Caline 3 - A Graphical Solution Procedure For Estimating Carbon Monoxide (CO) Concentrations Near Roadways

December 1980

U.S. Department
of Transportation

Federal Highway Administration

Introduction

This report represents a graphical procedure for estimating CO concentrations near highway facilities. The procedure is based on the computerized CALINE 3 line-source air quality model developed by the California Department of Transportation (CALTRANS). Due to the complexities of the CALINE 3 data input,* certain assumptions have been made in the graphical solution to simulate a simple roadway segment. A limited scenario has been assumed since it would be highly impractical to develop solutions for all the many possible conditions that can be solved using the CALINE 3 computer program. Careful judgment should be exercised in the application of the graphical solution procedure to specific air quality analyses. It is assumed the user of this graphical procedure is familiar with the CALINE 3 computerized procedure.

When to Use the Graphical Solution Procedure

The graphical solution procedure was developed using a simple roadway configuration. It is intended for use in noncomplicated analyses. Careful judgment should be exercised in its use for other situations. It may be used to provide a quick, first-cut estimate of CO concentrations. In complex analyses or when there appears to be a potential for exceeding the air quality standards, the computerized version of CALINE 3 should be used to obtain a more refined estimate. It should be noted that an abbreviated version of CALINE 3 for use in HP-67197 and TI-59 programmable calculators is contained in the report, "CALINE 3 - A Versatile Dispersion Model for Predicting Air Pollutant Levels Near Highways and Arterial Streets."

Summary of CALINE 3

CALINE 3 estimates CO concentrations near roadways using source strength, meteorology, site geometry, and site characteristics. It mathematically disperses a given quantity of CO emitted by vehicles along a roadway to the surrounding area and calculates the CO concentration at individual receptor locations within the area. Data input for CALINE 3 includes the following:

1. Site variables - wind speed, wind direction, atmospheric stability class, mixing height, surface roughness, averaging time, and ambient concentration.

2. Link variables - traffic volume, composite emission factor, link height, link width, and link length (roadway section coordinates).

3. Receptor locations (receptor coordinates).

*For a complete discussion of CALINE 3, including a sensitivity analysis of input variables, see "CALINE 3 - A Versatile Dispersion Model for Predicting Air Pollutant Levels Near Highways and Arterial Streets" by Paul Benson (Report No. FHWA-CA-TL-79/23, November 1979).

Graphical Solution

Assumptions: (see figure 1: roadway section)

1. The roadway is straight, level at grade, 30 metres wide and has 4 lanes of pavement; the median is 10 metres or less in width.

2. Roadway segment length, 0.5km.

3. Receptor height is 1.8 metres; the receptor distance is measured along a perpendicular line from the roadway centerline to the receptor (see figure 1: roadway section).

4. Traffic volume, 4,000 vehicles/hour (1,000 vehicles/lane/hour).

5. Ambient (background) CO concentration, 0 ppm.

6. Wind speed, 1 metre/second; the receptor is located downwind of the roadway, center of roadway segment.

7. Surface roughness, 10 cm.

8. Mixing height, 1000 meters.

9. Averaging time, 60 minutes.

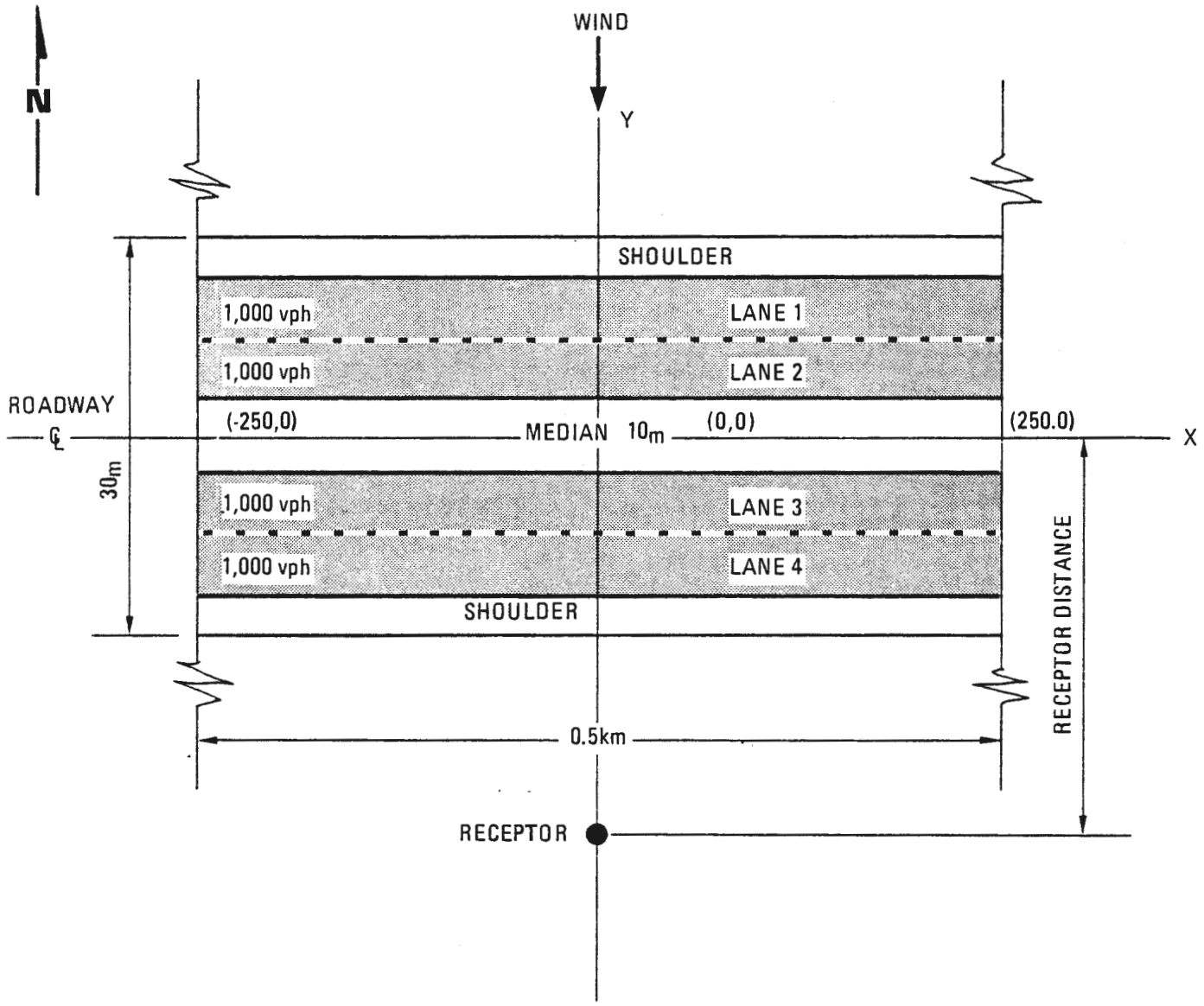
Traffic Adjustment

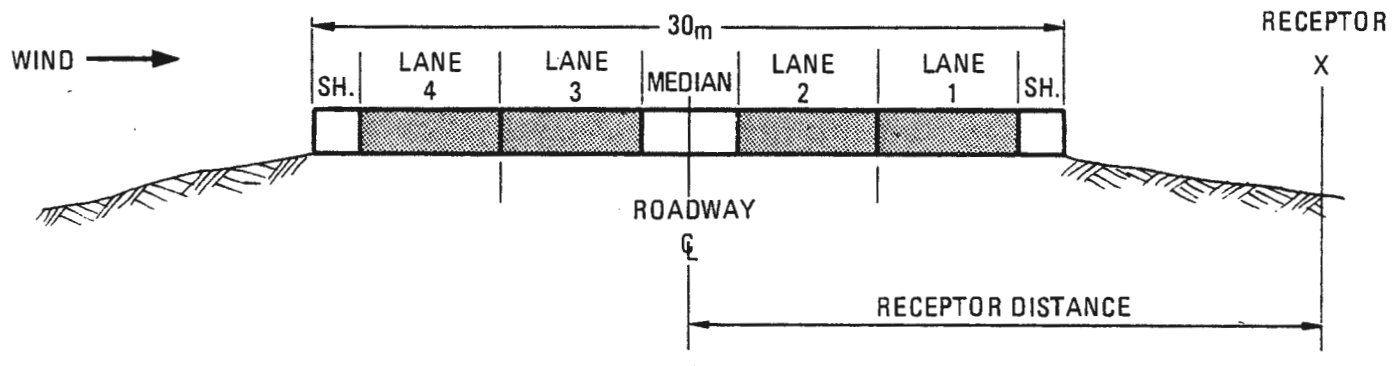
In developing the graphical solution procedure, the assumption was made that roadway traffic volume was 4,000 vehicles/hour (1,000 vehicles/hour/lane). The CO concentration obtained with the procedure must be linearly adjusted for the actual traffic volumes being analyzed. For example, if the concentration at a receptor is 10 ppm for 4,000 vehicles/hour, it will be 15 ppm for 6,000 vehicle/hour ($10 \times \frac{6,000}{4,000} = 15$) all other things being equal.

Wind Angle

CALINE 3 computerized version requires the wind angle input variable to be an azimuth bearing between 0 degrees and 360 degrees measured clockwise relative to the positive Y-axis. The wind angle used in the graphical solution procedure differs from this in that it is always an angle between 0 degrees and 90 degrees measured relative to the centerline of the roadway. For example, a wind angle of 0 degrees is always parallel to the centerline of the roadway, and a wind angle of 90 degrees is always perpendicular to the centerline of the roadway. (See figure 1).

FIGURE 1: ROADWAY SECTION





Instructions for Using the Graphical Procedure

Step 1. Select the stability class of atmosphere (D, E, or F) and the wind angle in degrees (0, 10, 20, 30, 45, or 90) that are to be used in the analysis; and then turn to the appropriate graph for that stability class and wind angle.

Step 2. Obtain the CO composite vehicle emission factors for the analysis. This is a weighted average of the emission factors for individual vehicle classes. Care should be taken that the latest Environmental Protection Agency (EPA) emission factors are used.*

Step 3. Determine the receptor distance, in metres, by measuring along a perpendicular line from the roadway centerline to the receptor. (Receptor distances are shown on the graphs by diagonal lines.) To convert from feet to metres, multiply by .305.

Step 4a. To determine the CO concentration for a receptor distance shown on the graph, read horizontally across from the appropriate composite emission factor (gm/mi) to the line for the appropriate receptor distance and then down vertically to the CO concentration in ppm. Continue to Step 5.

Step 4b. To determine the CO concentration if the desired receptor distance line is not explicitly shown on the graph, find the CO concentration for the two nearest receptor distances (shown on the graph) between which the desired receptor distance lies. Then, use linear interpolation to determine the concentration for the desired receptor distance. For example:

Let D_d = Desired receptor distance

D_f = Far receptor distance

D_n = Near receptor distance

C_f = CO concentration in ppm for far receptor

C_n = CO concentration in ppm for near receptor

X = Unknown increment of CO concentration in ppm.

Then, CO concentration for desired receptor = $C_f + X$

Where $$\frac{C_n - C_f}{D_f - D_n} = \frac{X}{D_f - D_d}$$

$$X = \frac{D_f - D_d}{1} \cdot \frac{C_n - C_f}{D_f - D_n}$$

*FHWA Technical Advisory T6640.1 (November 16, 1978).
EPA User's Guide to Mobile 1: Mobile Source Emission Model, EPA-400/9-78-007, August 1978

Step 5. Adjust the CO concentration for actual traffic conditions. To obtain the final concentration in ppm, multiply the CO concentration by: $\frac{\text{actual traffic (vehicles/hour)}}{\text{4,000 vehicles/hour}}$.

Step 6. If desired to obtain the CO concentration expressed in micrograms per cubic metre (mg/m^3) instead of in ppm, multiply the result of Step 5 by 1143.

Example 1

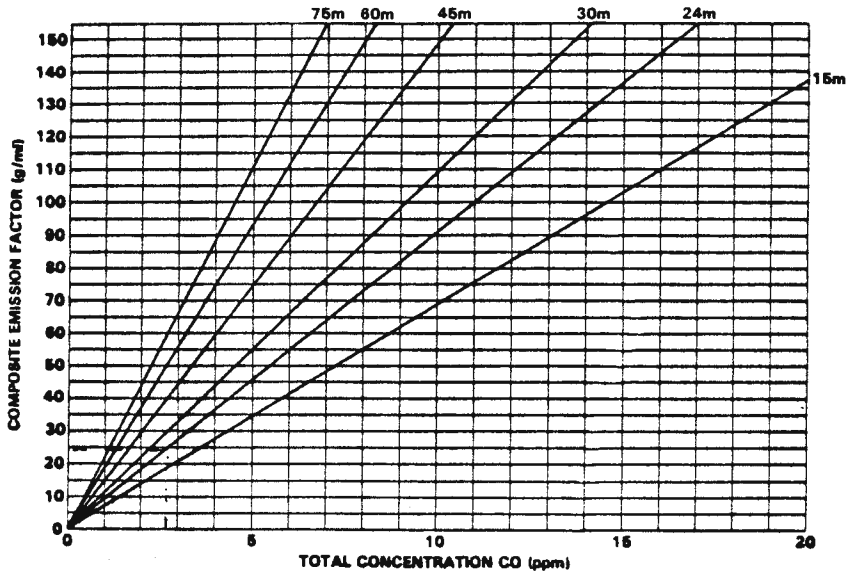
A receptor is located 24 metres from the roadway. The traffic flow is 10,000 vehicles per hour with a CO composite emission factor of 25 grams per mile. The wind speed is 1 metre per second at a wind angle with respect to the roadway of 30 degrees for an atmospheric stability class of D. Find the CO concentration at the receptor.

Step 1

Turn to the graph showing a 30 degree wind angle and a stability class of D.

Steps 2-4a

Read horizonatally across from a composite emission factor of 25 grams per mile to the receptor line for 24 metres. Then, read down vertically to obtain a CO concentration of 2.6 ppm.



Step 5

Adjust the CO concentration for traffic conditions.

$$\text{CO concentration} = 2.6 \text{ ppm} \times \frac{10,000}{4,000}$$

$$= 2.6 \times 2.5$$

$$= 6.5 \text{ ppm}$$

Step 6

If desired, multiply the result of Step 5 by 1143 to obtain the CO concentration expressed in micrograms per cubic metre (mg/m^3).

CO concentration = 6.5 ppm x 1143 = 7,430 mg/m^3

Example 2

A receptor is located 20 metres from the roadway. All other analysis data remains the same as in Example 1. Find the CO concentration at the receptor.

Steps 1

Turn to the graph showing a 30 degree wind angle and a stability class of D.

Steps 2-4b

Read horizontally across from a composite emission factor of 25 grams per mile to the receptor lines for 15 metres and 24 metres. Read vertically down to obtain CO concentrations of 3.5 ppm and 2.6 ppm respectively.

CO concentration for 20m = (2.6 + X) ppm

Where $\frac{(3.5 - 2.6)}{(24-15)} = \frac{X}{(24-20)}$;

$$\frac{0.9}{9} = \frac{X}{4}$$

$$X = 0.4$$

CO concentration for 20m = 2.6 + 0.4 = 3.0 ppm

Step 5

Adjust the CO concentration for traffic conditions.

$$\text{Actual CO concentration} = 3.0 \text{ ppm} \times \frac{10{,}000}{4{,}000}$$

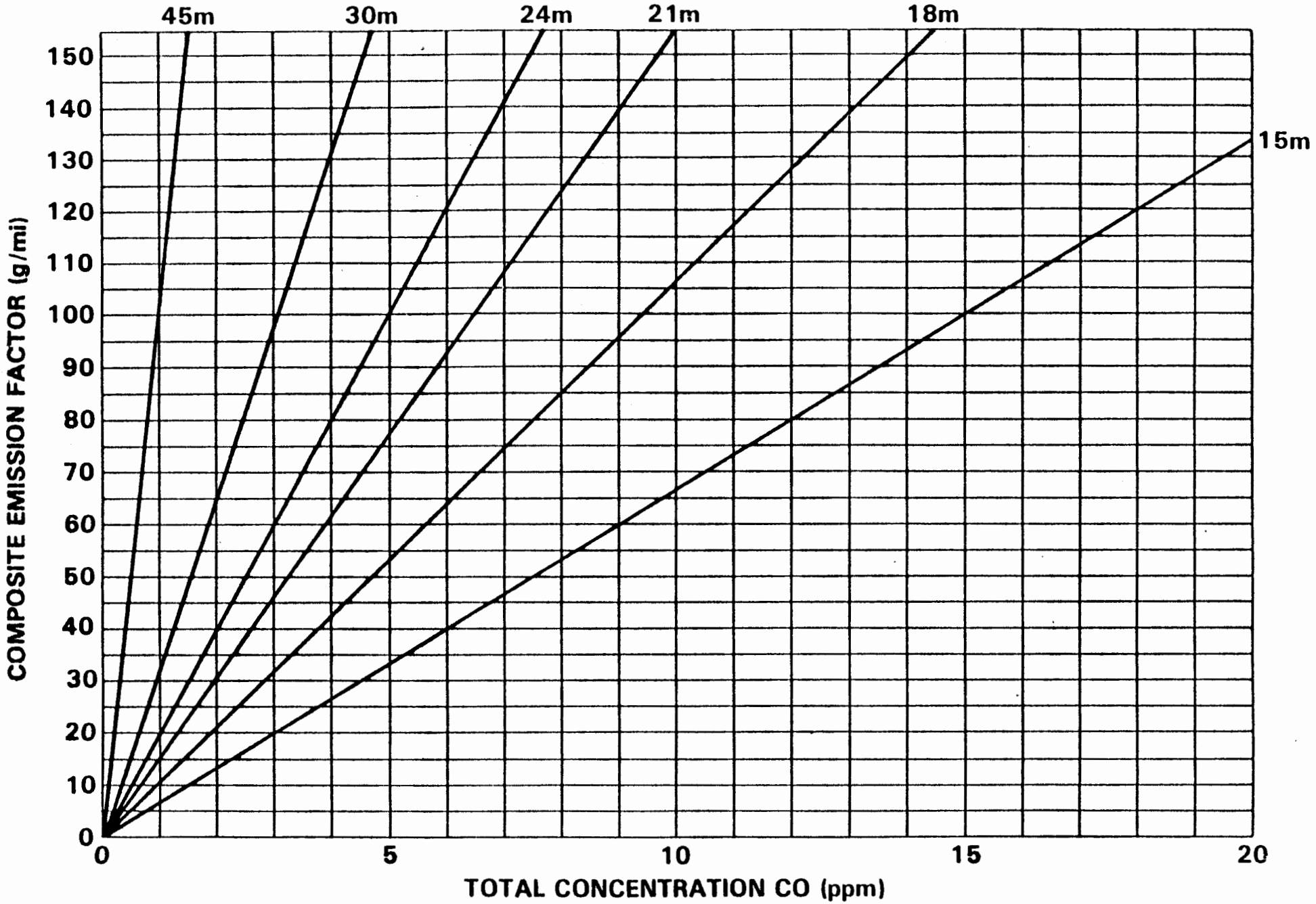
$$= 3.0 \times 2.5$$

$$= 7.5 \text{ ppm}$$

Step 6

If desired, multiply the result of Step 5 by 1143 to obtain the CO concentration expressed in micrograms per cubic metre (mg/m^3).

CO concentration = 7.5 ppm x 1143 = 8, 572 mg/m^3



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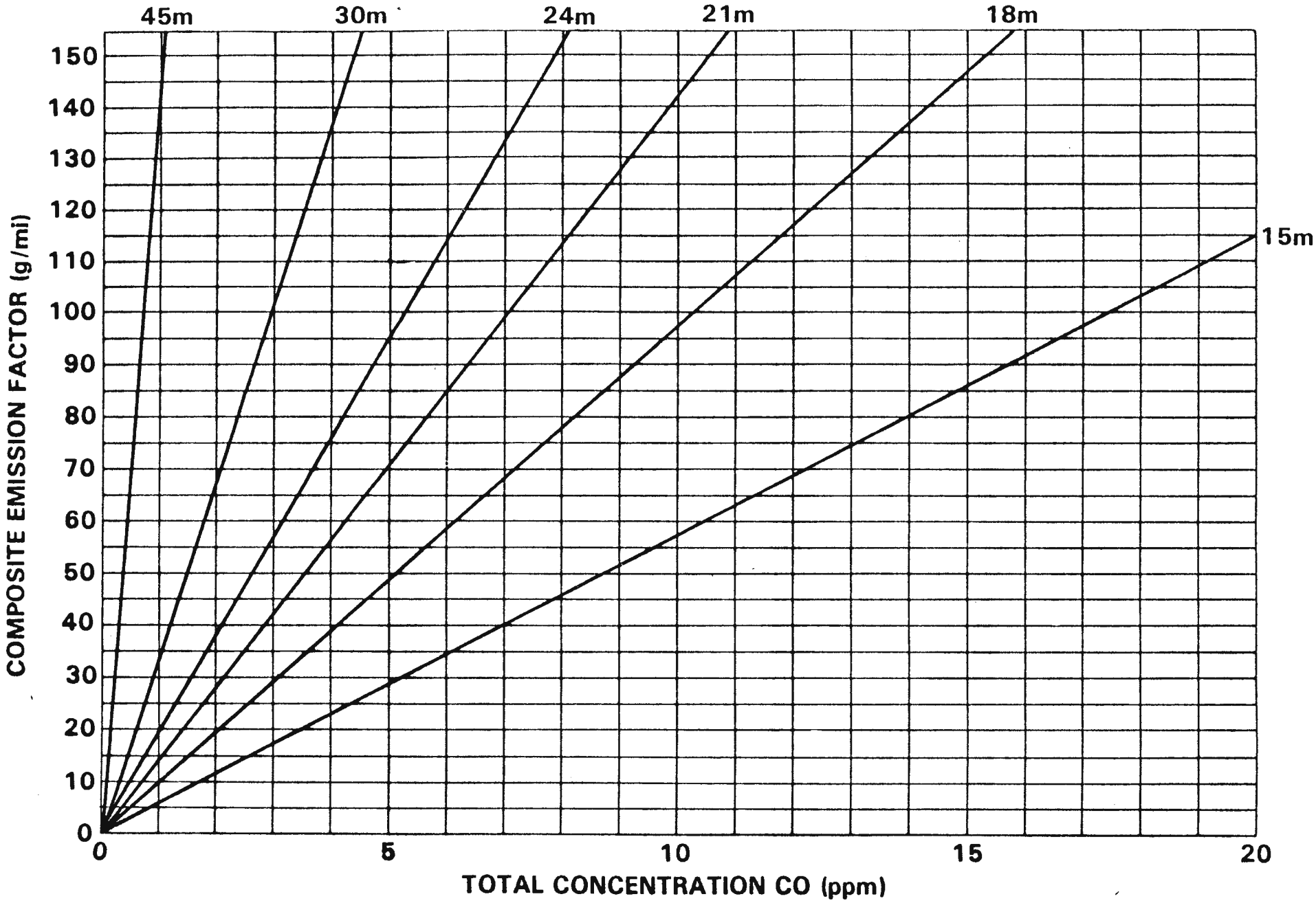

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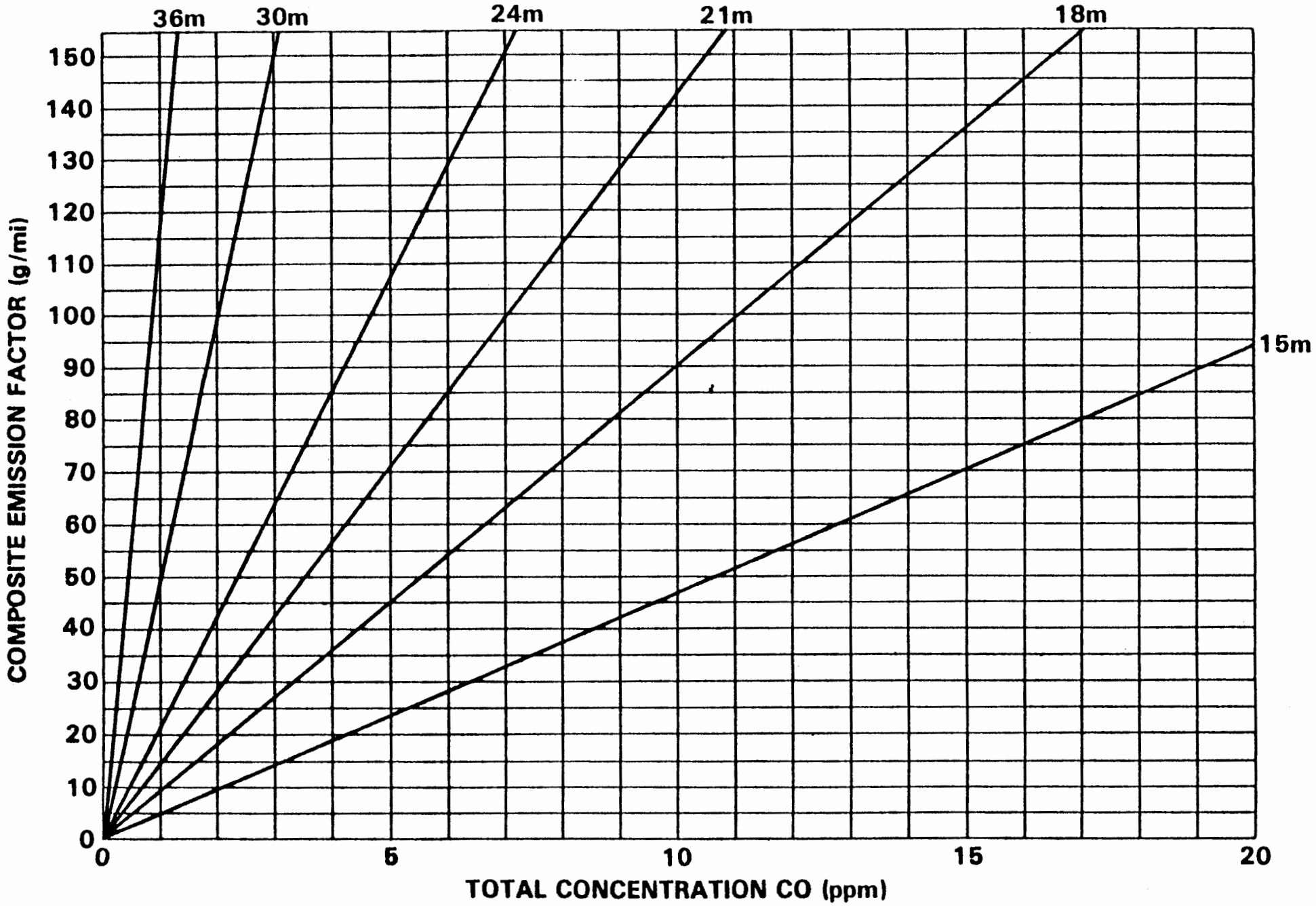

Wind Angle 0

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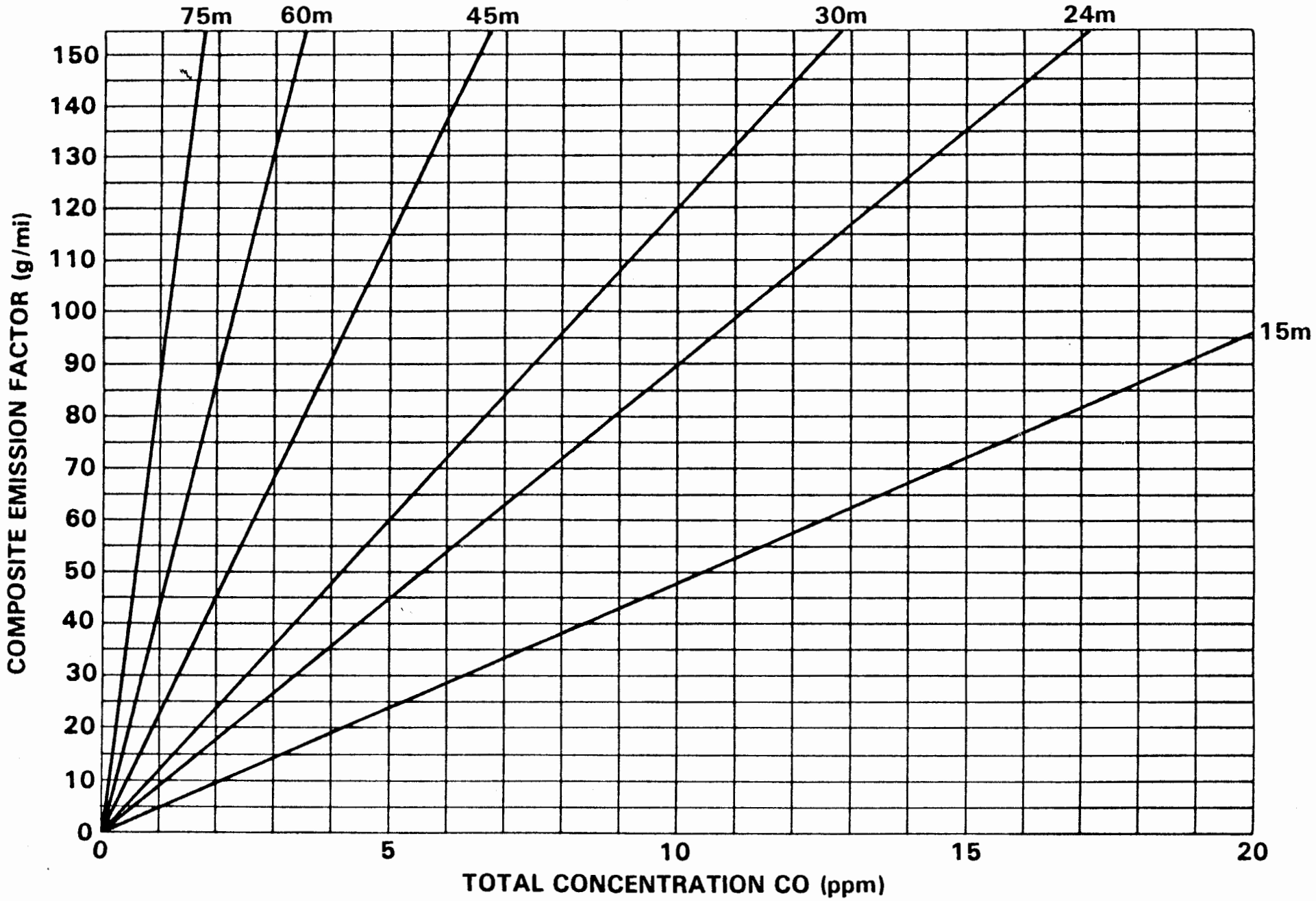

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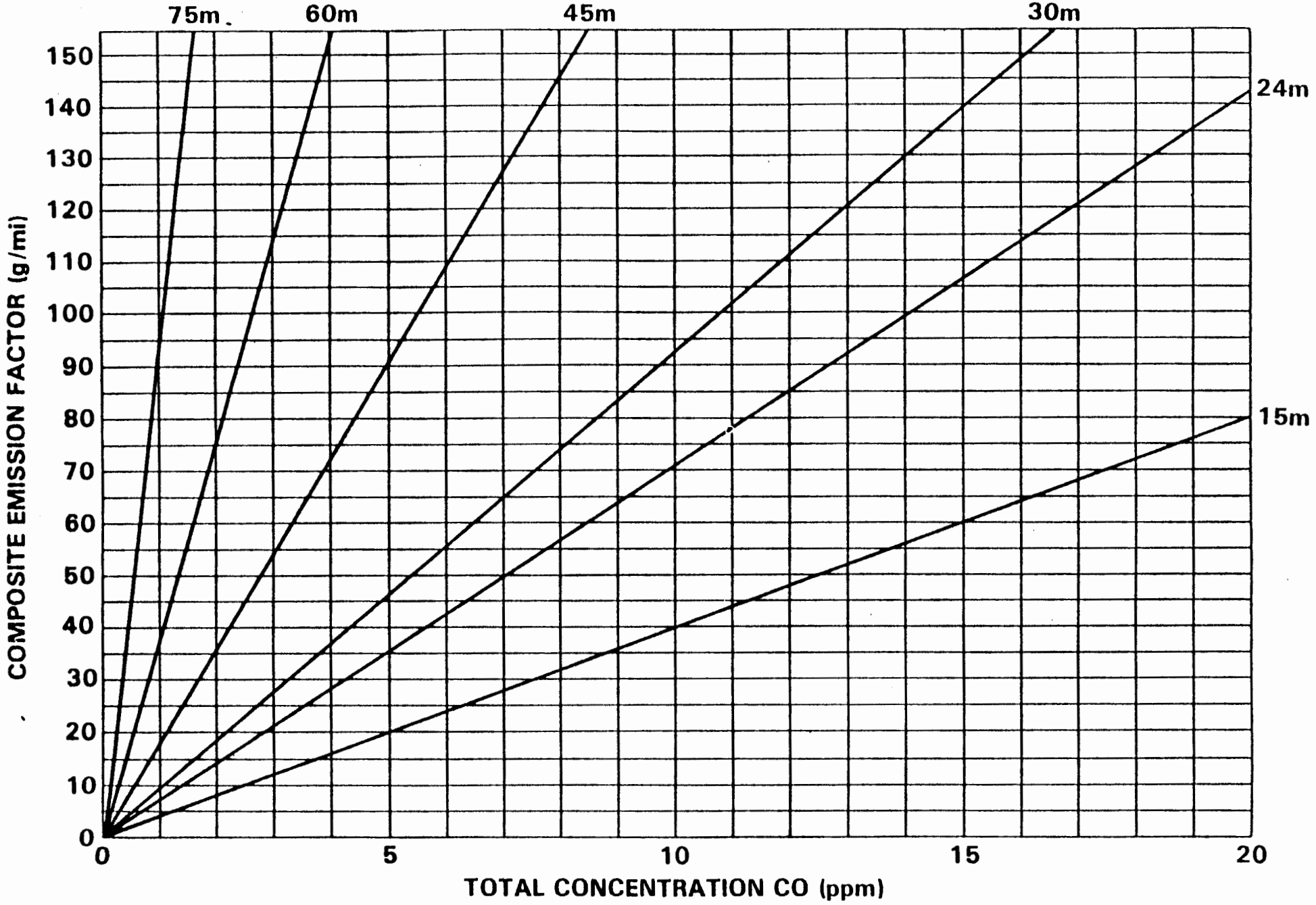

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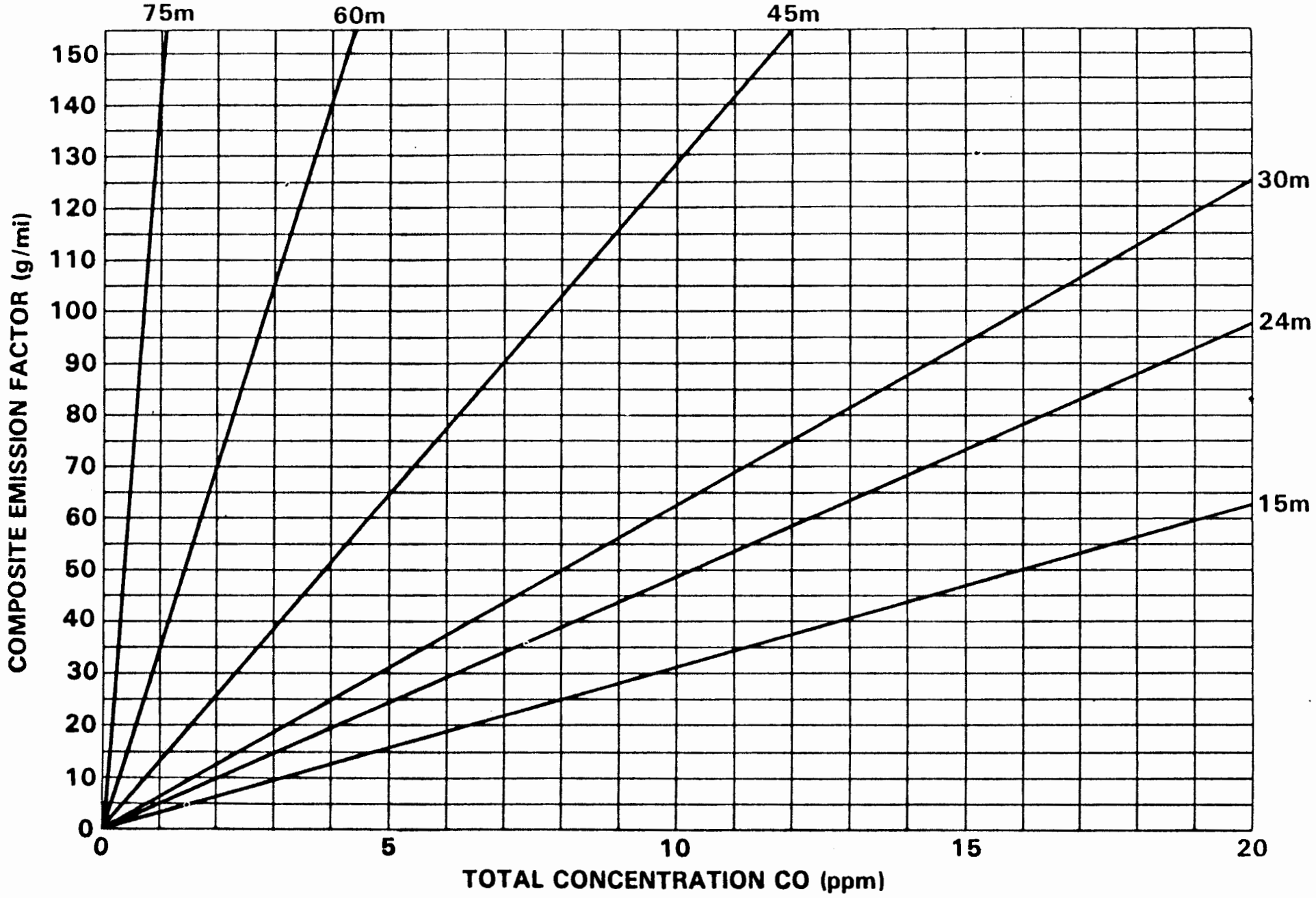

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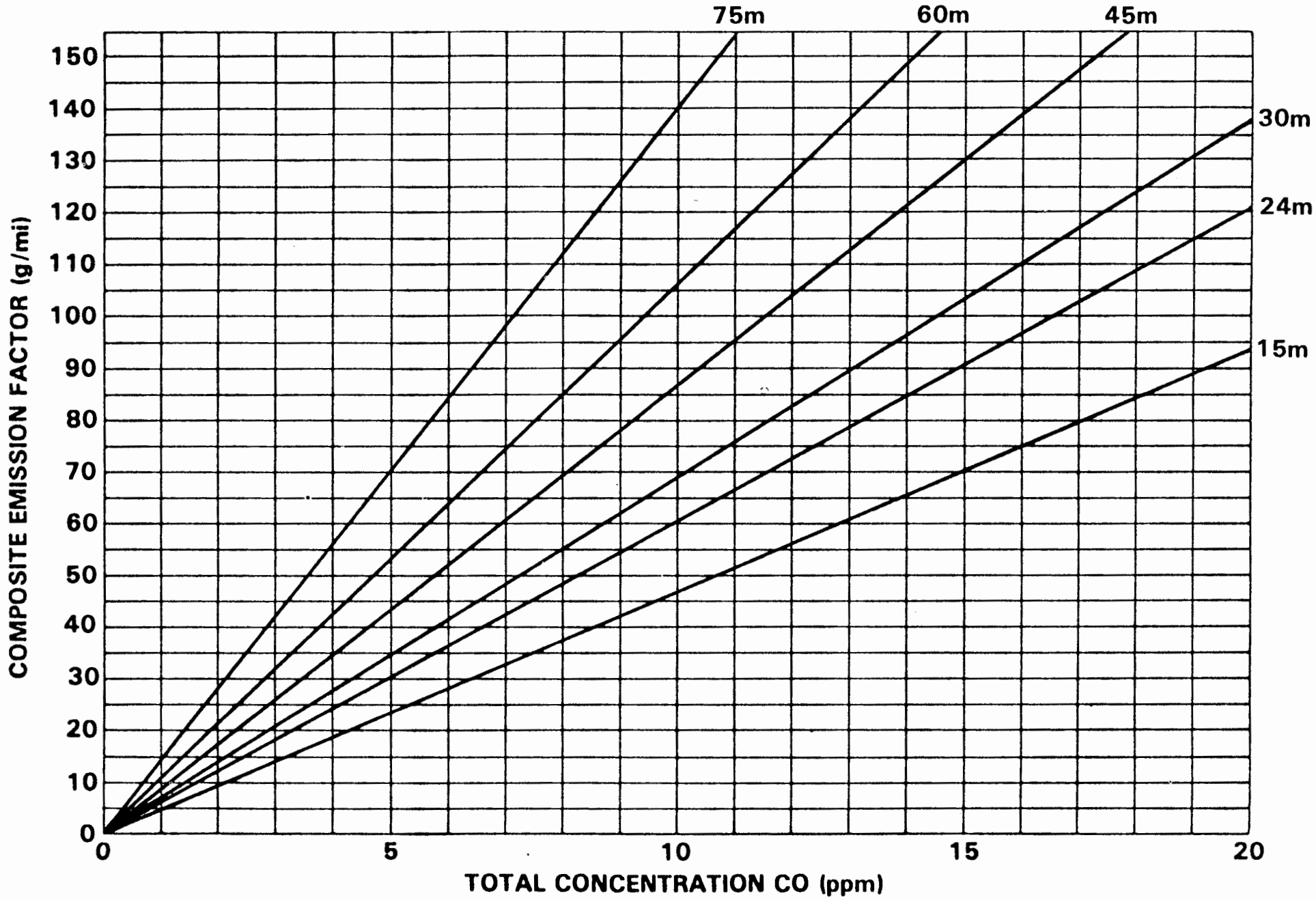

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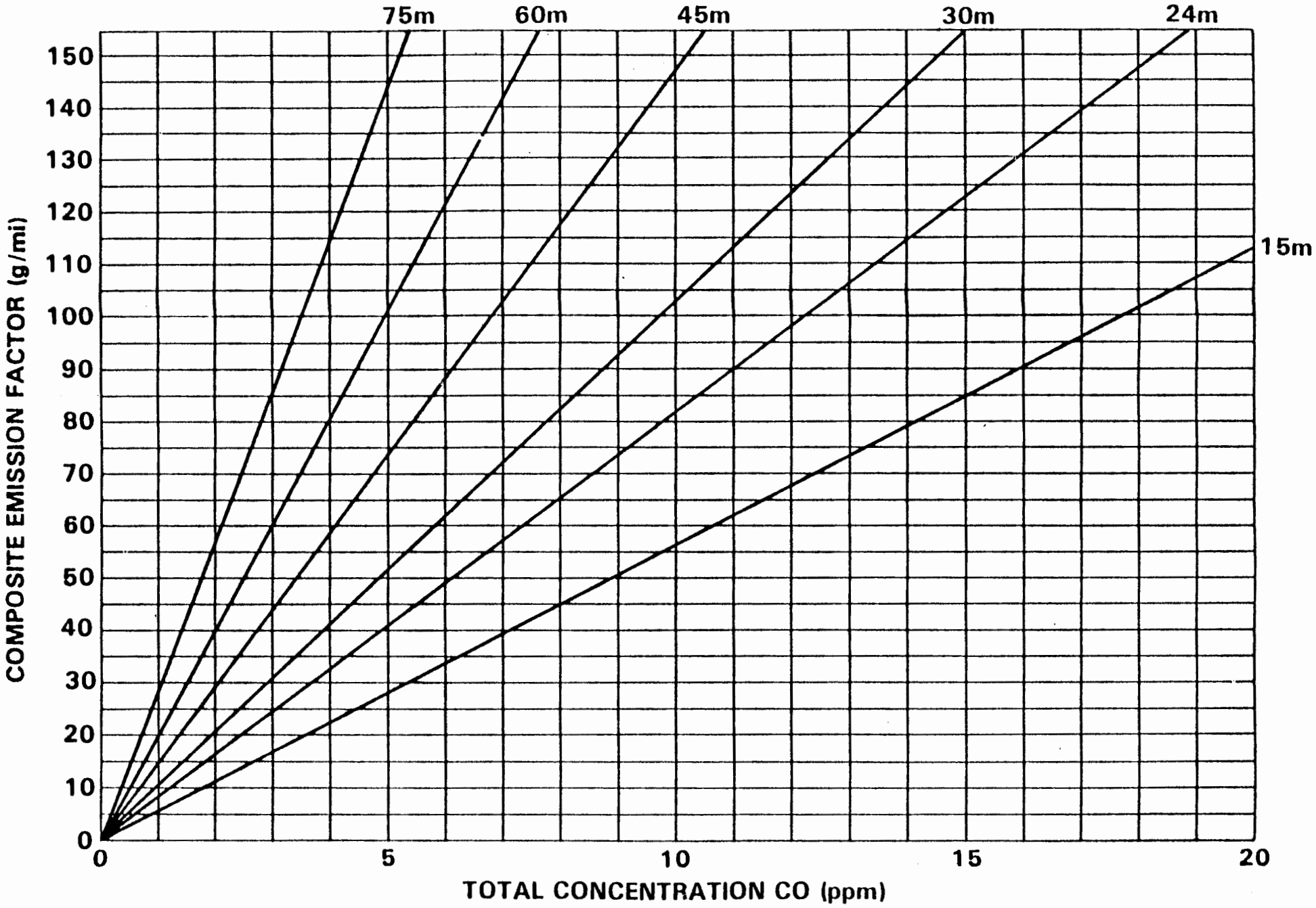

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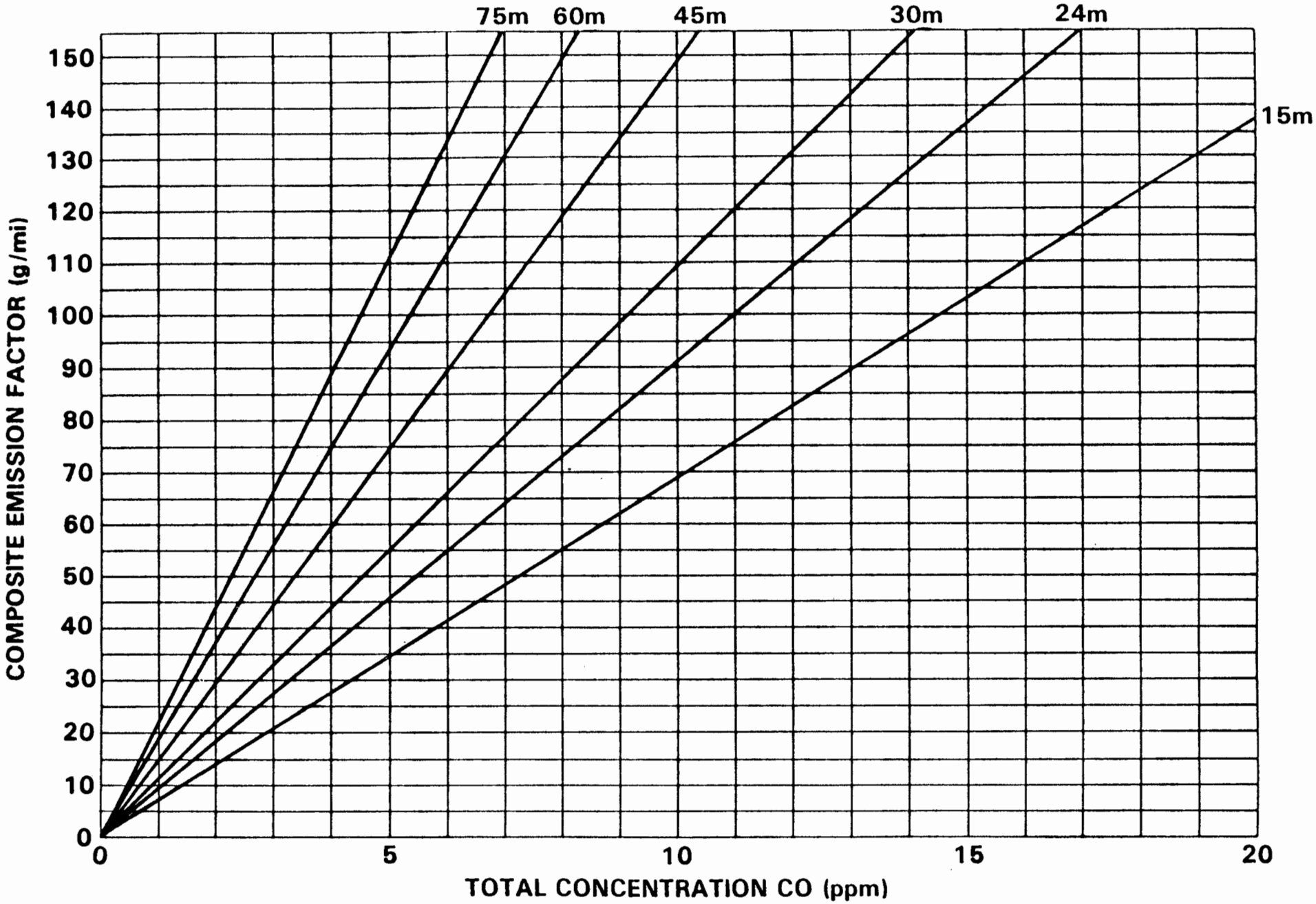

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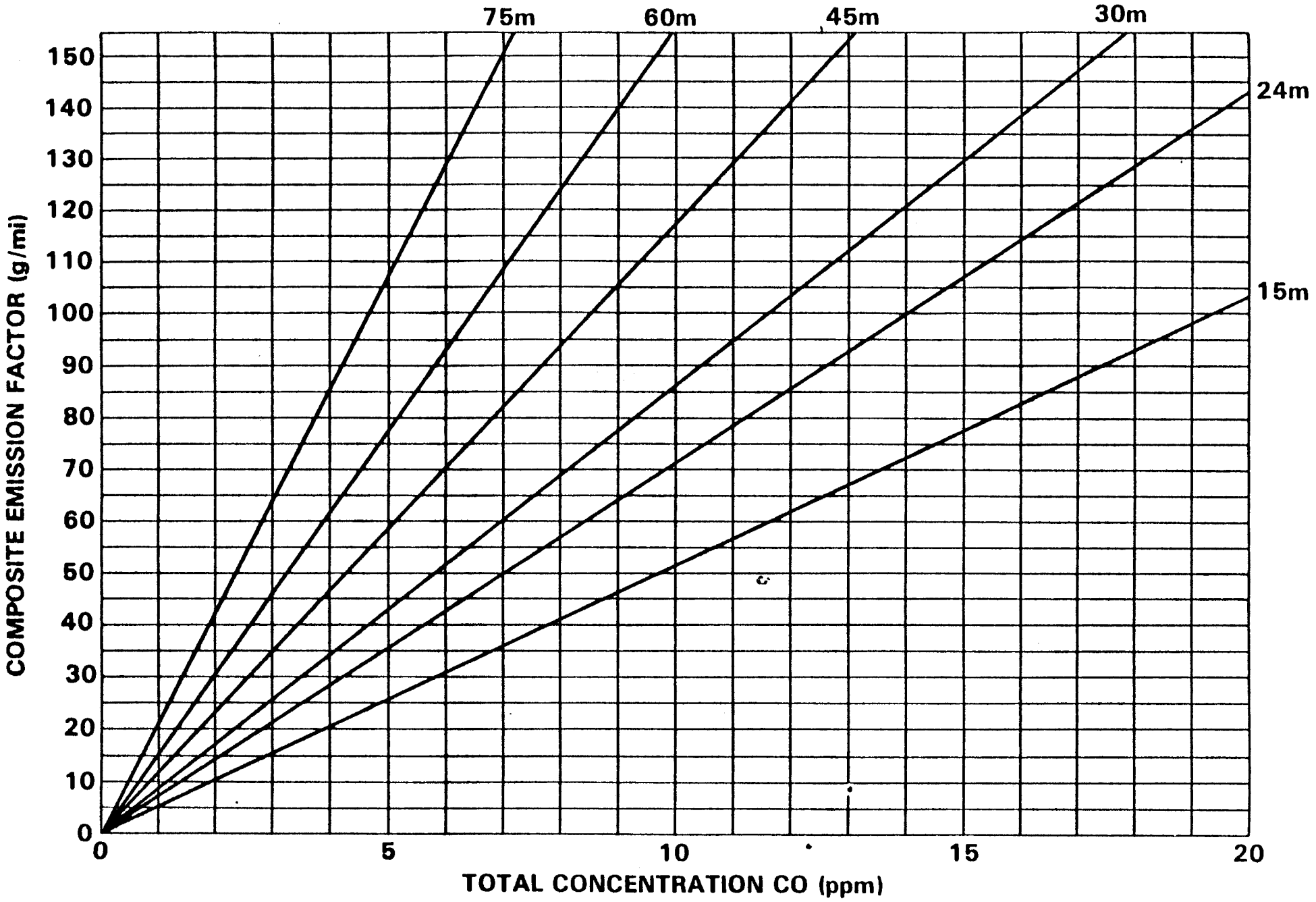

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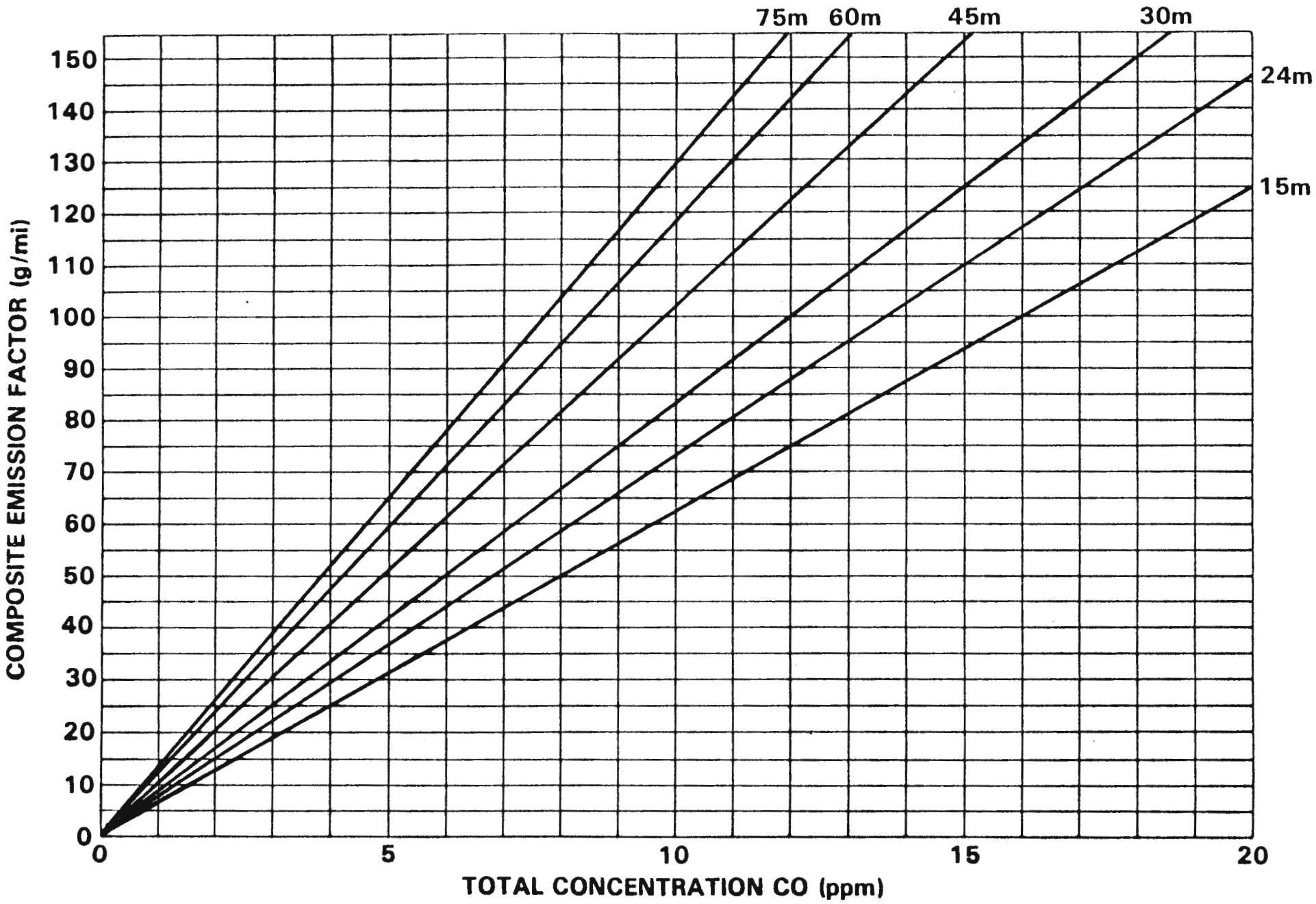

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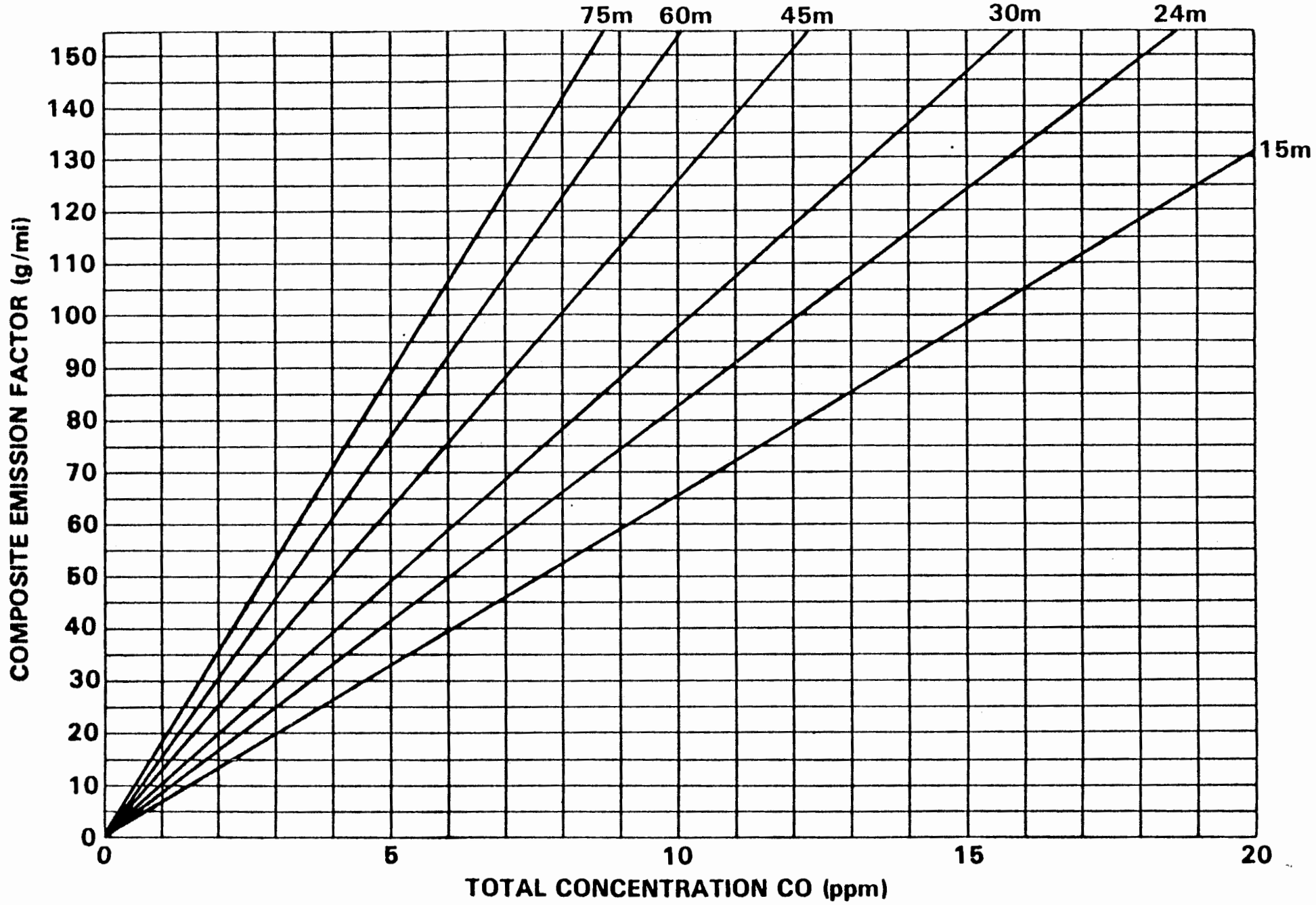

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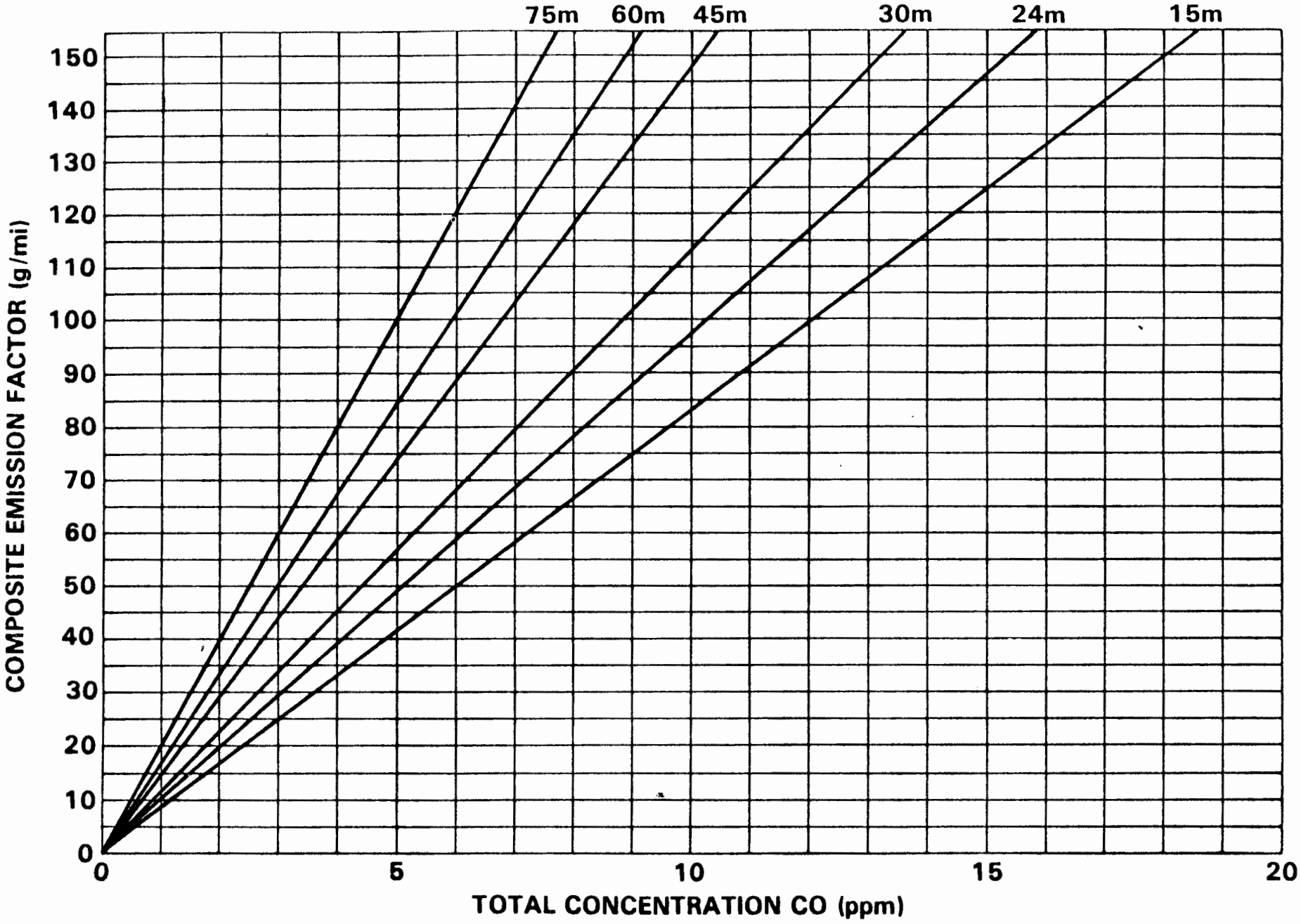

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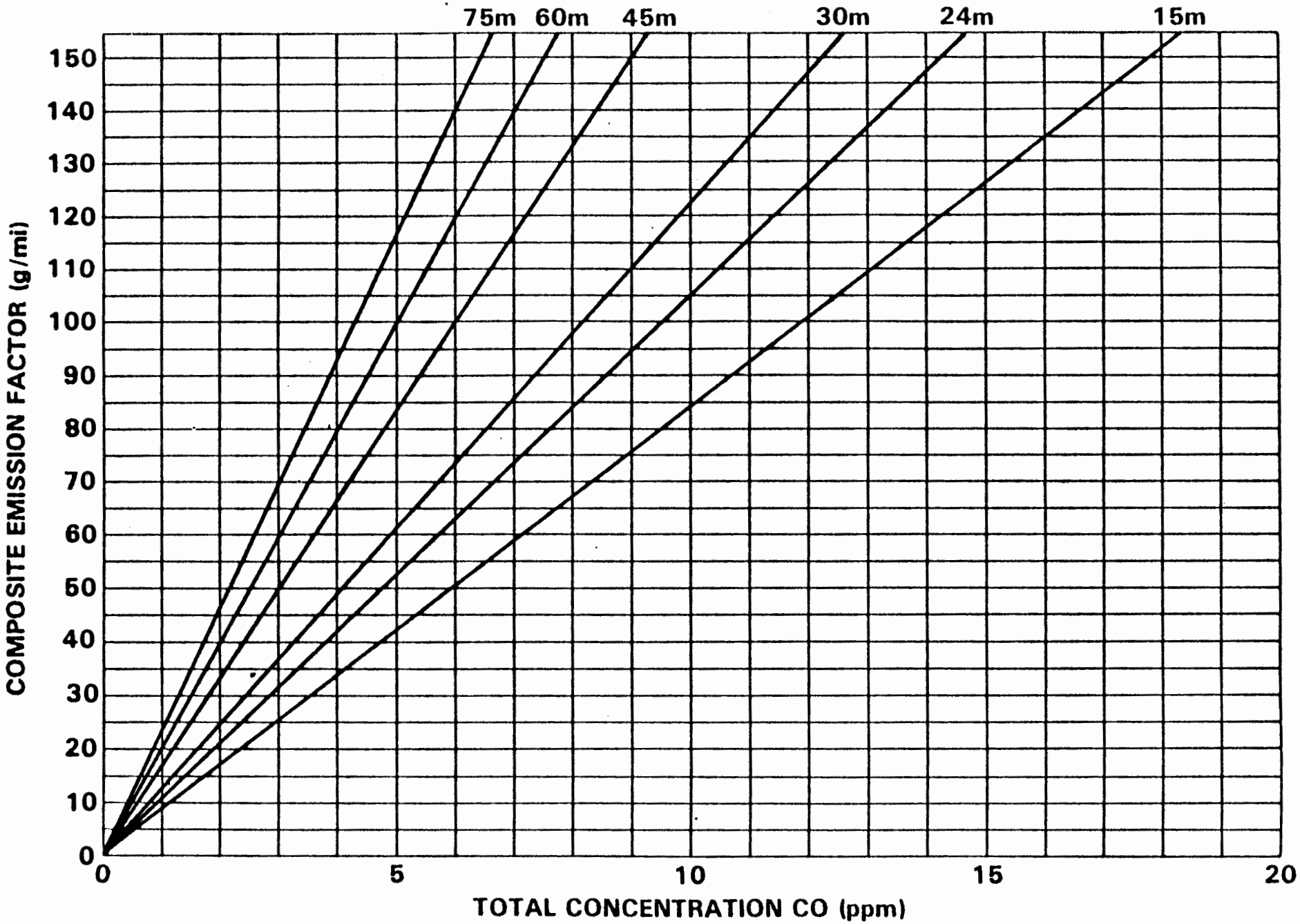

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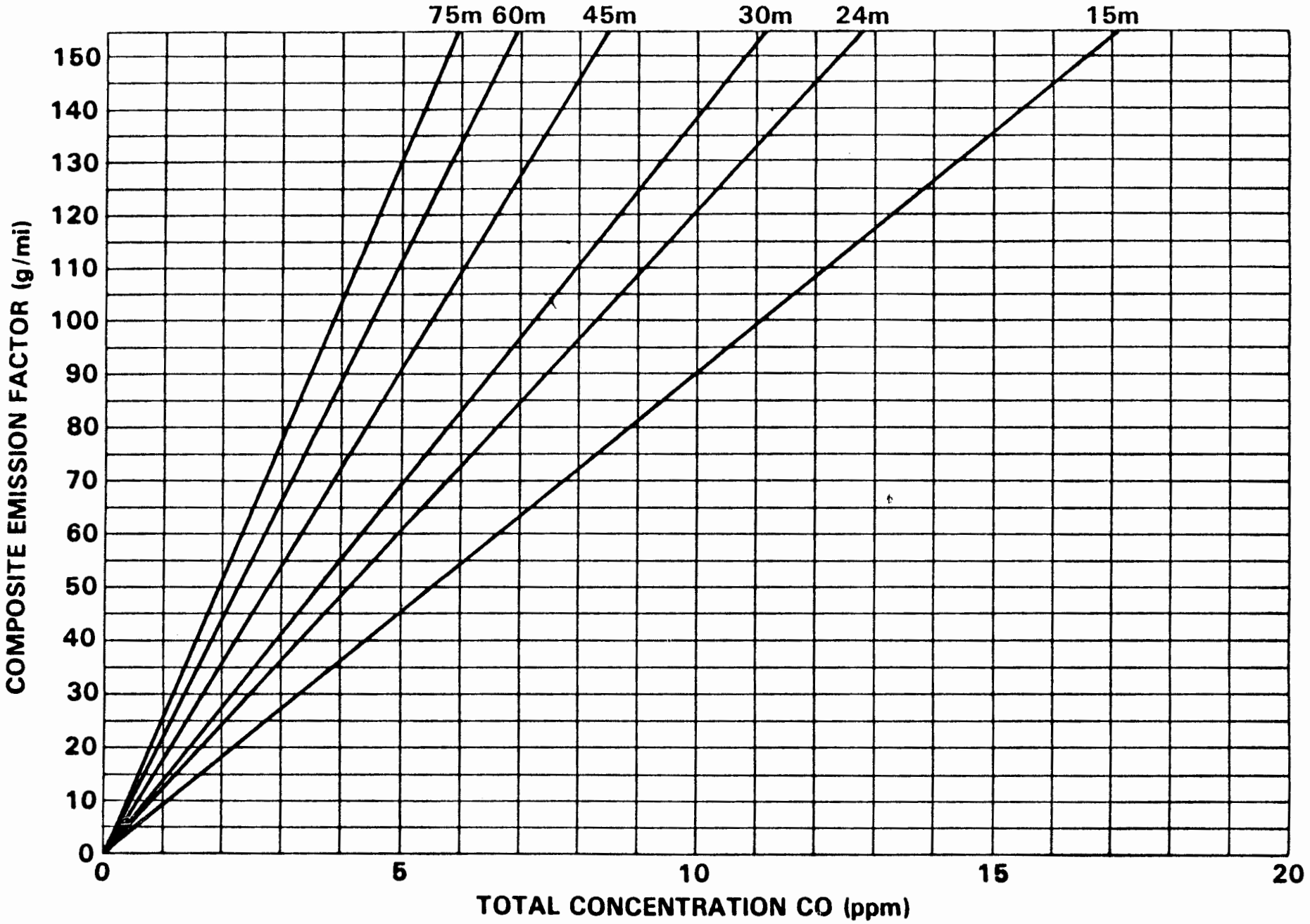

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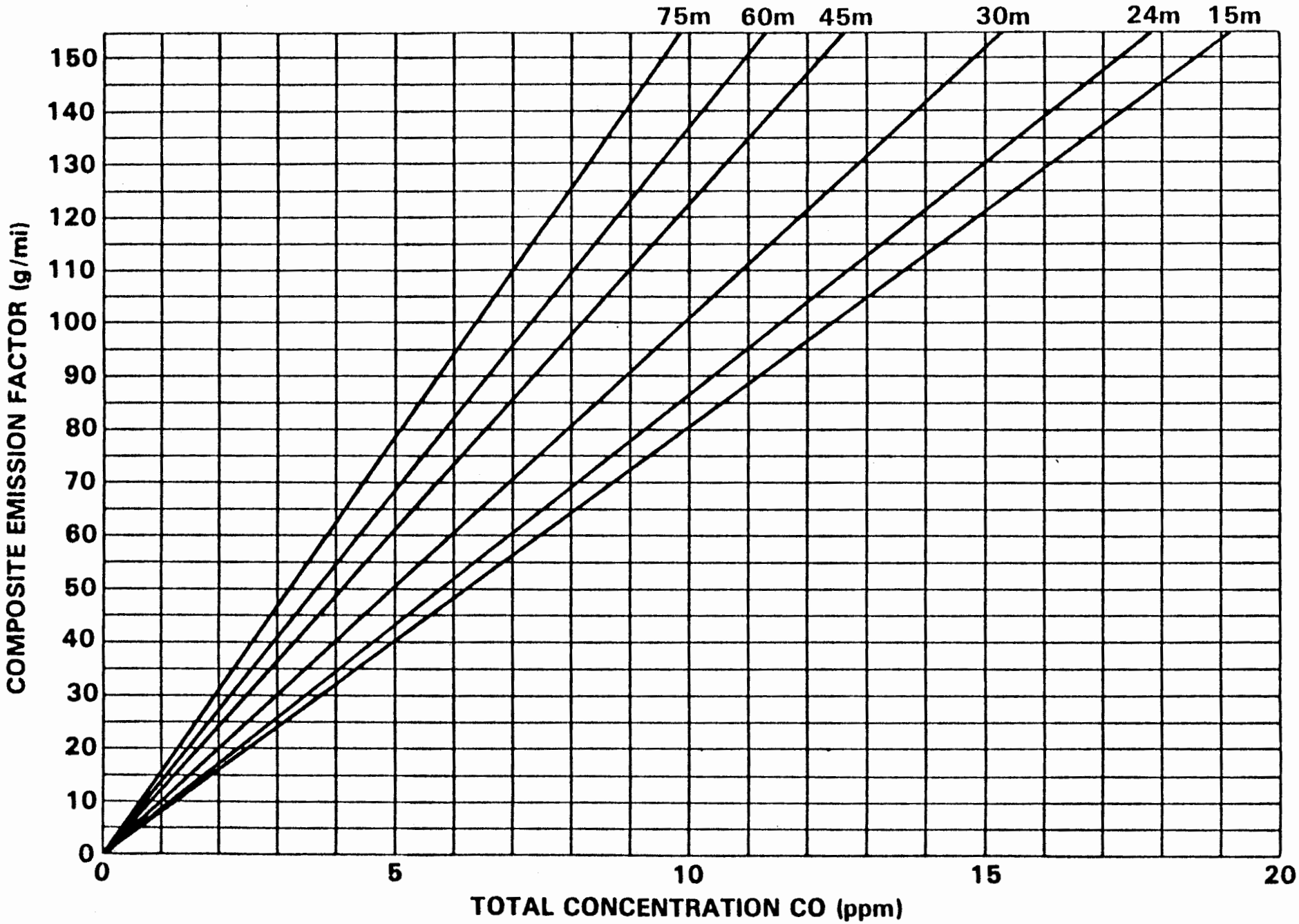

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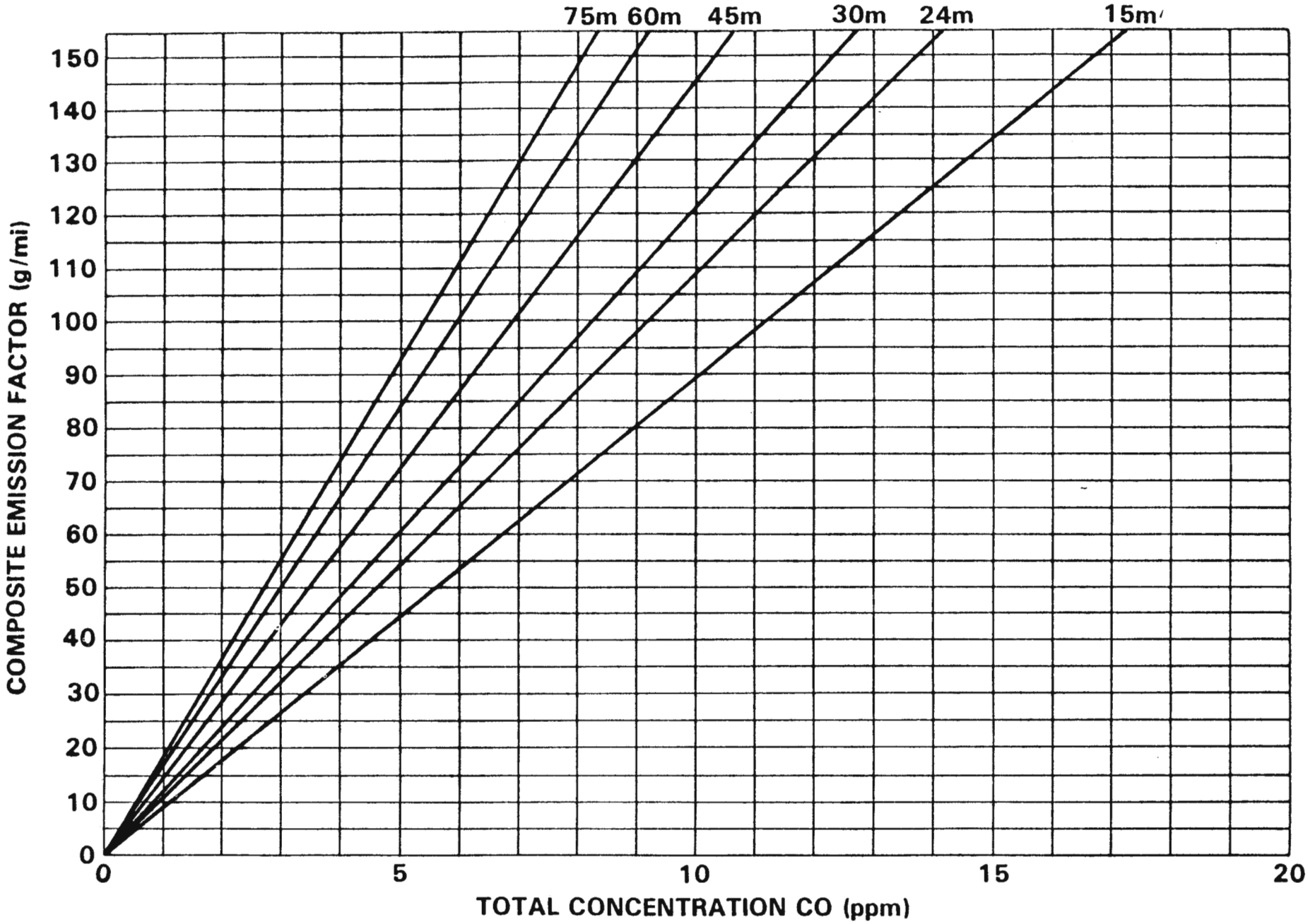

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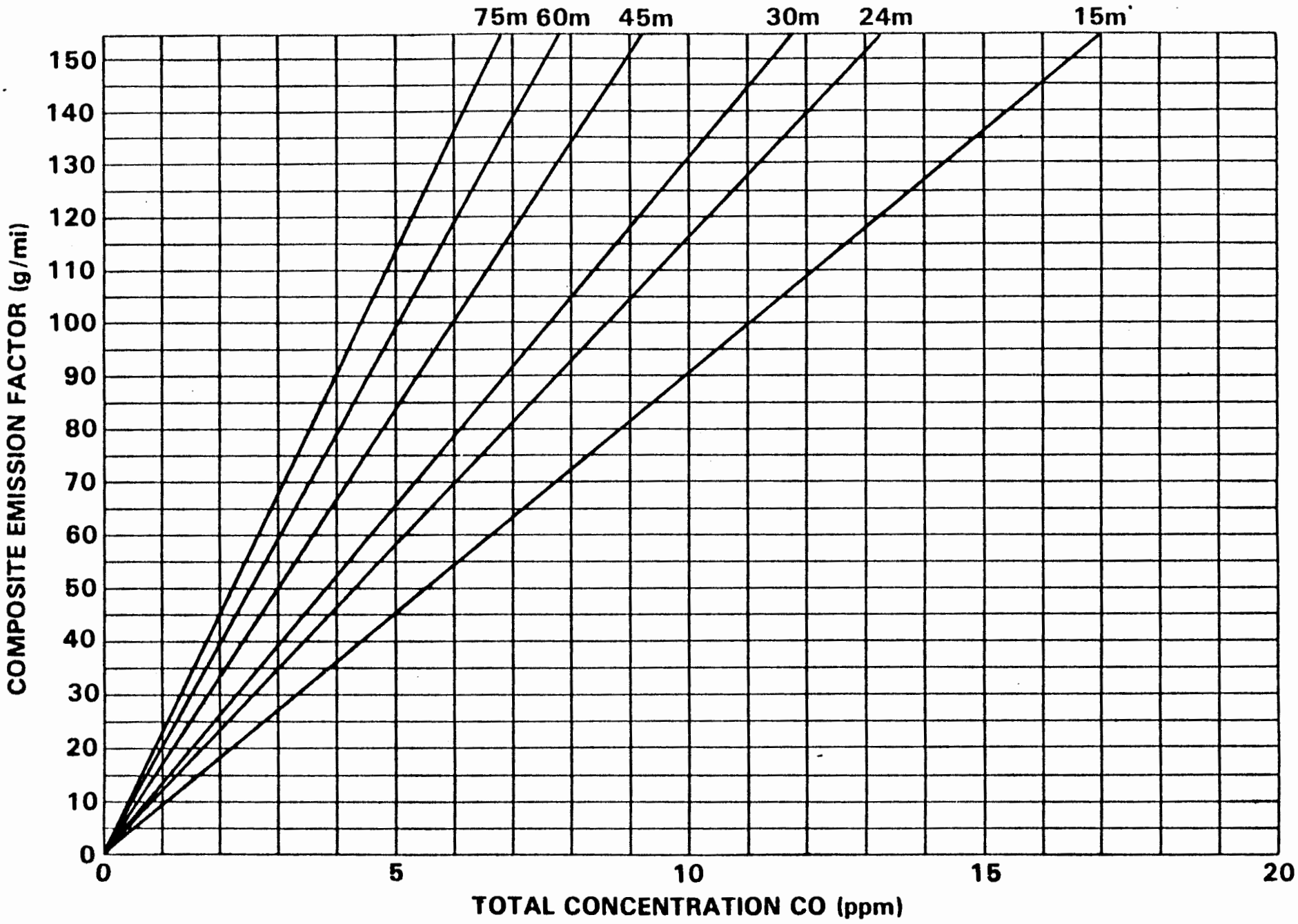

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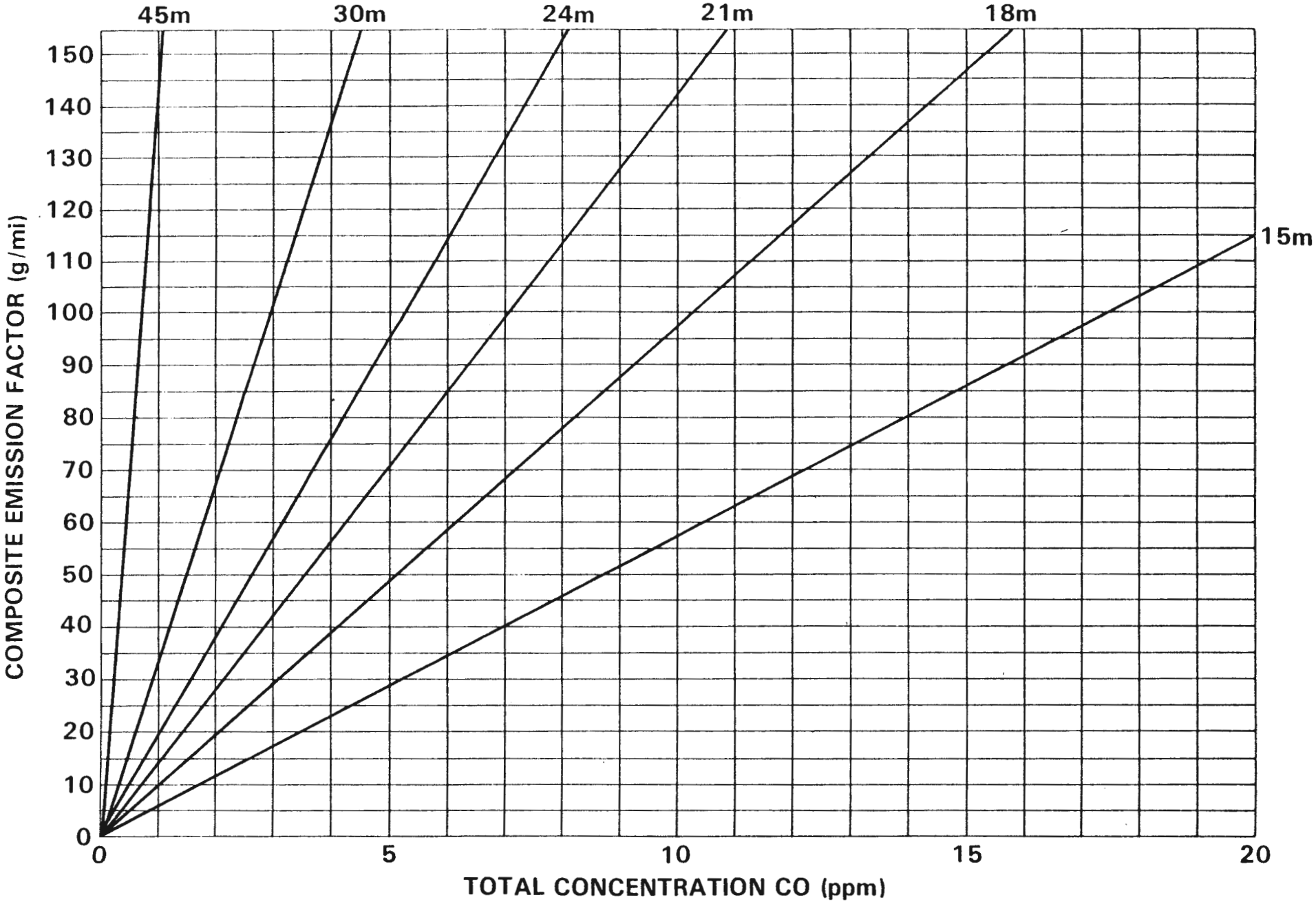

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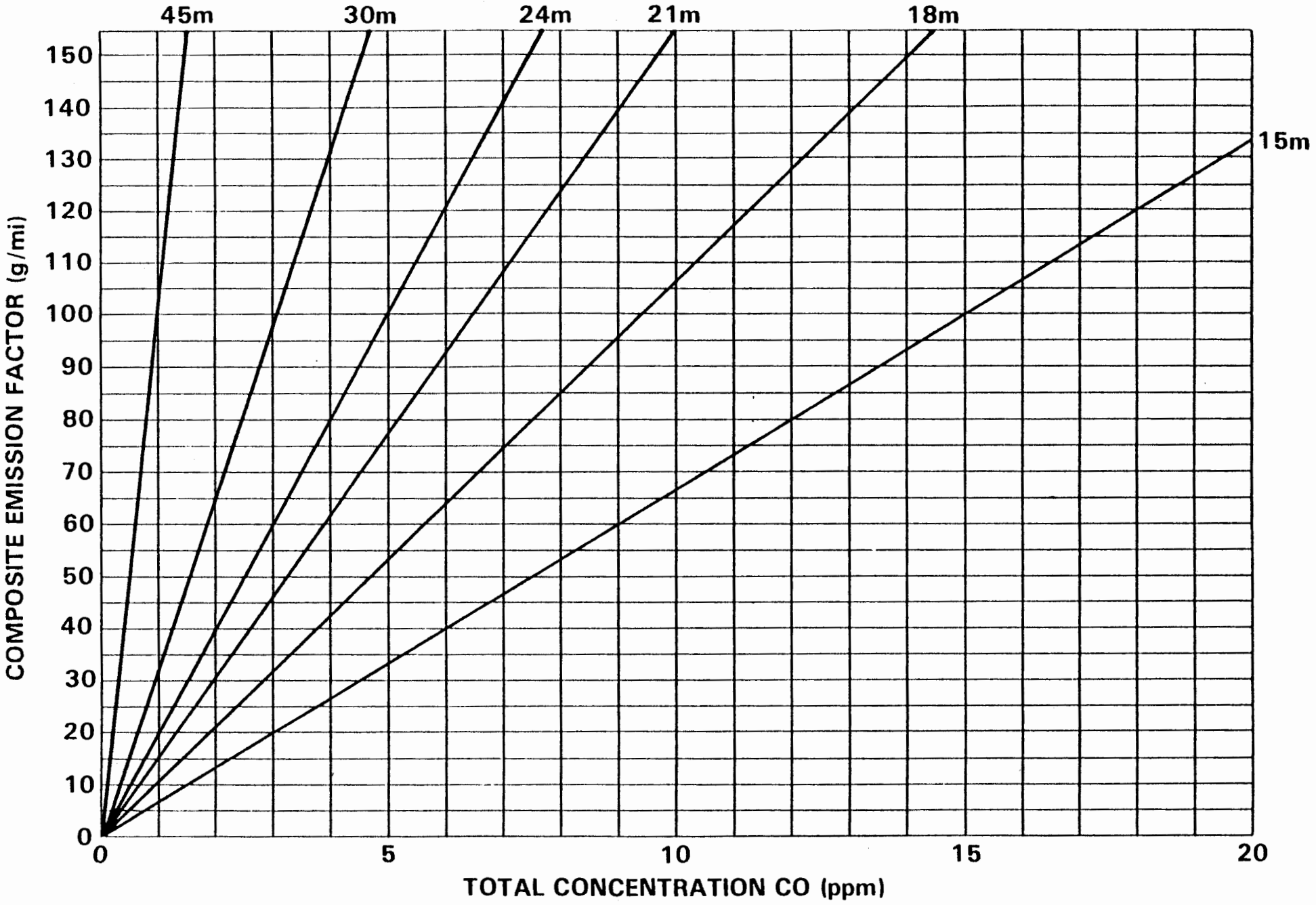

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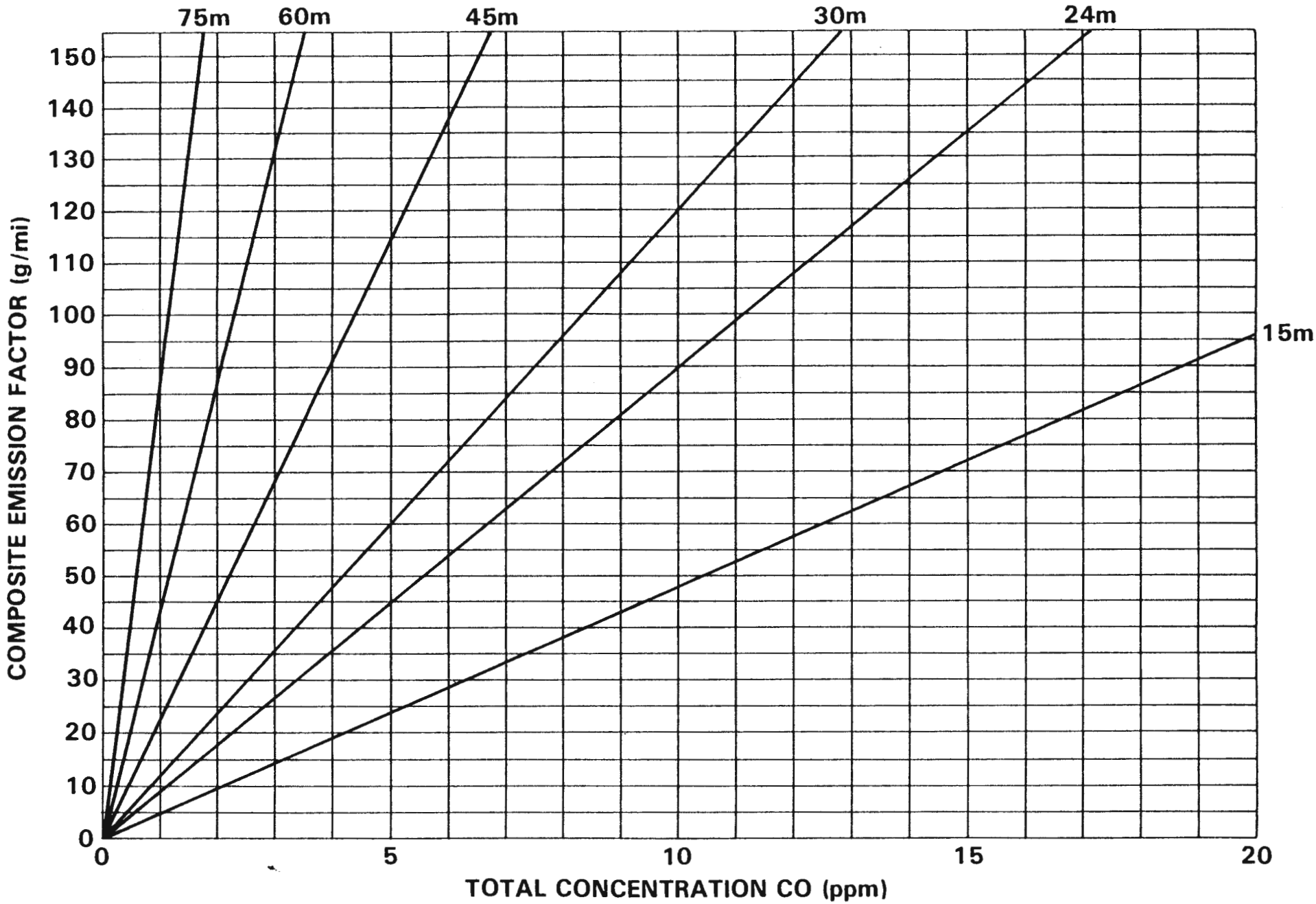

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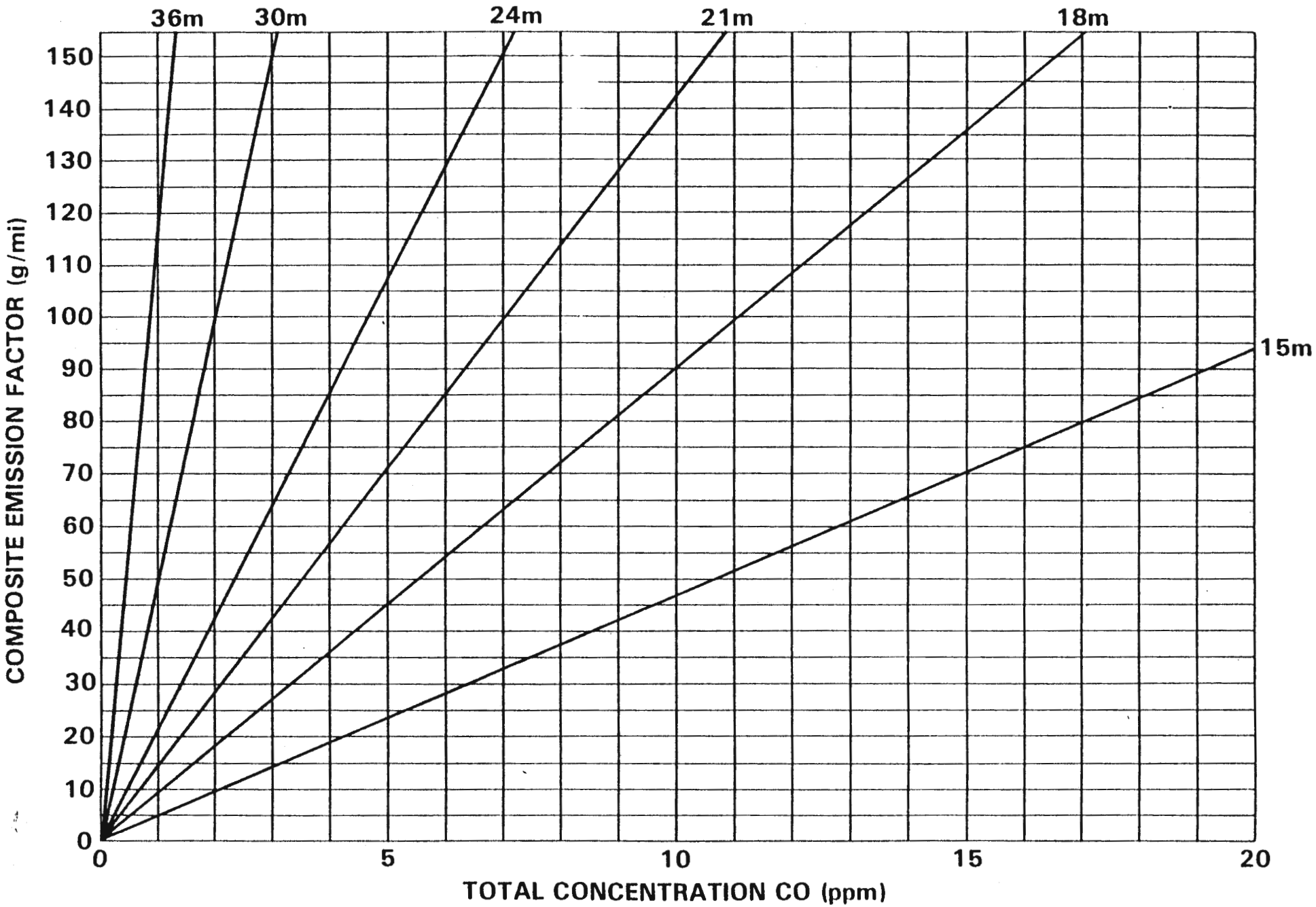

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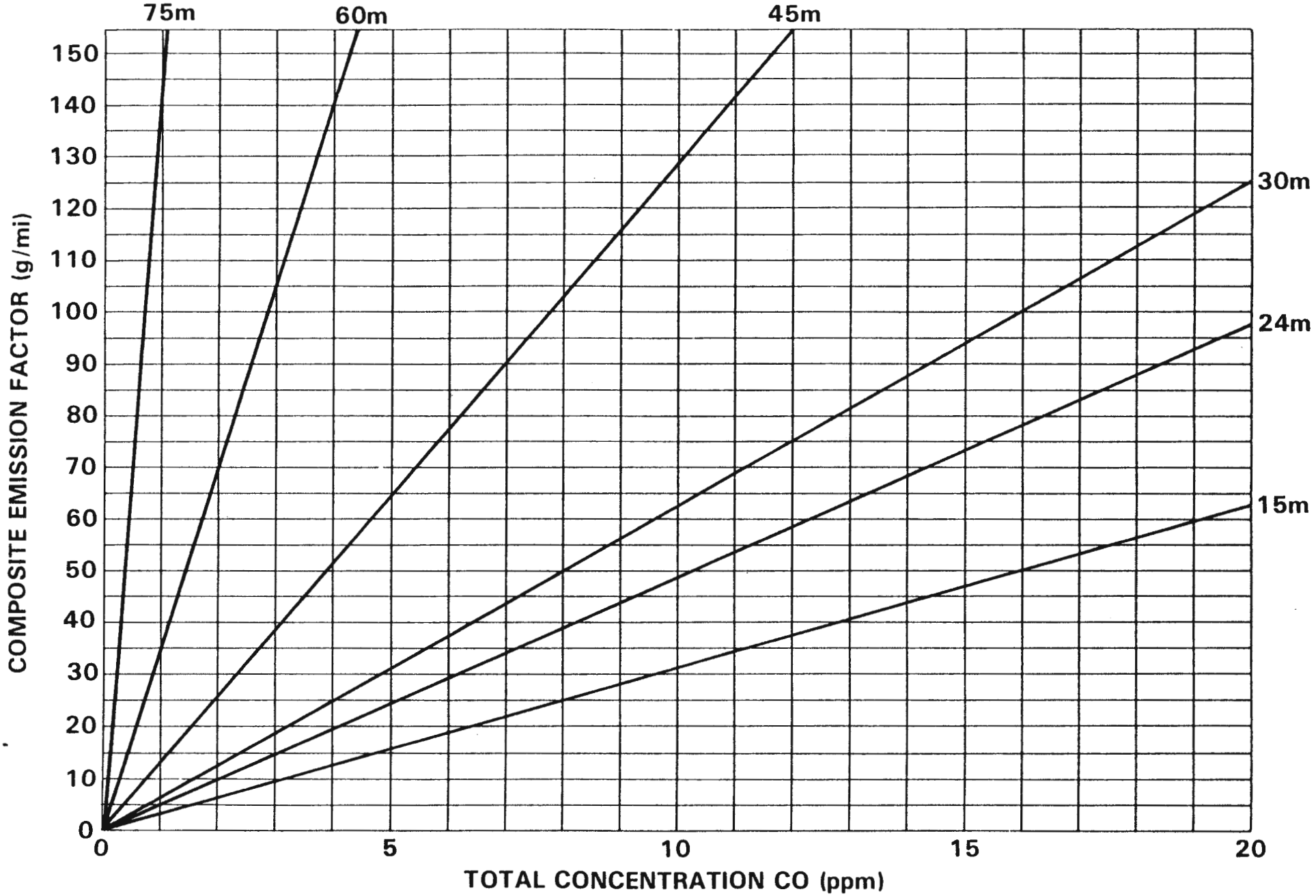

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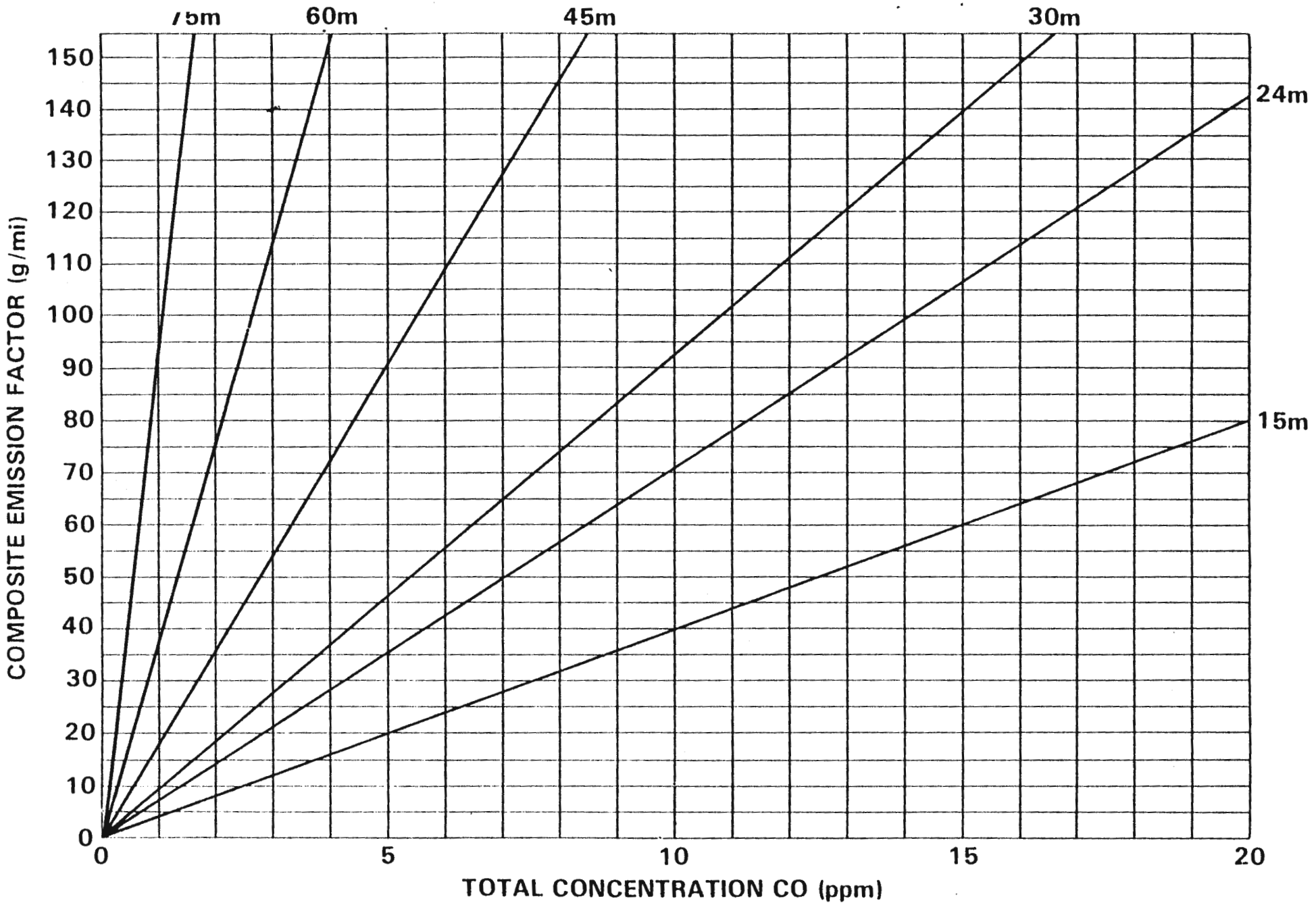

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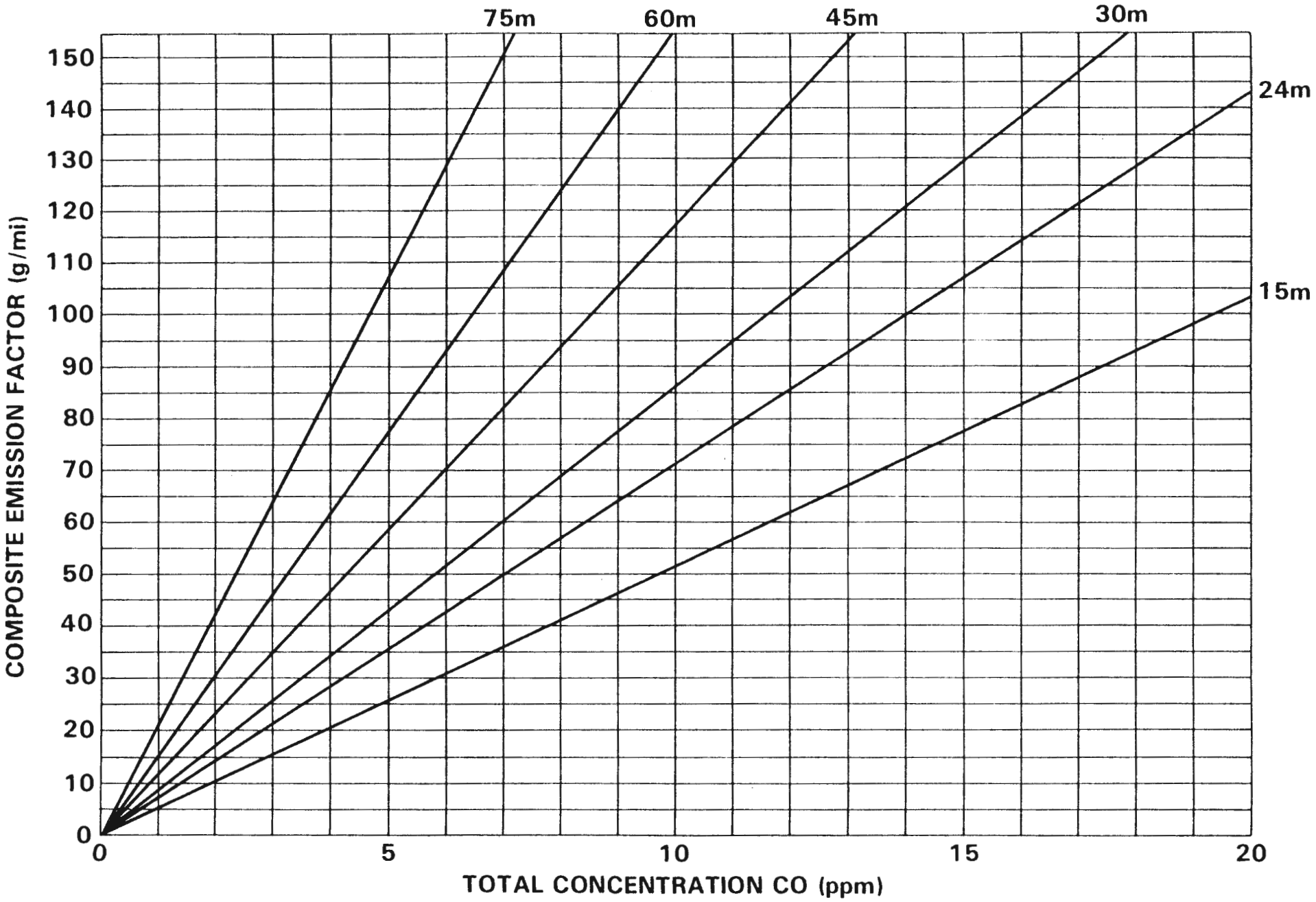

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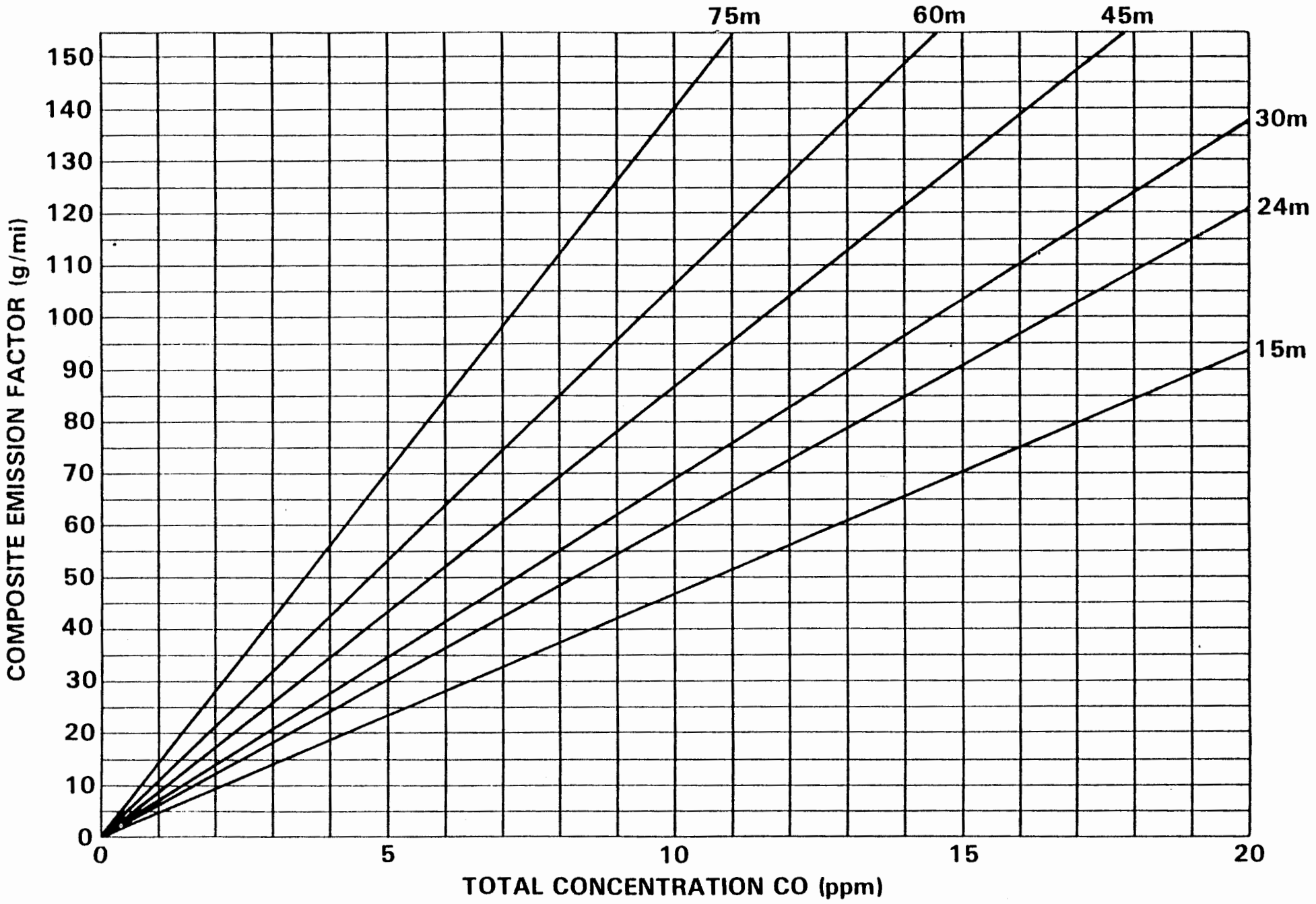

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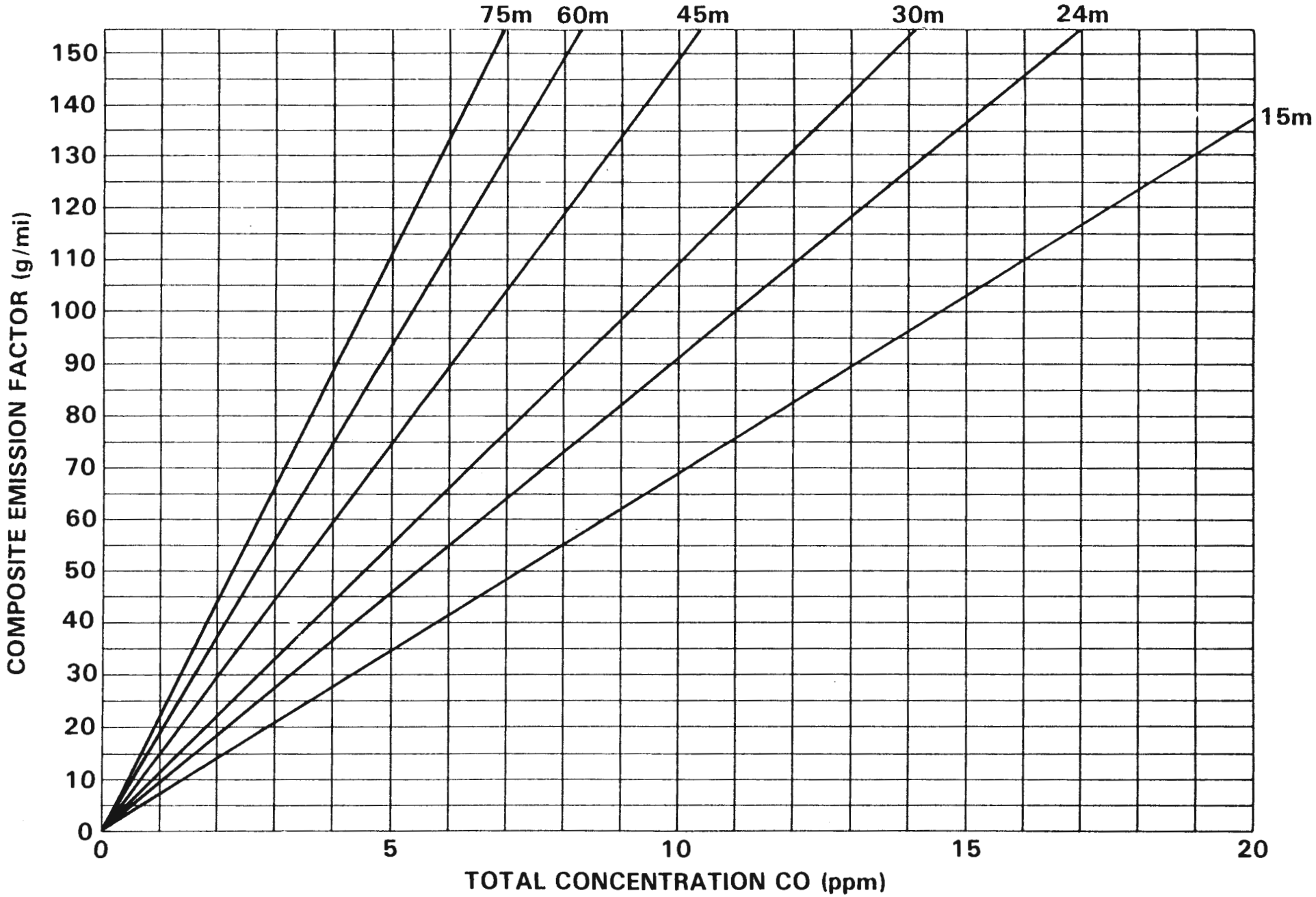

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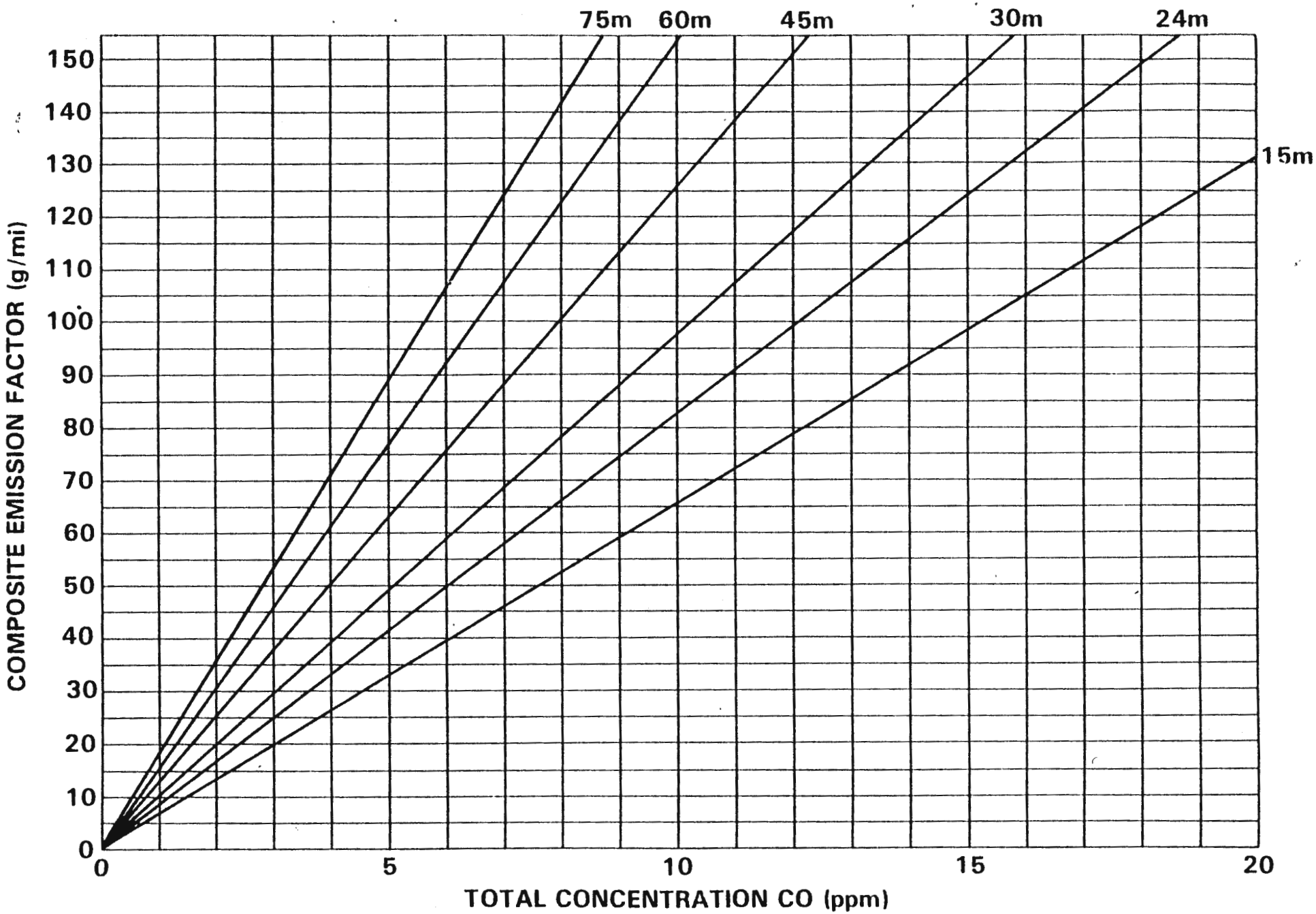

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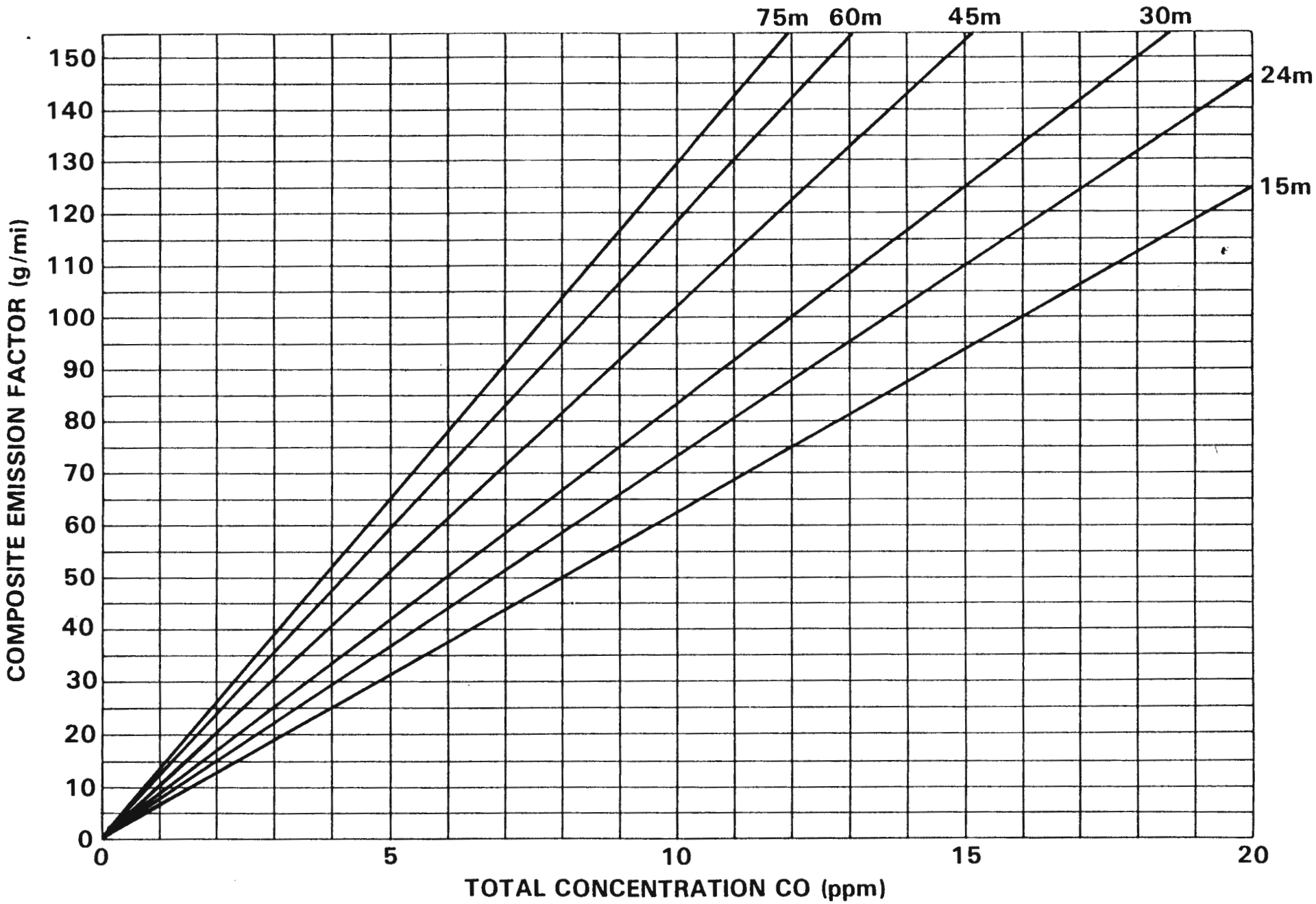

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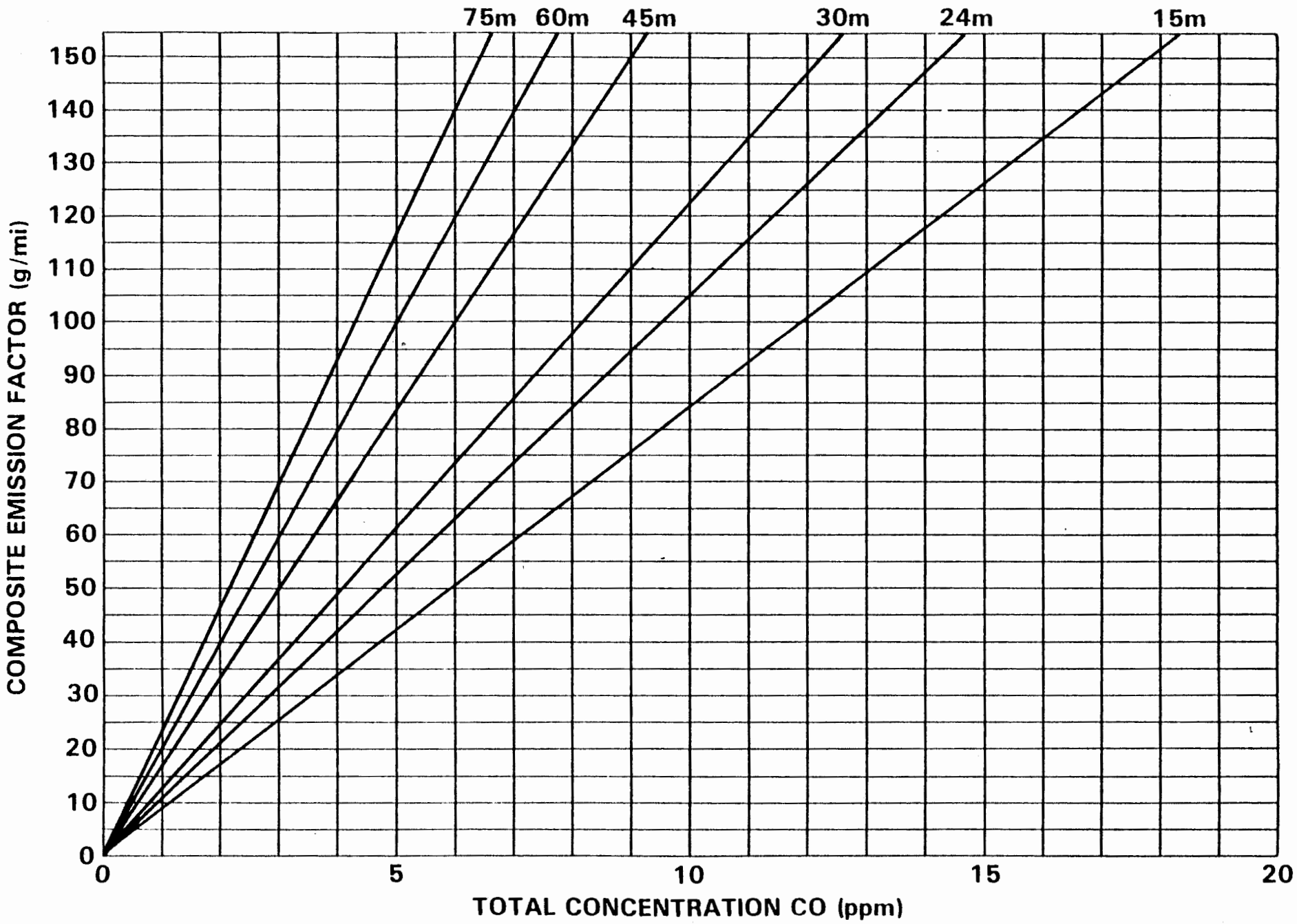

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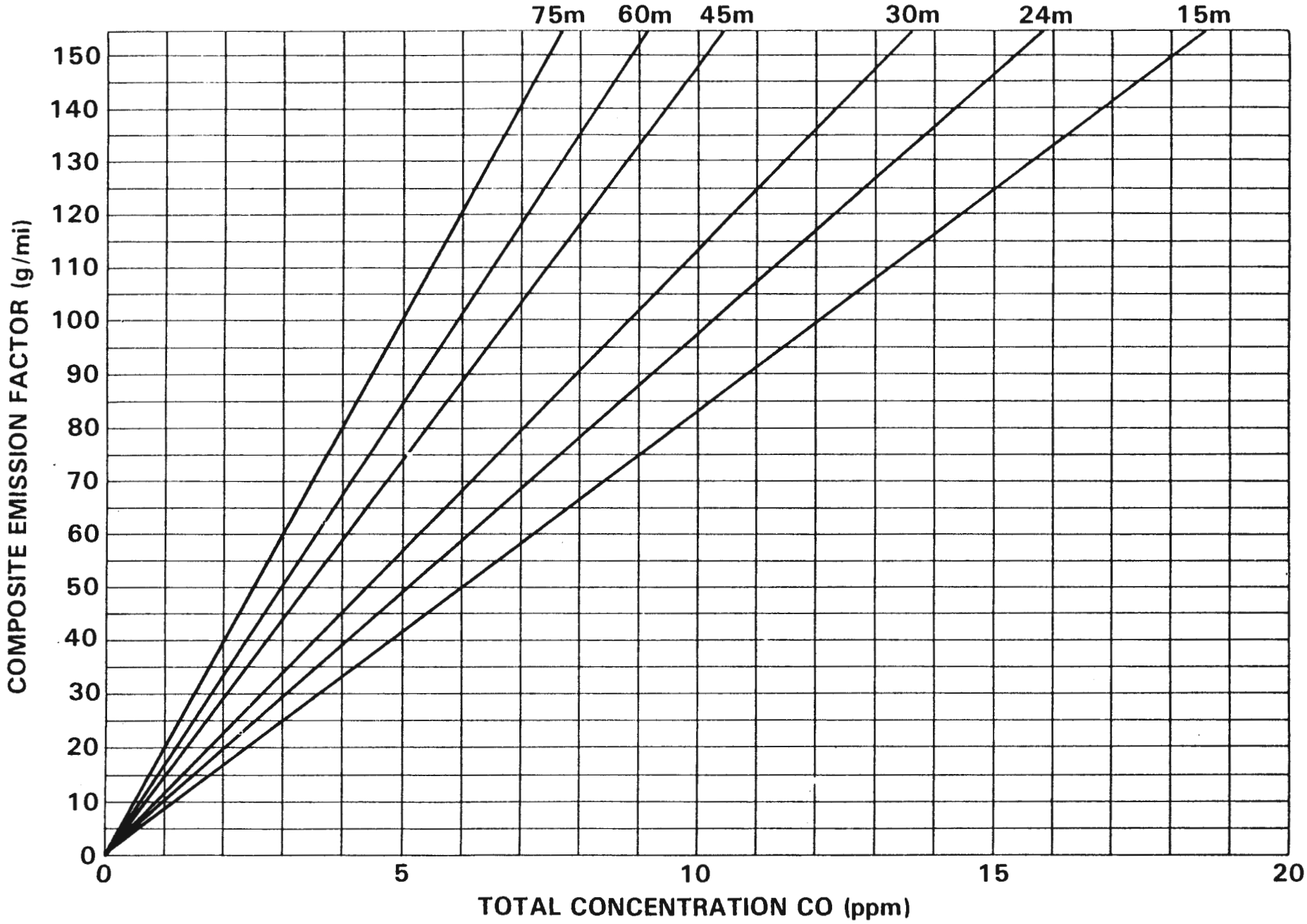

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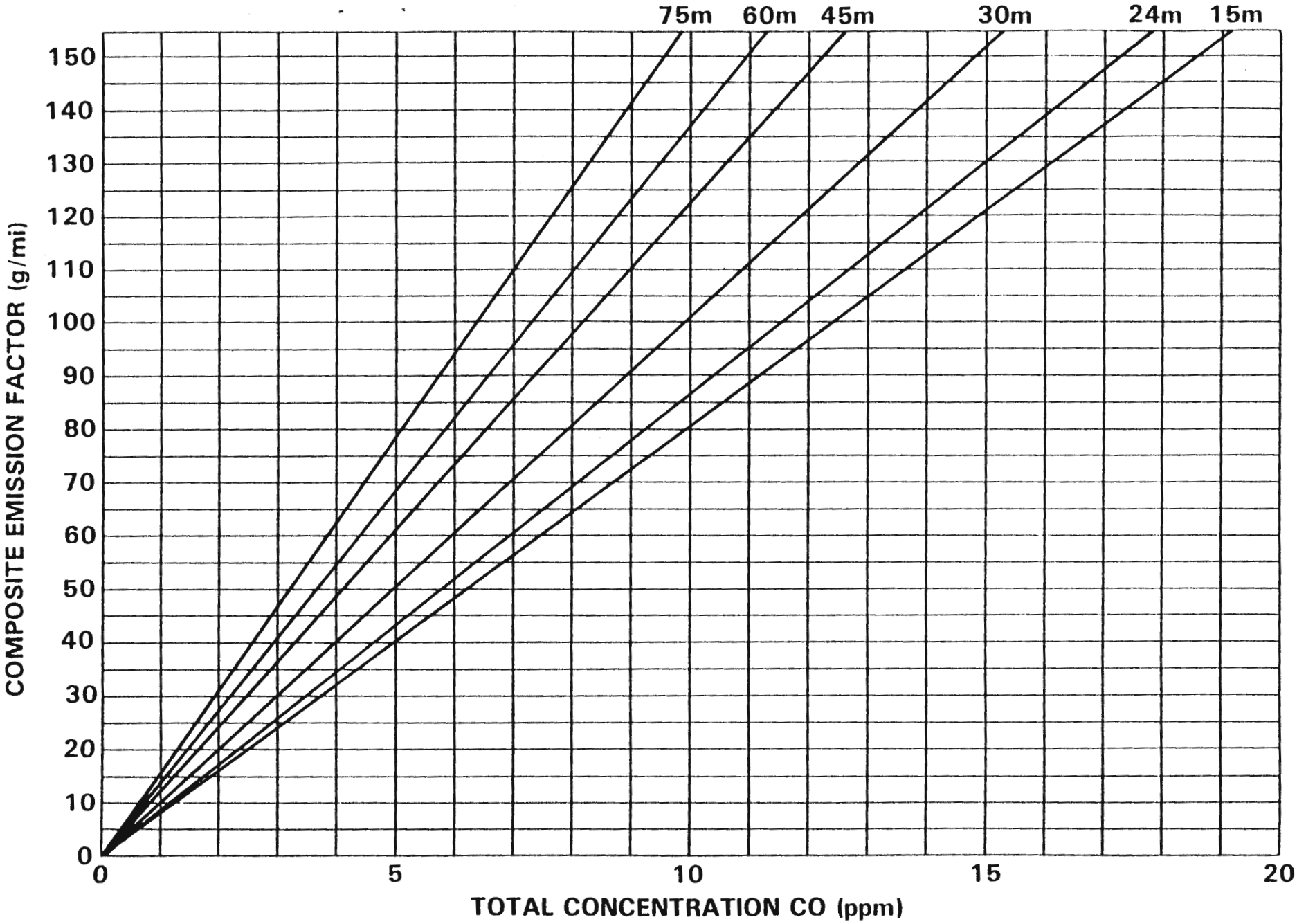

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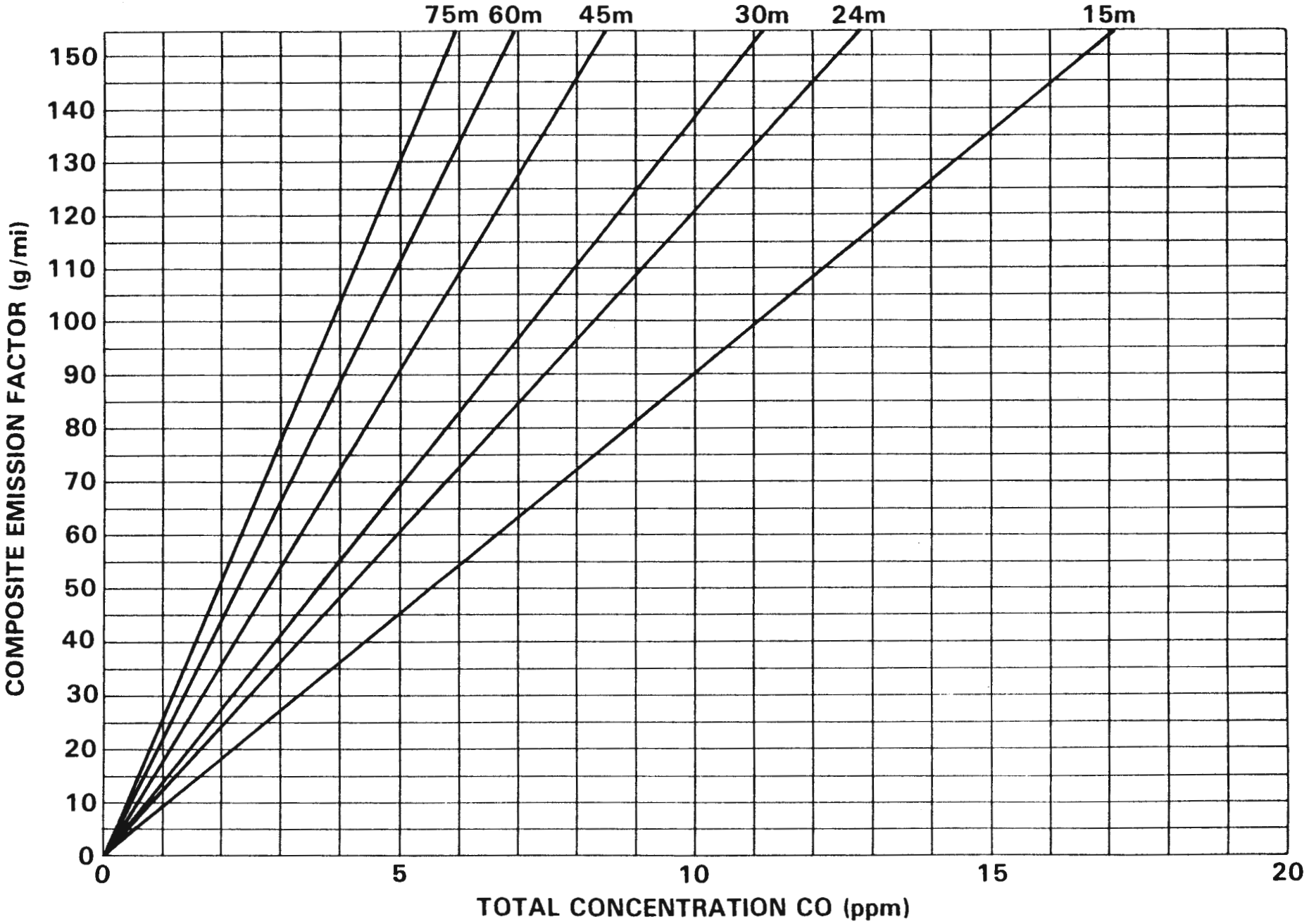

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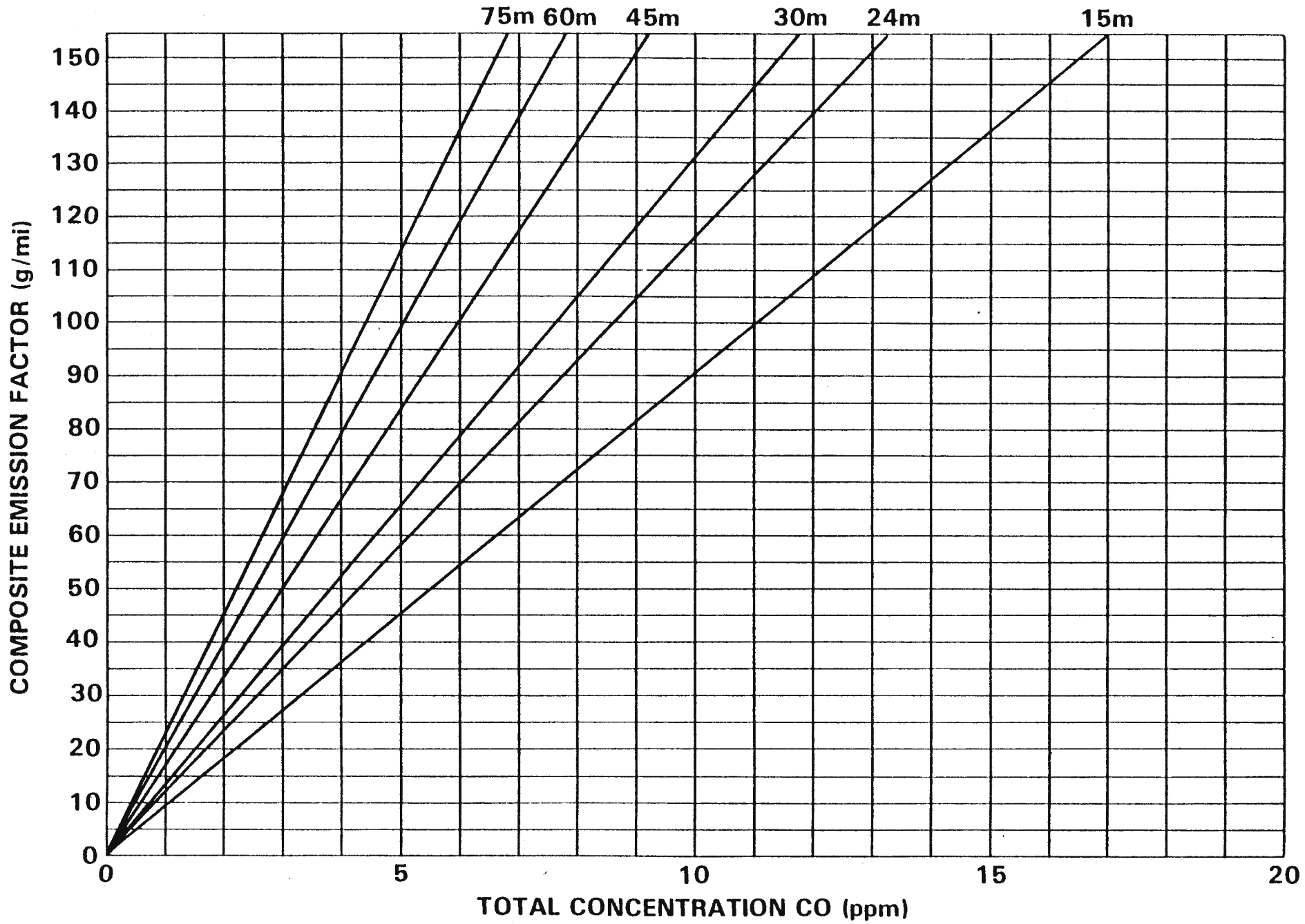

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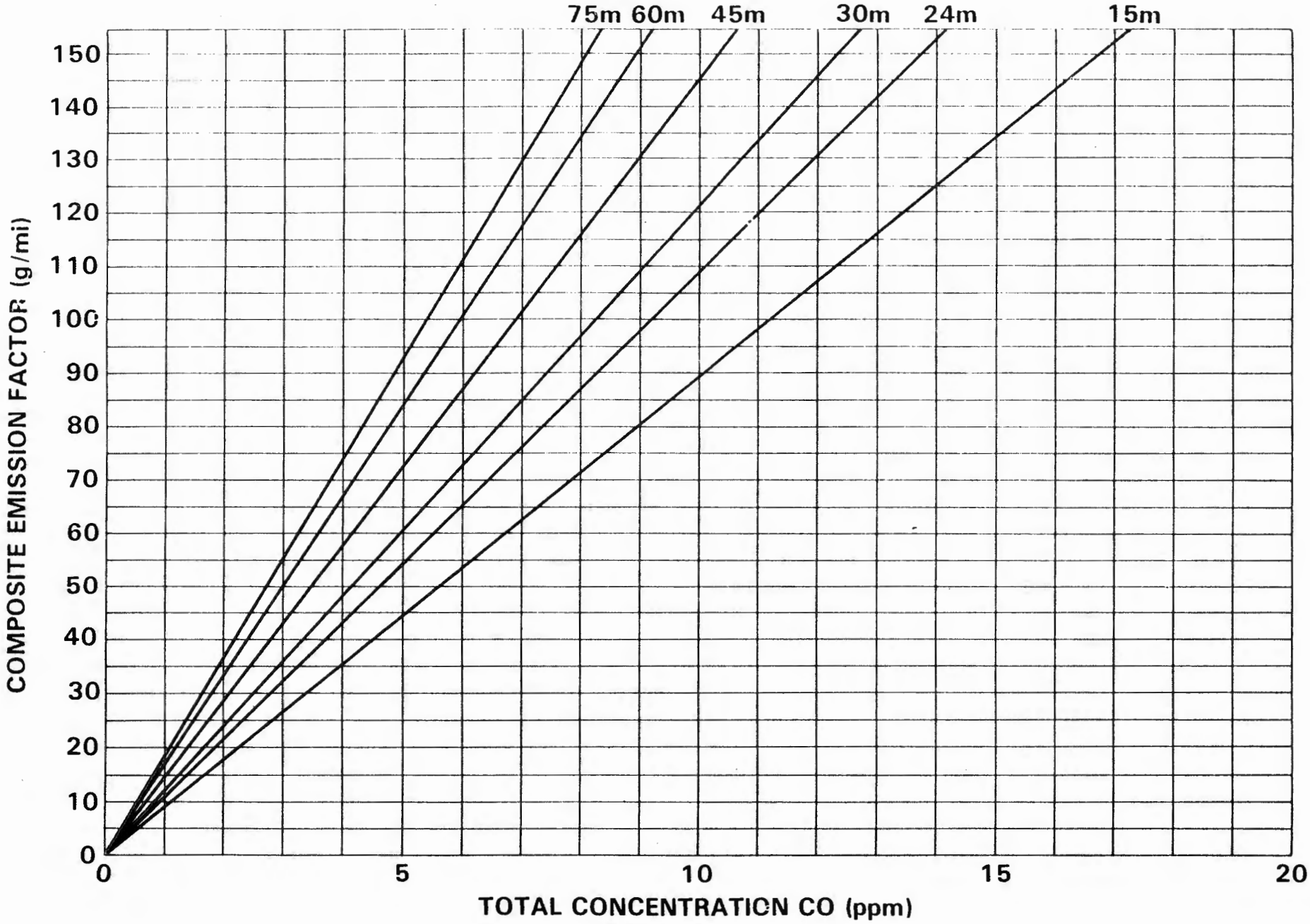

Wind Angle 90

Stability Class F

*U S GOVERNMENT PRINTING OFFICE; 1981 723-724/719