contribute approximately 70 percent of the contribution of all queues combined.
- Although the normalized contribution of queue and free flow emissions are comparable, the excess emissions assigned to the queue are often several times higher than the free flow emissions.
- If free flow emissions were allowed to influence the choice of the critical receptor and the wind angle, the wind angle which would have been selected for the 10 meter road-receptor configuration would have been too small in terms of finite queues or finite line sources. The assumption of an "infinite" line source for free-flow traffic does not apply very well near intersections, hence the use of the limiting wind/road angle dependent on queues.

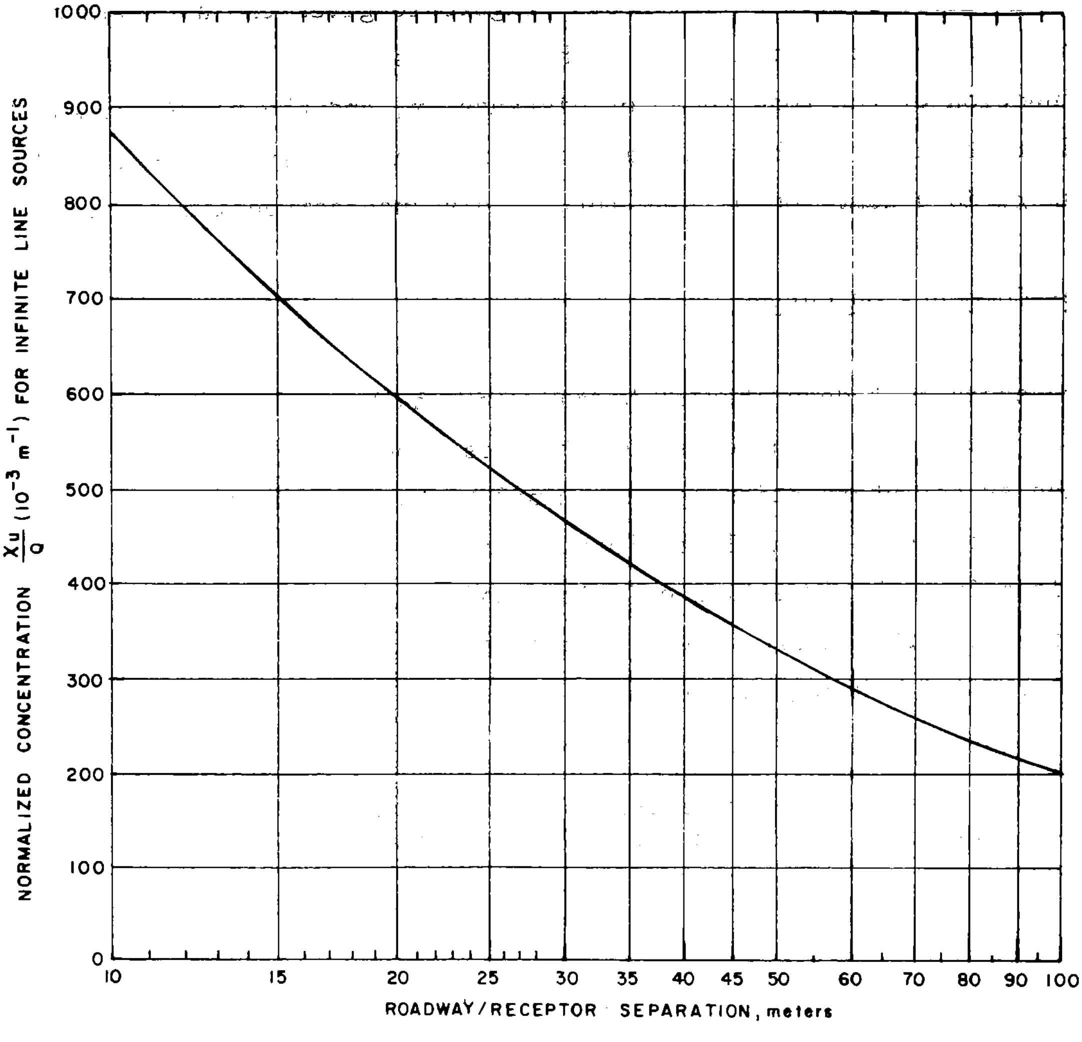


Figure 10. Normalized CO concentration contribution from each traffic stream at locations of uninterrupted flow

The green phase length is a fraction of the signal cycle time minus the total amber time. A 3-second amber time is assumed for all green phases. The green phase length of phase j is given by the following equation:

$$G_j = Cy \frac{\max\limits_{i} (V_{i,j}/Cs_{i,j})}{\sum\limits_{\text{all } j} \max\limits_{i} (V_{i,j}/Cs_{i,j})} - 3 \qquad (6)$$

where $\max\limits_{i} (V_{i,j}/Cs_{i,j})$ is the maximum V/Cs ratio on all approaches i moving on green phase j.

3 is an assumed 3-second amber time.

$\sum\limits_{\text{all } j} (V_{i,j}/Cs_{i,j})$ is the sum of the V/Cs ratios that control the green phase durations.

The approach capacity, C, is found by multiplying the approach capacity service volume by the appropriate green to cycle ratio and summing for all applicable phases. The capacity of an approach is given as follows:

$$C_i = \sum_j Cs_{i,j} \; Gj/Cy \qquad (7)$$

where j are those green signal phases that allow traffic to move on intersection approach i.

Unsignalized Intersection Traffic Movement

At unsignalized intersections, the number of queued vehicles, N, is given simply by

$$N = \frac{V}{C-V} \qquad (8)$$

The queue length is found using equation (3) or 40 meters as before, and the idle time is

$$Rq = \frac{360 \text{ ON}}{C} \qquad (9)$$

For an unsignalized intersection, the approach capacity, C, is estimated differently than for a signalized intersection. Instead of depending on the G/Cy ratio, it is a function of the traffic flow on the cross street and the time gap between cross street vehicles that is acceptable to a driver wanting to cross or turn onto the cross street. In this case C is found from

$$C_i = \frac{(2V)\ e^{-T(V_m + V_n)/3600}}{1 - e^{-T(2V)/3600}} \tag{10}$$

where V is the volume in one direction on the cross street in vph.

2V is the assumed two-way volume on the cross street.

The capacity on the cross street is assumed to be equal to the free flow capacity on that street. It is also assumed that no vehicles on the cross street stop at the intersection. The parameter T is the acceptable time gap (seconds) between cross street vehicles. It was assumed to be 4 seconds in developing Table 11 of Volume I. While this value is lower than that given in the Revised Indirect Source Guidelines and hence produces a higher capacity and fewer queued vehicles, it was chosen as being more appropriate for congested, potential hot spot locations where more aggressive driver behavior would previal.

Excess Emission Calculation

To calculate the excess emissions produced due to the queue length, Le, and the idle time, Rq, emissions must be known as a function of driving mode as well as speed. Thus, rather than using average speed as in AP-42,[6] an emissions estimating technique called the Modal Model[10] is used. The Modal Model calculates total emissions over a user-specified driving sequence by adding the emissions from each 1-second time interval of the driving sequence. The emissions during each interval are found as the product of the "instantaneous" emission rate and the 1-second time interval. The instantaneous emission rate, e, during deceleration and acceleration modes is a function of speed, v, and acceleration or deceleration, a:

$$\dot{e}_D\ (v,a) \text{ or } \dot{e}_A\ (v,a) = b_1 + b_2v + b_3a + b_4av + b_5v^2$$
$$+ b_6a^2 + b_7v^2a + b_8a^2v + b_9v^2a^2. \qquad (11)$$

where for this application it is assumed $a = 2.5$ mph sec^{-1}, a typical value.

During cruise mode it is a function of speed only:

$$\dot{e}_c\ (v,o) = b_{10} + b_{11}v + b_{12}v^2. \qquad (12)$$

These two equations were modified to calculate modal emissions for hot spot analysis as described below.

All Modal Model emission estimates above are from a user-specified vehicle age mix. The effect of different vehicle age mixes is to change the b_i coefficients of equations (11) and (12). These empirical coefficients were derived using 1975, warmed-up light-duty vehicle emission data deteriorated to 1977 emission levels.

Excess emissions are those occurring over and above those which would have occurred had the vehicle not stopped. This may be expressed by:

$$E_E = E_A + E_D - E_C + E_{ID}\ R_q \qquad (13)$$

where E_E = total excess emissions per vehicle

E_A = total emissions due to acceleration per vehicle

E_D = total emissions due to deceleration per vehicle

E_{ID} = total idle emissions per vehicle/per second

R_q = average queueing time (seconds)

E_c = total cruise emissions per vehicle

The emissions during acceleration or deceleration are found by relating speed to acceleration and time. Under constant acceleration or deceleration the speed can be expressed as a function of time as:

$$v = v_o + at \tag{14}$$

where v_o is the initial speed of the vehicle .
v is the vehicle speed after time, t
a is the rate of acceleration or deceleration
t is the time of travel

Substituting Equation (14) in Equation (11), and integrating over the time (T) to come to a stop or to reach cruise speed:

$$\begin{aligned} E_A &= \int_o^T \dot{e}_A \, (v(t),a) \, dt, \text{ grams per vehicle} \\ E_D &= \int_o^T \dot{e}_D \, (v(t),a) \, dt, \text{ grams per vehicle} \end{aligned} \tag{15}$$

Implicit in these equations is that the initial approach and the final departure speeds are assumed to be equal.

The emissions due to idling are not estimated using the Modal Model, but are calculated using AP-42 (1978) mobile source emission factors since the estimate of idle emission from the Modal Model, that is the use of b_{10}, is less accurate than the AP-42 factor. This is because AP-42, is from observed data and the Modal Model from an empirical fit. The cruise emissions may be estimated by using the vehicle speed in Equation (12). This is the estimated emissions per vehicle on an uninterrupted roadway. The cruise emissions used in Equation (13), however, must only be over the acceleration and deceleration distance so that only those emissions had the vehicle not stopped are subtracted.

When constant acceleration is assumed as in this analysis, the time (T) to cover the distance a vehicle travels accelerating from 0 mph to cruise speed, is traveled by a cruising vehicle in ½T. Hence, to calculate the equivalent emissions of a cruising vehicle during acceleration and deceleration, Equation (12) is modified so that v is a function of time (as in Equation (14)) and integrated with respect to ½T:

$$E_c = 2\int_0^{T/2} \dot{e}_c \,(v(t),0)\, dt, \text{ grams per vehicle} \qquad (16)$$

This is two times the integral to allow for both the acceleration and deceleration portions.

In deriving the excess emissions for the hot spot guidlines, the estimated idle emissions from AP-42 times the idle time plus the integrated Modal Model estimates in Equations (15) and (16) are summed as in Equation (13).

Converting to units of $gm^{-1}sec^{-1}$ by considering the number of vehicles that stop, N, the total cycle time, C_y, the average running time for <u>all</u> vehicles, R_q, the volume demand, V, and the queue length, Le, (and letting $E_{AD} = E_A + E_D - E_C$) Equation (13) becomes:

$$E_E = \left(\frac{E_{AD}N}{C_y} + \frac{E_{ID}\,R_q\,V}{3600}\right)/Le \qquad (17)$$

which gives the emissions occurring per unit length of queue from accelerating, decelerating, and idling vehicles.

Free Flow Emissions

Similarly, the cruise emissions, $\dot{e}_c$, in Equation (12) may be used to estimate free flow emissions for all vehicles travelling through an intersection or for uninterrupted flow. Considering the number of vehicles per hour, V, and the distance traveled by those vehicles in 1 hour, X, (i.e., the speed, mph), the following equation results:

$$E'_c = \frac{\dot{e}_c\,V}{X\;1609}\;(gm\;m^{-1}\;sec^{-1}) \qquad (18)$$

where 1609 is the conversion from miles to meters.

Derivation of Emission Correction Factors

As stated in the last section, the Modal Model[10] is used instead of AP-42[6] to generate emissions estimates for these guidelines for the acceleration, deceleration, and cruise modes of vehicle travel. The Modal Model is used because it can more accurately estimate emissions over variable driving sequences, such as occur at intersections, than can AP-42.[6] One drawback to using the Modal Model is that the emissions are only applicable to one set of emission conditions, viz:

calendar years = 1977
75°F ambient temperature
$$\left.\begin{array}{l}\text{0 percent cold starts}\\ \text{0 percent hot starts}\end{array}\right\} \text{(100 percent stable)}$$
low altitude
non-California
light duty vehicles.

These will be called base conditions. In order to combine the best features of the Modal Model (variable driving sequences) with the best features of AP-42 (variable average speed, cold starts, hot starts, temperature, calendar year, and region) it is necessary to make an assumption relating the two procedures. The assumption is essentially that the ratio of estimated emissions under other than base conditions to those estimated under base conditions are equal for AP-42 and the Model Model; i.e.:

$$\frac{\text{(AP-42) Scenario}}{\text{(AP-42) Base}} = \frac{\text{(MM) Scenario}}{\text{(MM) Base}} \tag{19}$$

where AP-42 estimates are calculated assuming the average vehicle speed of the driving seauence in the Modal Model

and (MM) Base are calculated using any driving sequence under base conditions in the Modal Model

and (MM) Scenario is the unknown being solved.

Hence, to correct for calendar years, temperatures, cold starts, hot starts, average speed, and regions other than the base conditions, total emission factors using AP-42 (henceforth called composite emission factors) are calculated for (AP-42) Scenario, and divided by the AP-42 emissions for light duty vehicles for base conditions. This ratio is multiplied by the Modal Model composite emission factor under the same base conditions and thus solves for (MM) Scenario. This emission factor reflects adjustments for both variable driving sequence and variable environmental and calendar year conditions.

In the following subsections the above procedure will be discussed as it applies to each vehicle category and finally how to apply a total correction factor to the Modal Model emissions using vehicle proportions as weighting factors.

Light Duty Vehicles (LDV)

To adjust the Modal Model emissions estimates to reflect the user specified light duty vehicle emissions conditions, the ratio technique discussed above must be applied. The AP-42 emissions may be more specifically defined by:

$$(\text{AP-42})_{cy} = \Sigma\, E_{cy,i}\, M_i\, R_i \tag{20}$$

where $(\text{AP-42})_{cy}$ is the composite emission factor for a given calendar year (composite meaning total of all model years still running in that calendar year)

$E_{cy,i}$ is the emission factor for each model year in the given calendar year

M_i is the fraction of annual vehicle travel by model year

R_i is the correction factor for cold starts, hot starts, temperature, and speed by model year.

Thus (AP-42) Scenario and (AP-42) Base are estimated and multiplied by the Modal Model emissions for the base conditions to yield the AP-42 adjusted Modal Model estimate for the desired scenario. For convenience this AP-42 adjustment will be called R^*_{LDV} or:

$$R^*_{LDV} = \frac{(AP\text{-}42)_{cy,\ Scenario}}{(AP\text{-}42)_{by}} = \frac{\Sigma E_{cy,i}\ M_i\ R_i}{\Sigma E_{by,i}\ M_i\ R_{by,i}} \tag{21}$$

where the subscript, by, refers to base year.

Light Duty Trucks (LDT) and Motorcycles (MC)

The derivation of correction factors for light duty trucks and motorcycles is similar to that for LDV's. The only difference of note is that the $E_{cy,i}$ AP-42 estimates are for trucks (or motorcycles).

Heavy Duty Trucks (Gas-HDG and Diesel-HDD)

Correction factors for heavy duty trucks only apply to adjustments for speed and model year. The correction factors (C*) are calculated by taking the ratio of the composite AP-42 emission factors for the calendar year of interest and the composite AP-42 emission factors for LDV's under the base conditions. Thus:

$$C^*_{HDG} = \frac{\Sigma(E^{HDG}_{cy,i}\ M_i\ V_{s,i})}{\Sigma(E^{LDV}_{by,i}\ M_i\ V_{s,i})} \tag{22}$$

and a similar expression for heavy duty diesel trucks (C^*_{HDD}).

Application of Correction Factors

A composite correction factor must be calculated combining all vehicle types at the roadway under analysis in order to make the CO concentration estimates reflect all vehicle categories. Thus a total composite correction factor C_T may be given by:

$$C_T = P_{LDV}\ R^*_{LDV} + P_{LDT}\ R^*_{LDT} + P_{HDG}\ C^*_{HDG} + P_{HDD}\ C^*_{HDD} + P_{MC}\ R^*_{MC} \tag{23}$$

where P_{LDV}, P_{LDT}, P_{HDG}, P_{HDD}, P_{MC} are the proportion of each vehicle type

R^*_{LDV}, R^*_{LDT}, R^*_{MC}, C^*_{HDG}, C^*_{HDD} are composite correction factors as described previously.

Since the verification methodology employs precalculated tables of cruise and excess emission rates to compute emissions on each link, a separate C_T must be applied to both the cruise emissions and the excess emissions.

With these basic correction factors in hand, base emissions may now be varied to other scenarios. Since the cruise component of emissions (i.e., free flow) has a known speed, s, the corrected cruise emission can be calculated, viz:

$$(C_T)_s \, (E_C) = (E_C) \text{ corrected} \tag{24}$$

where E_C is the cruise emission rate estimated from the Modal Model, speed, and volume of traffic and $(C_T)_s$ is the composite correction factor as discussed above for given cruise speed.

The corrected excess emissions is the difference over the queue length (or acceleration and deceleration distance), between the cruise emissions and the emissions to decelerate, idle, and accelerate. The average speed of the cycle of deceleration, idling, and acceleration is very low - in almost all situations less than 5 miles per hour. For the purposes of screening and hot spot verification the R-factors of AP-42 are calculated at 5 mph to correct the excess emissions at intersections.

Thus, corrected excess emissions are:

$$C_{T,5}(E_{AD} + E_C + E_{ID}) - C_{T,S}(E_C) = (E_E) \text{ corrected} \tag{25}$$

Note that the correction factor is applied to total queue emission rates (E_C is added back into E_{AD}) and not to excess emissions. This allows the cruise emissions to be separately accounted for at the actual cruise speed and then subtracted to yield corrected excess emissions.

It is important to note that the cruise emissions in Equation (25) is the cruise emissions that would have occurred for the vehicles that stop, if they had not stopped, and not the total cruise emissions. It is for this reason that the tables of excess emission rates in Volume I list two numbers, the total queue emissions and the cruise emissions that would have occurred had the vehicles in the queue not stopped.

SECTION III

DEVELOPMENT OF THE HOT SPOT SCREENING PROCESS

INTRODUCTION

This section describes the development of the hot spot screening techniques presented in Volume I. In essence these screening procedures graphically protray the results of repeated applications of the verification procedure. The primary input parameter is traffic volume. For each roadway/receptor situation, there is a critical traffic volume above which the potential for a violation of the CO standard exists (according to the model implicit in the Indirect Source Guidelines).[2] Thus, utilizing traffic volumes and several simplifying assumptions about traffic and dispersion, a determination can be made as to whether a given location has hot spot potential.

Separate techniques have been developed for analyzing three broad categories of roadway facilities, including: signalized intersections, nonsignalized intersections, and uninterrupted flow locations. Furthermore, separate provisions are provided for considering particular types of locations within each category, such as freeways versus nonfreeways for uninterrupted flow locations, two-lane versus four-lane approaches in the intersection categories, and so on.

Because the effort here was directed toward development of a general guideline for identifying carbon monoxide hot spots, consideration had to be given to several issues that have an influence on the methodology being utilized. First, the guidelines will be used to evaluate literally hundreds of street sections and intersections within any municipality;

therefore the parameters considered must be general enough to require the absolute minimum of data input, yet the process must yield a reliable assessment of hot spot potential. Second, the process should be relatively simple and capable of being accomplished quickly, utilizing data that are ordinarily available from state or city agencies. Third, the process is intended to be applicable to any city or town where the existence of a hot spot problem is suspected. These factors, plus the fact that traffic operating characteristics are often highly varied among similar locations (for example, among signalized intersections), indicated that the screening process had to involve a very general approach, relying to a large extent on the validity of applying an assumed set of conservative traffic emission and dispersion parameters in order to reduce to a minimum the number of variables considered in the process.

Consequently, the screening guidelines were developed utilizing generalized assumptions regarding several of the variables in the verification procedure, thus simplyifying the amount of data and computing needed for CO assessment.[*] A sensitivity analysis described below verifies the reasonableness of the simplifying assumptions and shows the direction of the effects on air quality of variations in the parameter assumptions.

The screening guidelines were first presented in previous documents describing a procedure for identifying hot spot locations.[3,4] Subsequent to the publication of these volumes, the Indirect Source Guidelines,[5] and AP-42 emission factors[6] were revised. These revisions are reflected in both this volume and Volume I of the Guidelines.

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[*] The screening curves are generated by a computer program described in Volume IV of these Guidelines. The program is set up so that new curves may be computed for assumptions other than those made in this section.

ASSUMPTIONS REGARDING BACKGROUND CONCENTRATIONS

As mentioned previously, ambient concentrations of carbon monoxide at any location on an urban highway network are actually a result of emissions from the nearby source (highway) plus a background concentration resulting from emissions generated at more distant sources. Consequently, it was necessary to account for background concentrations in the screening guidelines. Various methods are suggested in the Indirect Source Guidelines[5] and Volume I of the Hot Spot Guidelines for determining the background concentration for a particular area; however, these methods require a certain amount of short-term, local air quality monitoring and also assume that historical ambient air quality data are available from a permanent monitoring station within the general area of the site. Given the cost and time requirements for short-term monitoring, and the extent of current long-term air quality monitoring programs, it is highly unlikely that these procedures could be used in the context of the hot spot screening. In an attempt to develop a simple yet reasonable method for identifying background concentrations, the results of diffusion modeling (using the APRAC diffusion model) efforts in three New England cities were analyzed.[7] The data available for analysis included estimates of background concentrations at 20 receptors in each city computed from local traffic data, and local meteorological data for a 1-year period. The averages of the maximum background concentrations computed for the 20 receptors in each city were 2.9 mg/m^3 (2.5 ppm), 3.3 mg/m^3 (2.9 ppm), and 5.9 mg/m^3 (5.1 ppm) (averaged over 8 hours). These data were developed for conditions during 1973-74. If these averages are projected for 1982-83 conditions, the results (conservatively) are 1.4 mg/m^3 (1.2 ppm), 1.6 mg/m^3 (1.4 ppm), and 2.9 mg/m^3 (2.5 ppm). Clearly, this shows that there may be significant variations among cities with regard to background concentrations. However, it can be postulated that a value of about 2.9 mg/m^3 (2.5 ppm) may be representative of the upper portion of the range in which 8-hour average background levels occur. Assuming that this is a <u>reasonable</u> conclusion, then the corresponding 1-hour average background can be estimated by applying the correlation factor (0.7)[*] developed for relating 8-hour to 1-hour average concentrations. This results in an estimated 1-hour average background concentration of about 4.1 mg/m^3 (3.6 ppm).

The need for this "standard value" is again stressed because of anticipation that sufficient local data will not be available in all instances to permit a determination of actual background concentrations. Therefore, a standard value of background will be used in the generation of the screening curves.

Data and procedures in the Indirect Source Guidelines[2] are oriented to the maximum 1-hour average concentration of carbon monoxide while the 8-hour average concentration is of interest here. Analysis of air quality data from a number of continuous monitoring stations[8,9] indicate that the relationship between the maximum 1-hour and 8-hour average concentrations can be expressed by:

$$\chi_8 = P\chi_1 \tag{26}$$

where χ_8 = highest expected 8-hour average concentration

χ_1 = highest 1-hour average concentration (in same 8-hour period)

P = 8-hour correlation factor.

While the value of the correlation factor can be expected to vary depending on local traffic and meteorological characterists, data analysis described below indicates that a value of 0.7 may be considered appropriate, especially in the range of 1-hour average concentrations of from 10 mg/m^3, to 20 mg/m^3. In this analysis, monthly summaries of carbon monoxide concentrations measured at several monitoring stations in three cities were reviewed. The analyses consisted of determining the ratios of the maximum daily 8-hour average concentrations to the maximum daily 1-hour average concentrations for various monitoring sites in each city. The maximum 8-hour average concentration used in the analyses included the maximum

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[*] Discussed later in this section.

daily 1-hour average concentration in its averaging period. Further, these ratios were examined for three ranges of maximum daily 1-hour average concentrations - where the maximum 1-hour average was (1) between 0 and 7 mg/m^3 (6 ppm), (2) between 7 mg/m^3 (6 ppm) and 11.5 mg/m^3 (10 ppm), and (3) greater than 11.5 mg/m^3. Considering the higher range separately, the analysis indicated that for moderately active downtown locations (locations typified by occasional traffic congestion) with apparently good atmospheric ventilation (that is, fairly wide streets and sidewalks and building heights generally not exceeding five or six stories), that the ratio of the maximum 8-hour average concentration to the maximum 1-hour average concentration ranges from about 0.6 to 0.7. For downtown areas where heavy traffic congestion occurs throughout much of the day and where ventilation is somewhat restricted by narrow streets and tall buildings, values of from 0.7 to 0.8 were indicated for this ratio. Conditions in most areas where hot spot analyses are conducted are like to be somewhat less severe (with regard to traffic conditions and ventilation) than those in the congested area referred to here. Given this assumption, the value of 0.7 is considered "reasonable" for use as a "standard value" to describe the ratio of the maximum 8-hour average concentration to the maximum 1-hour average concentration, for cities and towns lacking sufficient data to permit development of a more specific value. The verification procedure does allow the use of a locally-derived 8-hour correlation factor.

The maximum 8-hour average concentration of carbon monoxide for a particular location, then, can be expressed by the general equation:

$$\chi_8 = (\chi_1 + \chi_B)\ P \qquad (27)$$

where χ_8 = the estimated maximum 8-hour concentration

χ_1 = the total estimated concentration contributed by a nearby source (roadway)

χ_B = the 1-hour average background concentration, assumed to be 3.6 ppm (4.1 mg/m^3)

P = 8-hour correlation factor = 0.7

If χ_8 is set equal to the National Ambient Air Quality Standard for 8-hour concentrations (10.0 mg/m^3 (9.0 ppm)) then the only unknown in the equation becomes χ_1, or:

$$\chi_1 = \frac{\chi_8 - \chi_B(P)}{P} = \frac{(10.0) - (4.1)(0.7)}{0.7} = 10.2 \text{ mg/m}^3$$

Therefore, for every roadway condition where the calculated 1-hour average concentration contributed by the roadway is about 10.2 mg/m^3, there is a potential for <u>violations</u> to the 8-hour standard, given the above assumptions.

UNINTERRUPTED FLOW CONDITIONS

General

For conditions of uninterrupted flow on streets and highways, vehicle speed is a key determinant of emissions intensity. Because average travel speeds vary to such a large extent throughout a highway network, it is necessary to separately consider facilities where speed characteristics are expected to be quite dissimilar. For this analysis, two facility-types were considered, these being (1) freeways, expressways, or other limited access, high speed highway classes; and (2) arterial streets and highways.

The verification procedure presents a technique for expressing an empirical relationship between air quality and various combinations of roadway volume and capacity. Again, other parameters, mainly meteorology, emission factors, and certain operating characteristics, have been included, but as nonvariables (the reader is referred to the previous section for a discussion of the assumptions made regarding these parameters). An implication of the air quality-volume-capacity relationships expressed by the verification procedure is that for every given value of lane capacity there is a critical volume demand which, once reached, will generate concentrations of carbon monoxide that are in violation of the National Ambient Air Quality Standards.

Representative vehicle operating speeds are needed to estimate the emissions from free-flowing traffic. The assumptions used here are based on relationships between volume-capacity ratios and operating speeds on various types of roadways with specified average highway speeds as estimated from the Highway Research Board's _1965 Highway Capacity Manual_.[11] Traffic on the roadway is assumed to be accommodated at the maximum level of service consistent with the indicated v/c ratios. This procedure is followed in deriving the screening curves for freeways and for arterials. For the free-flow curves in the screening procedures, _demand_-capacity ratios are assumed identical with _volume_-capacity ratios. This assumption implies that, under free-flow conditions, traffic _is_ moving at the maximum level of service consistent with the specified volume-capacity ratio. Thus, the operating speeds on a roadway are possible to estimate given the demand-capacity ratio. The combinations of operating speeds and demand-capacity ratios derived for arterial streets and expressways, along with the corresponding levels of service appear in Tables 1 and 2.

To be representative of as large a portion of the country as possible and to insure usability under representative adverse emissions conditions, about 20 percent of the vehicle population is assumed to be operating under cold-start conditions and 0°C is assumed appropriate for worst case temperature in the winter months (the season where CO concentrations have most commonly been high).

An additional adjustment was to adjust the curves to apply to the winter of 1982 to 1983, to correspond with the statutory attainment date for the carbon monoxide NAAQS. The adjustment is identical to that described previously for the verification procedure.

Curve Generation and Discussion

The result of the analyses performed was the identification of the critical (minimum) ADT which could result in a violation to the National Ambient Air Quality Standard for 8-hour average carbon monoxide concentrations.

Table 1. ASSUMED OPERATING SPEEDS, LEVELS OF SERVICE AND DEMAND-CAPACITY RATIOS FOR MAJOR STREETS AND CORRESPONDING EMISSION FACTORS FOR FREE FLOW CONDITIONS

Assumed operating speed (mph)	Demand-capacity ratio	Level of service	Description
30	≤0.60	A	Completely free flow
25	0.70	B	Stable flow (slight delay)
20	0.80	C	Stable flow (acceptable delay)
15	0.90	D	Approaching unstable flow (tolerable delay)
15	1.00	E	Unstable flow (congestion, intolerable delay)

Table 2. ASSUMED OPERATING SPEEDS, LEVELS OF SERVICE AND DEMAND-CAPACITY RATIOS FOR URBAN EXPRESSWAYS[a] AND CORRESPONDING EMISSION FACTORS FOR FREE FLOW CONDITIONS

Assumed operating speed (mph)	Demand-capacity ratio	Level of service	Description
57	0.1	A	Completely free flow
55	0.2	A	Completely free flow
53	0.3	A	Completely free flow
50	0.4	A	Completely free flow
47	0.5	B	Stable flow (upper speed range)
45	0.6	C	Stable flow
42	0.7	C	Stable flow
40	0.8	C	Stable flow
37	0.9	D	Approaching unstable flow
30	1.0	E	Unstable flow

[a] Average highway speed assumed to be 60 mph.

Figures in the screening guidelines show these critical volumes for various configurations of limited and uncontrolled access facilities. The figures provide the basis for screening roadways where conditions of uninterrupted flow prevail. The resulting procedure provides a "go/no-go" type of analysis. The procedure simply indicates that a hot spot potential exists or does not exist.

The procedure for screening highway sections where uninterrupted flow conditions prevail requires only very basic data regarding the roadway network. Essentially, the data required involve traffic volumes and traffic flow characteristics, and general physical data including number of travel lanes, and estimates of other capacity determinants, such as lateral lane clearance. The data required allow estimates to be made of the facility's lane capacity which, through the use of the curves presented in Volume I, can be related to a corresponding "critical" ADT which, potentially, would result in a violation to the National Ambient Air Quality Standard (NAAQS) for 8-hour average concentrations of carbon monoxide. This critical ADT is then compared with the estimated ADT on the facility, and a potential hot-spot is indicated when the estimated ADT for the facility equals or exceeds the critical ADT.

INTERRUPTED FLOW CONDITIONS - SIGNALIZED INTERSECTIONS

General

Near signalized intersections, emissions intensity is affected by vehicle operating characteristics including acceleration and deceleration rates, time in idle mode, volume of vehicles that stop, and total volume. These operating characteristics, in turn, are influenced by such elements as intersection capacity, amount of green (signal) time allocated to each approach, location of the intersection (e.g., rural, residential, or downtown), and the proximity of other signalized intersections. Emissions intensity is also related to the physical layout of the intersection with respect to lane configuration as well as receptor location relative to the emissions source. Since there is a large number of variables that can significantly affect carbon monoxide concentrations, 40 prototypical intersections were developed as the basis for the screening process.

A number of assumptions in addition to those in the verification procedures were required in developing a general procedure for assessing the hot spot potential of signalized intersections. These concern mainly traffic volume distribution, receptor distance, and general intersection operating characteristics, as discussed below.

Assumptions

It was assumed, again, that the basic parameter of traffic volume would be expressed as ADT. Also, the following assumptions were used regarding ADT. It is recognized that conditions vary widely in urban areas; the following conditions are assumed to be typical:

- peak hour traffic represents 8.5 percent of the ADT
- an even directional distribution occurs on two-way facilities during the peak hour
- for multilane facilities, the volume on the lanes are equally distributed.

The distance from the edge of the roadway to the receptor was assumed to be 5 meters.

Two different cruise speeds were used in developing the screening procedure - the first was 15 miles per hour used for conditions where congestion is highly likely (e.g., within urban business districts), while 30 miles per hour was used for noncongested areas.

Assumptions regarding cold operation and temperature correction for signalized intersections were the same as those described in the previous section dealing with uninterrupted flow conditions. These assumptions were that the ambient temperature representative of winter operation is 0°C and that 20 percent of the vehicles passing any point in the highway network would be operating under cold conditions. These issues are discussed in detail in a previous portion of this section. Data were also adjusted to 1982 to 1983, as before.

Curve Generation and Discussion

The results of the analyses were the identification of the critical (minimum) ADT's for several basic configurations of intersecting streets that could result in violations to the National Ambient Air Standard for 8-hour average carbon monoxide concentrations. In the analysis, eight general intersection approach configurations were considered, including:

(a) 4-Lane, 2-Way in congested areas
(b) 4-Lane, 2-Way in noncongested areas
(c) 3-Lane, 2-Way in congested areas
(d) 3-Lane, 2-Way in noncongested areas
(e) 2-Lane, 2-Way in congested areas
(f) 2-Lane, 2-Way in noncongested areas
(g) 2-Lane, 1-Way
(h) 3-Lane, 1-Way

For each of these, five configurations of intersection street-types were analyzed and corresponding "critical" ADT's determined. Thus, a total of 40 separate intersection configurations were evaluated; results are presented in the screening procedures.

For screening signalized intersections, traffic volume data, physical layout and traffic operational characteristics are of primary importance. The traffic volume and physical/operational characteristics of each approach to the intersection are then related to the physical/operational characteristics of the opposing roadways and, from these, the "critical" volumes are determined for the opposing traffic. If the actual volumes on these cross streets are greater than or equal to the "critical" volumes, a hot spot potential is indicated for the approach being analyzed.

INTERRUPTED FLOW CONDITIONS - NONSIGNALIZED INTERSECTIONS

General

Although nonsignalized, at-grade intersections are by far the most common type of intersection, they are also the least studied with regard to operational characteristics and capacity. Nonsignalized intersections are very seldom a critical factor of capacity or level of service on through routes although they are of great significance with regard to the minor cross route.[10] Typically, when a point is reached where traffic flow on the major route is affected to any degree by traffic from a minor cross street, a signal is installed.[*] To date, most of the research that has been conducted on capacity and operational aspects of nonsignalized intersections has tended to produce data representative of local conditions only.

In perspective, however, nonsignalized intersections are also probably the least likely hot spot locations since they are generally characterized by relatively low volumes on the minor cross streets, and produce little, if any, interference to main street flow. This being the case, the main stream legs of many nonsignalized intersections can be assessed for hot spot potential using the technique described earlier in this section for uninterrupted flow conditions. For the minor street legs, however, a different analysis must be performed.

The concept, then for develping a screening procedure for nonsignalized intersections was the same as that used in developing the screening process for both uninterrupted flow conditions and signalized intersections. In essence, this involved identifying volume relationships which result in concentrations (based on the verification procedure) high enough to potentially violate the NAAWS for 8-hour average concentrations of carbon monoxide.

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[*] Four-way stop sign controlled intersections are excluded to keep the scope of these guidelines manageable. Such intersections, with their typical low traffic volumes, are unlikely hot spots.

Assumptions

Assumptions used regarding peak hour volume, directional split, and lane distribution were the same as were used for development of the screening procedure for signalized intersections. The minimum distance from the edge of the nearest lane to a receptor was assumed to be 5 meters.

Curve Generation

The verification procedure and the assumption noted above were utilized to develop critical volumes for various configurations of STOP-sign controlled intersections, as shown in the guideline volume. Included are the following:

- 2-lane, 2-way minor; 2-lane major (congested area
- 2-lane, 2-way minor; 2-lane major (noncongested area)
- 2-lane, 2-way minor; 4-lane major (congested area)
- 2-lane, 2-way minor; 4-lane manor (noncongested area)
- 4-lane, 2-way minor; 4-lane major (congested area)
- 4-lane, 2-way minor; 4-lane major (noncongested area)
- 2-lane, 1-way minor; 2-lane major
- 2-lane, 1-way minor; 4-lane major

EFFECTS OF VARIATION IN PARAMETER ASSUMPTIONS

The analysis presented here is performed to show the sensitivity of the computed CO concentrations to changes in the input parameters for the screening curves. Assumptions for six traffic and air quality parameters were among those required to compute the values for the plotting of the hot spot screening curves. These assumptions are calculated in Table 3 for the analysis of a signalized intersection composed of a 4-lane/2-way roadway in a noncongested area which is crossed by a 2-lane/2-way facility.

Table 3. ASSUMPTIONS FOR CO CONCENTRATION COMPUTATIONS[a]

Parameter	Value assumed in screening curves
Directional volume split on main street	50% - 50%
Roadway edge to receptor distance	5 meters
Percent ADT during peak hour	8.5%
Background concentration, 1 hour	5.8 mg/m^3
Acceleration-deceleration	2.5 mph sec^{-1}
8-Hour correlation factor	0.70

[a] Analysis of a 4-lane/2-way roadway in a noncongested area crossed by a 2-lane/2-way roadway. Intersection is fully signalized.

The estimates for the parameters are regarded as producing an accurate model of the proposed generalized conditions. Since all estimates, however, are subject to some amount of uncertainty, a sensitivity analysis, discussed in the following text, helps in analyzing and understanding the effects of variations in the values of the control parameters.

The process selected for the sensitivity analysis was to vary one parameter at a time and recompute the CO concentration screening curve for that new set of parameters. The variations in the parameter values selected for use in the sensitivity analysis are listed in Table 4. The results of the analyses show that most of the selected changes (Table 4) in most parameters can have substantial effects on the curves. The only exception is acceleration, in which a change of 0.5 mph sec^{-1} had no effect. The basic screening curves and the seven variations are plotted on Figure 11 for comparison. The percentage variation in the allowable volumes are presented in Table 5, along with the differences in the parameter values.

Table 4. VARIATION IN ESTIMATED PARAMETER VALUES FOR SENSITIVITY ANALYSIS

Parameter	Value used in sensitivity analysis
Directional volume split	60% to 40%
Roadway edge to receptor distance	2 meters
Percent ADT during peak hour	10%
Background concentration, 1 hour	4.8 mg/m^3
Deceleration-acceleration	2 mph sec^{-1}
8-hour correlation factor	0.9

The significance of this analysis of possible variations in the parameters is that it exhibits the effects on expected CO concentration of differences between the assumed conditions and conditions at an actual site. In addition, it shows the direction and relative magnitude of the effect on air quality of changes in site conditions that might be brought about through some of the control measures.

The results shown in Table 5 and plotted on Figure 11 exhibit the variations possible with example changes in the estimated values of the parameters. It is considered that the set of values for the generalized conditions used in the screening analysis yield satisfactory results for average conditions. Uncertainty in the use of these estimated values will undoubtedly occur at unusual or complex locations. The uncertainty for these special cases, however, would be eliminated during application of the verification process.

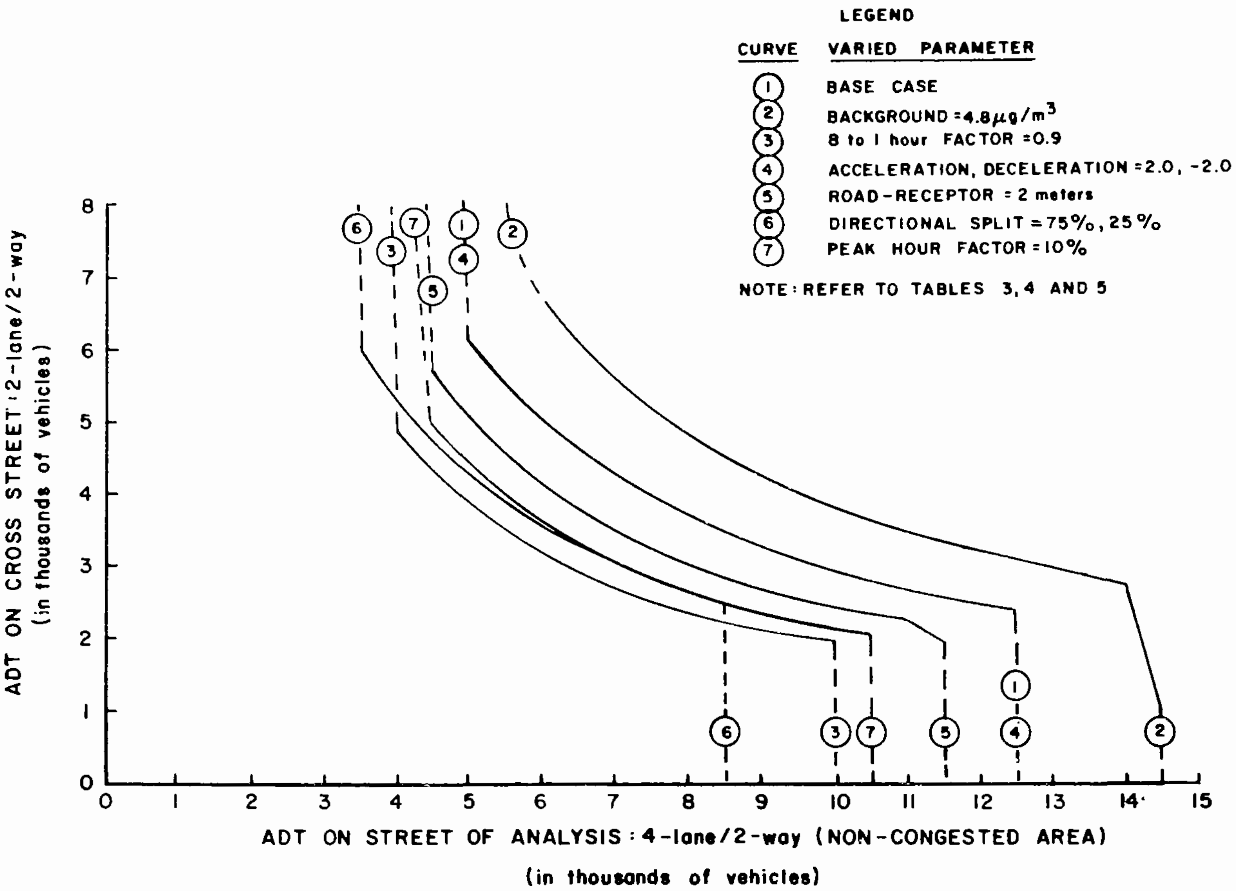

Figure 11. Examples of effects on screening curves of variations in parameter assumptions

Table 5. CHANGES IN PARAMETERS VERSUS CHANGES IN ALLOWABLE VOLUMES

Parameter	Difference in value of parameter between screening curve assumption and sensitivity analysis	Approximate change in allowable volumes (percent)
Background concentration	- 1 mg/m^3	+35%
8-Hour correlation factor	0.2	40%
Acceleration, deceleration	0.5 mph/sec	no change
Roadway edge to receptor distance	-3 meters	-15%
Directional volume split	25%	-25%
Percent ADT during peak hour	+2.5%	-25%

SECTION IV

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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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16. ABSTRACT

This report presents the rationale used in developing the analytical techniques for the carbon monoxide hot spot guidelines.

Discussed in this report are the technical aspects of the guidelines, including the assumptions used in developing hot spot procedures. Since the guidelines were based largely on EPA's Indirect Source Guidelines, these are discussed in some detail, as well.

17. KEY WORDS AND DOCUMENT ANALYSIS

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