Report No. CDOH-P&R-R&SS-72-13

AIR POLLUTION AT HIGH ALTITUDE CONSTRUCTION SITES

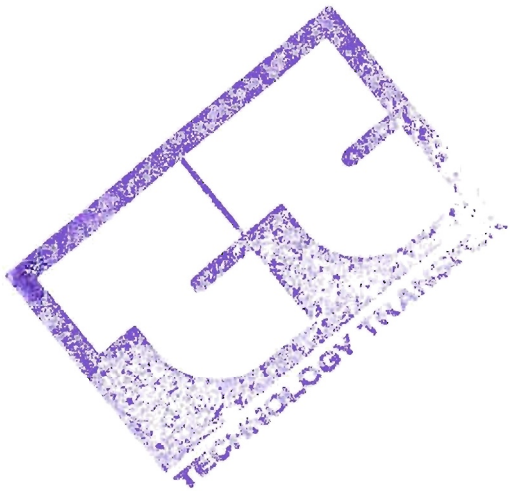
BY

LAURENCE C. BOWER
COMMITTEE SC-2
HIGHWAY RESEARCH BOARD
CONSTRUCTION AND MAINTENANCE DIVISION
Chief Engineer
Colorado Division of Highways

AND

BURRELL B. GERHARDT
Research and Special Studies Engineer
Colorado Division of Highways

FOR
Presentation at the Highway Research Board Meeting
January 1973
Washington, D. C.



A B S T R A C T

Air pollution is a matter of concern everywhere, but at high altitudes it may have more significance because of the difficulty that some people have breathing rarified air. Much of the construction in Western States is above the 6,000 foot level, and highways have been constructed above the 14,000 foot level.

The results of tests for carbon monoxide, hydrocarbons, nitrogen oxides and particulates at construction sites in Colorado are presented in this report. Tests on exhaust show that gasoline and diesel engines emit more pollutants as the altitude increases, but the concentrations near construction equipment do not build up at the same rate. Apparently the increase in wind speed and turbulence caused by mountain topography diffuses the contaminants faster at high altitudes than at the populated lower elevations.

AIR POLLUTION AT HIGH ALTITUDE CONSTRUCTION SITES

BY
LAURENCE C. BOWER
COMMITTEE SC-2
HIGHWAY RESEARCH BOARD
CONSTRUCTION AND MAINTENANCE DIVISION
Chief Engineer
Colorado Division of Highways

AND
BURRELL B. GERHARDT
Research and Special Studies Engineer
Colorado Division of Highways

At high altitude, men and machinery do not function as well as they do at sea level. Engines and pumps put out less than their rated power, and man finds it harder to consume the 30 or 35 pounds of air that he needs every day. When this air becomes polluted with certain products of combustion, the situation is even worse. People affected by some diseases or disorders find the combination of high altitude and air pollution not only offensive but even hazardous to their health.

This study is an attempt to determine the amounts of some of the common pollutants created during construction operations at high altitudes, and the resulting concentrations of these pollutants near construction equipment. The findings are important in some of the Western States where as much as half of the construction is carried out above the 6,000 foot level. State

highways in Colorado go as high as the 14,264 foot level.

SOURCES OF POLLUTION AT HIGH ALTITUDES

There are so few industrial centers at elevations above 6,000 feet that the main source of pollutants is usually considered to be the combustion of gases in engines used for locomotion or for temporary supplies of energy. Gasoline and diesel engines provide the main source of this energy, as well as the main source of the air pollution. Plans are being made for reductions in the generation of these pollutants as shown in Figure 1. However, typical emission values for the gasoline and diesel engine now operating between 6,000 feet and 14,000 feet mean sea level are shown in Table I, prepared from reports published by the Environmental Protective Agency, engine manufacturers and results of this study.

From the figures in Table I and assumptions regarding the equipment necessary to accomplish typical construction operations in the mountains, Table II was prepared. It not only provides a general guide for the generation of air pollutants at high altitudes, but it also provides a setting for measurements of the concentrations of these pollutants at construction sites.

MEASUREMENTS OF POLLUTION

Measurements of carbon monoxide used in this study began in 1964 for the design of the tunnel for Interstate 70 under the Continental Divide. Hydrocarbons and nitrogen oxide have been measured at high altitudes in Colorado for the last two years, and measurements of particulates and fugitive dust began in 1972. Beckman analyzers are used for the CO and hydrocarbons,

and a Scientific Industries Visible Absorption Analyzer is used to measure nitrogen oxides. The instruments are checked by means of calibration gases carried with the equipment in a Van. Pumps, filters and an analytical balance are used to measure particulates and fugitive dust. See Figure 2.

The results of the measurements vary over a wide range due to the size of the construction operation, the weather and the location. However, average or typical values for mountain work are shown in Table III. The values are for areas where construction workers operate their equipment, such as near the pneumatic drills, pile drivers, on the dozers and on the laydown machines.

ANALYSIS OF EMISSION AND CONCENTRATION VALUES

Test sites and data are not available in Colorado for direct comparison of all the high altitude values with sea level values. From a search of literature, however, it is possible to make some comparisons.

Carbon monoxide emission data on the gasoline engine is available from several sources. The results from tests made on 40 cars in Colorado are shown in Figure 3. Increase in altitude does not increase the percentages of the other contaminants to the degree that CO is increased. The pollutants from diesel engine exhaust vary only slightly with altitude because of the high air-fuel ratio made possible by the turbo fans. However, measurements of carbon monoxide in the exhaust from diesel engines operating at 10,000 feet elevation have shown as much as 10 gr./minute which is a value slightly higher than values usually published for sea level operation.

L. C. Bower

B. B. Gerhardt

Concentration of the pollutants is very much a function of the wind speed and background concentration. For instance, the carbon monoxide and hydrocarbon concentrations around asphalt laydown machines in busy urban areas are often about 65 ppm for the CO and 23 ppm for the hydrocarbon due to slow traffic, etc. By 10:00 AM when the wind is up to 12 mph, the same pavement operation out in open flat country may show a concentration of only 5 ppm of CO and 3 ppm of hydrocarbon.

Formulas for concentrations of pollutants usually are of the form:

$$\text{Concentration} = \frac{\text{Background}}{\text{Reading}} + \frac{\text{emission factor}}{\text{wind speed}} \times \exp\left[-\frac{\text{turbulence}}{\text{constant}} \times \text{distance}\right]$$

showing that:

1. The background concentration is additive (from many sources) and it may be quite high from sources other than the source being investigated.
2. The higher the wind velocity, the lower the concentration (and wind velocities and turbulence generally become greater with increasing elevation above sea level).
3. The concentration is dependent upon the rate of emission, and during construction operations (in contrast to energy generation operations), the emission of a particular gas may be quite erratic. Many engines are accelerated and decelerated continuously throughout the day, and so they do not build up the concentration as much as would be expected

Generally, the nitrogen oxide concentration is about 1/25 of the hydrocarbon concentration, and unlike "downtown" conditions, the hydrocarbon

concentration and the carbon monoxide concentration are nearly the same in high altitude construction areas. See Table III. This is due to the high percentage of the diesel engines, of course, which emit fairly even amounts of these two pollutants at high altitudes. See Table I.

COMPARISON OF HIGH ALTITUDE CONSTRUCTION SITES WITH OTHER AREAS

Table IV shows a comparison of the concentrations of the pollutants found at high altitude construction sites with concentrations of the same contaminants which might be found in clean air, on the open highway, in crowded stop and go traffic, in tunnels and in an EPA publication of acceptable levels for health.

It is apparent that the equipment used for typical construction operations does contribute to air pollution. On the other hand, the measurements made at Colorado construction sites indicate that the contribution is quite minimal - and it is becoming less in most instances. Fugitive dust (particles larger than 30 microns which settle out) were once on the order of 5 grams per square foot per hour at batch plants. With baghouse filters and tight bins, the area around plants where workmen operate, now often show less than .05 gram per square foot per hour.

There is still room for improvement, of course. Hard rock drilling still generates dust in a spectacular fashion. Large particles fall close to the drills with little annoyance, but the fine dust, which constitutes only about 1 percent of the weight of the material from the hole, fills the air the way crushing and screening operations used to do. Wet driling or some type of reflector near the bottom of the drill stems may improve this condition

someday where nearby inhabited areas or health conditions of operators warrant their use.

One condition where it is doubtful that a solution is imminent is the generation of contaminants (chiefly nitrogen oxides) during blasting operations. Gas from fissures in a blasted area continue to vent for an hour after the shot. Measurements show that the actual venting gases are made up of over 1000 ppm carbon monoxide, 6 percent nitrogen oxides, and 600 ppm hydrocarbons. At high altitudes, however, the wind and force of the explosion itself does much to dissipate the contaminants. Fifteen minutes after blasting an area as large as 2000 cubic yards, the level of the carbon monoxide may fall to 15 ppm, the hydrocarbons to 10 ppm, and the nitrogen oxides to 3 ppm, at a point 50 feet from the fissures.

CONCLUSIONS

This study showed that construction at high altitudes does contribute to air pollution, but in a very moderate way compared to the contributions from power plants, crowded city streets, etc. Emission and concentration values vary so much that it is difficult to present anything but overall averages. Some of the measurements for this report showed values twice as high, and some one-half as much as the figures presented as typical or average values in the Tables. In this study no attempt was made to determine the effect of these pollutants upon construction workers because the concentrations were found to be so low.

The turbulence and wind, which always seems to accompany high altitude

construction, appear to be primarily responsible for the dissipation of the pollutants. As many construction workers have commented during the course of this study, "You never notice any air pollutants after the clearing and grubbing operation. The wind always seems to find its way along a new road." At high altitudes, the supply of fresh air seems almost endless. The wind blows all the time.

FIGURE 1.

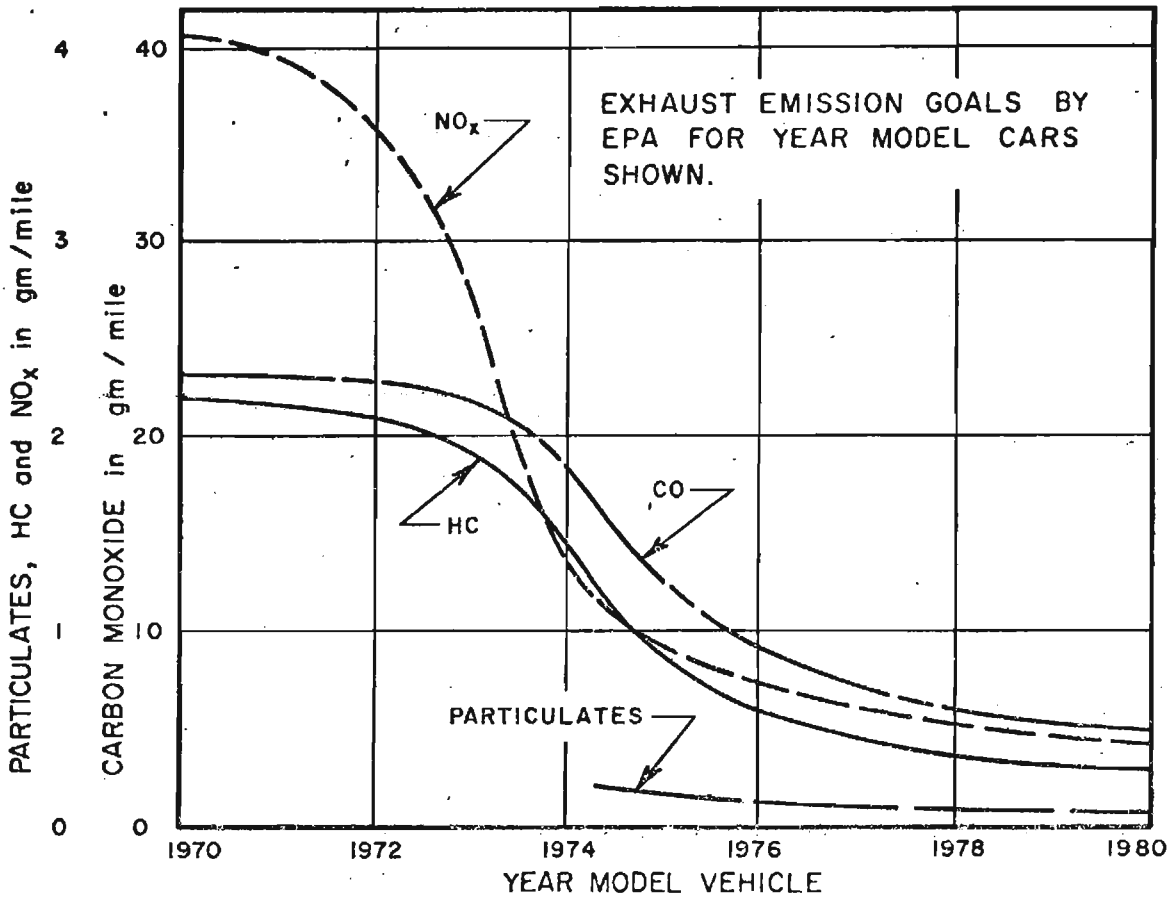
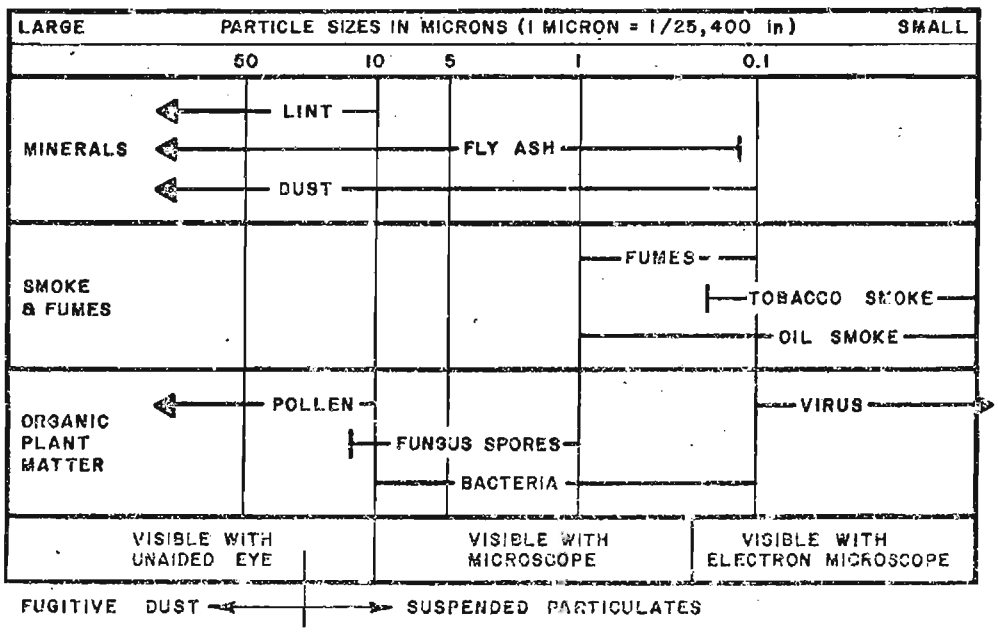


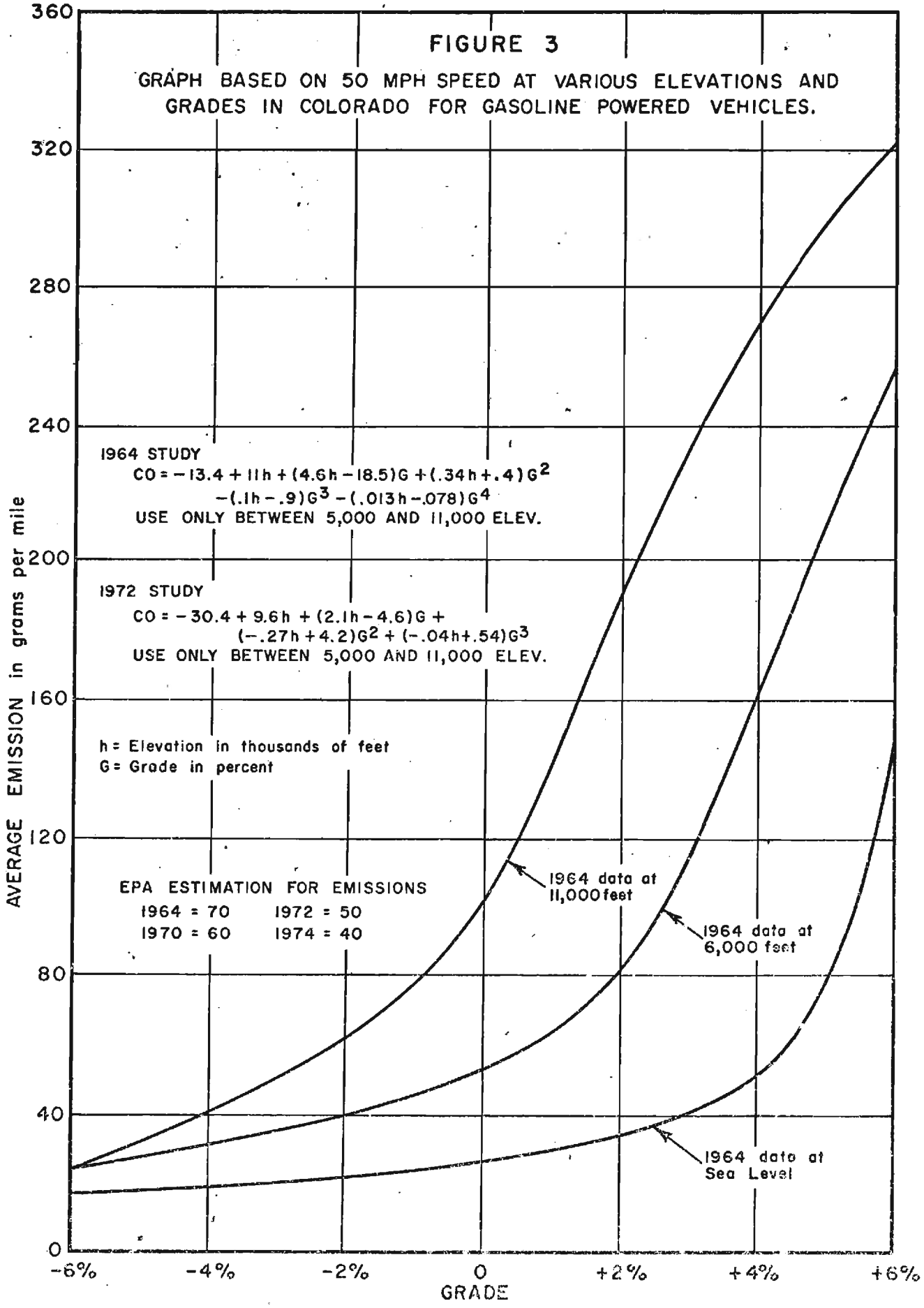
FIGURE 2



SIZE RANGE FOR PARTICULATES & FUGITIVE DUST

FIGURE 3

GRAPH BASED ON 50 MPH SPEED AT VARIOUS ELEVATIONS AND GRADES IN COLORADO FOR GASOLINE POWERED VEHICLES.



June 1972

TABLE I

TYPICAL EXHAUST EMISSIONS

FROM

GASOLINE AND DIESEL ENGINES

	Typical Gasoline Engine Used in Construction Above 6,000' MSL	Typical Diesel Engine Used in Construction Above 6,000' MSL
Exhaust gas flow, cubic feet per minute (Average for typical construction work)	40	400
Carbon Monoxide, grams per minute	100	8
Hydrocarbons, grams per minute	7	7
Oxides of Nitrogen, grams per minute	4	25
Particulates, grams per minute	.2	.6

L. C. BOWER

B. B. Gerhardt

TABLE II

TYPICAL VALUES

FOR

TAIL PIPE EXHAUST

EMISSION RATE OF POLLUTANTS AT HIGH ALTITUDES

	Values in gm/min CO	NO_x	HC	Suspended Particulates Oil Mist + Carbon black < 30 microns. milligrams/meter^3
Drilling and shooting at the rate of 1000 yds^3 of rock per day	75	30	15	1
Clearing and grubbing at the rate of 1000 yds^2 of trees and brush per hr. No open burning.	75	25	10	0.8
Mixing and placing concrete at the rate of 1000 yds^3 per day. No haul.	200	50	25	100 uncontrolled 10 controlled
Mixing and placing asphalt at the rate of 1000 yds^3 of mix per day. No haul.	200	60	50	15,000 uncontrolled 1,000 controlled
Pioneering and grading at the rate of 1000 yds^3 of roadway in mountains per hour.	20	50	15	.5
Excavating in cuts or tunnels at the rate of 1000 yds^3 per day.	120	50	20	2
Driving pile or sheeting at the rate of 1000 feet per day.	75	25	10	5
Placing pipe at the rate of 1000 feet per day.	120	50	20	1
Roadway finishing operations such as signing, striping, and placing guardrail.	100	25	20	.5
Welding steadily. One welder.	1	5	1	.3

TABLE III

AIR POLLUTION CONCENTRATIONS - TYPICAL VALUES

In the Vicinity of the Equipment Operator
at High Altitude Construction Sites

	CO (ppm)	NO_x (ppm)	CH (ppm)	Suspended Particulates Oil Mist and Carbon black <30 microns (milligrams/meter^3)
Drilling and shooting at the rate of 1000 yds^3 of rock per day.	10	.14	2	1
Clearing and grubbing at the rate of 1000 yds^3 of trees and brush per hour. No open burning.	5	.10	3	.4
Mixing and placing concrete at the rate of 1000 yds^3 per day. No haul.	4	.11	5	.5
Mixing and placing asphalt at the rate of 1000 yds^3 of mix per day. No haul.	7	.14	17	.1
Pioneering and grading at the rate of 1000 yds^2 of roadway in mountains per hour.	4	.17	3	.2
Excavating in cuts or tunnels at the rate of 1000 yds^3 per day.	6	.18	3	.3
Driving pile or sheeting at the rate of 1000 feet per day.	4	.10	3	.4
Placing pipe at the rate of 1000 feet per day.	5	.12	5	.2
Roadway finishing operations such as signing, striping and placing guardrail.	5	.12	7	.2
Welding steadily.	10	.1	5	.2
Values usually associated with a hazard to occupational health	50+	5+	18+	5+

TABLE IV

TYPICAL AIR POLLUTANT CONCENTRATIONS

	Carbon Monoxide ppm	Hydrocarbons ppm	Nitrogen Oxides ppm	Particulates Milligrams per Cubic Meter
Typical clean mountain air	0	.25	0	.030
High altitude construction sites	8	8	.14	.5
Typical air on an open (urban)freeway	12	3	.15	.2
Typical air for slow, heavy, stop and go traffic	35	10	2	.3
Typical for a tunnel with heavy traffic	120	12	3	.4
Upper EPA level for good health	35	.24	.05	.26

ESTIMATE OF CARBON MONOXIDE CONCENTRATION AT STRAIGHT CREEK TUNNEL AREA

	Inside Wind	No. Fans Operating	Vehicles per hour	Estimated CO Concentration At Roof Outlet Ducts	Estimated CO Concentration At ROW Line 200' Away
1973 to 1975 Condition WB bore of St. Creek carrying EB and WB Traffic. (Data based on 1972 model car emission)	Calm	2	500	35 ppm	9 + background
	Calm	2	1,500	105	27 + background
	Calm	4	500	16	7 + background
	Calm	4	1,500	48	22 + background
	Calm	6	500	12	6 + background
	Calm	6	1,500	37	21 + background
					Windward (ROW Line) / Lee Side (ROW Line)
	5 mph	2	500	25	0 - 4 ppm
	5 mph	2	1,500	75	1 - 10 ppm
	5 mph	4	500	38	0 - 5 ppm
	5 mph	4	1,500	40	0 - 10 ppm
	5 mph	6	500	10	0 - 3 ppm
	5 mph	6	1,500	30	0 - 10 ppm
Westbound = 1.6% uphill	5 mph	2	500	30	0 - 4
	5 mph	2	1,500	100	0 - 13
	5 mph	4	500	20	0 - 4
	5 mph	4	1,500	60	0 - 13
	5 mph	6	500	14	0 - 4
	5 mph	6	1,500	44	0 - 13
1976 + Condition Twin Bores for One Way Traffic	15 pmh	2	500	20	0 - 1
	15 mph	2	1,500	55	0 - 2
	15 mph	4	500	16	0 - 1
	15 mph	4	1,500	44	0 - 2
	15 mph	6	500	12	0 - 1
	15 mph	6	1,500	36	0 - 2
Eastbound = 1.6% downhill	5 mph	2	500	20	0 - 3
	5 mph	2	1,500	60	0 - 9
	5 mph	4	500	13	0 - 3
	5 mph	4	1,500	36	0 - 9
	5 mph	6	500	10	0 - 3
	5 mph	6	1,500	28	0 - 9
	15 mph	2	500	12	0 - 1
	15 mph	2	1,500	40	0 - 2
	15 mph	4	500	10	0 - 1
	15 mph	4	1,500	30	0 - 2
	15 mph	6	500	8	0 - 1
	15 mph	6	1,500	24	0 - 2

Note: 500 vph and 1500 vph in each direction represent a very heavy traffic condition.

The 1975 condition shown here is based on 1972 emission rates. 1975 emission rates may be considerably lower.

Total concentration at ROW line with wind at 5 mph for 500 vph westward and 500 vph eastward in twin tunnels should be about 7 ppm. With 1500 vph in each tunnel, the CO concentration should be about 20 ppm. High wind will reduce the concentration almost proportionally; that is, at 10 mph, CO concentration should not be over 10 ppm.