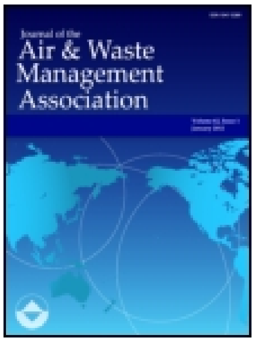

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LEAD, CARBON MONOXIDE *and* TRAFFIC*

A Correlation Study

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During the course of a study on the contribution of engine exhausts to air pollution, information was obtained on the monoxide and particulate lead concentrations in the atmosphere of a northeastern metropolitan city. The traffic density at each sample location was also obtained. The results showed high correlation between traffic density, average carbon monoxide concentration, and average particulate lead concentration.

A review of the literature showed that little work had been done on the relationships between these variables. Lykova,[22] Effenberger,[10a] and Clayton[9a, 9b] compared carbon monoxide and traffic density while Tufts[34] compared lead in air with traffic density. Their results are described in the discussion of the correlations evolved.

The carbon monoxide concentration for urban areas,[7] Cincinnati,[5] Detroit,[3, 9b] Los Angeles,[4, 16, 20, 24, 30] New York,[17] Baltimore,[4] Donora,[4] Salt Lake City,[4] Santa Clara,[31] London,[25, 35] Paris,[23] Milan,[12, 13] Naples,[15] Rome,[10] West Germany,[10a, 27] Brussels,[14] and Soviet cities[22] showed that the concentration in the air ranged from <1 to about 100 ppm. However, on occasion in heavily congested traffic, the CO level was reported as high as 500 ppm. Average CO levels in the cities tested were for the most part below 15 ppm. In tunnels in New York,[33, 36] other large U. S. cities,[1] and Berlin,[27] the carbon monoxide level reached upwards to 300 ppm with mean levels of about 70–100 ppm.

The atmospheric lead concentrations measured (including tests in tunnels) in Cincinnati,[4, 5, 29] Detroit-Windsor,[8, 9, 26] Chicago,[34] Los Angeles,[6, 16, 21, 29, 30] New York,[29] numerous other U. S. cities,[4, 29] a Michigan county,[2] Milan,[12, 13] Zurich,[28] and Switzerland[18] had a range of <1 to 27 mmg/cu m. Lead concentrations below 10 mmg/cu m were most common. In garages, the level reached was as high as 60 mmg/cu m.[19] A peak level of 18.8 mmg/cu m was reported[28] in a tunnel through which about 12 cars/min passed.

Experimental

Traffic density was obtained by physically counting, using a manual counter, all the cars and trucks passing sample location for 5–10 min each half hour during the eight-hour sample day. The data are presented in vehicles per minute.

Particulate lead was obtained by metering air through a rotameter at about 10 l/min and then through a Millipore molecular sieve filter paper, unbacked, in a closed filter holder assembly. The total weight of the lead collected was determined colorimetrically by a dithizone procedure similar to that described by Elkins.[11] The results are calculated in mmg/cu m.

Carbon monoxide concentration was determined in a partially continuous manner similar to that outlined by Shepherd, et al.[32] This was done by metering air through a rotameter at a constant rate of about 100 cc/min through a silica gel trap and then into three commercially available carbon monoxide indicator tubes in parallel. The color developed, which varies from yellow to dark green, is a function of the concentration of carbon monoxide and the quantity of air sampled. By visually matching the shades obtained to a reference color standard and noting the time and sampling rate necessary for the color change, the concentration of carbon monoxide in the air was determined in ppm.

The three tubes in parallel were used as a means of eliminating possible defective tubes, although in the study none were found. The color in all sets of tubes changed simultaneously to the same shade, as closely as could be determined visually. The tubes were changed in sets of three when a predetermined shade was matched. If the color in the tube had not reached a reference standard, the final sample of the day required interpolation.

Sampling Schedule

The schedule was arranged to minimize bias in sampling. Each sample location in the study was used five times. The program was operated five days a week, Thursday through Monday, during a three-week period in July and August, 1959. Sampling started at 10:30 AM and continued through 6:30 PM each day. The Thursday-through-Monday schedule was chosen so that weekend as well as weekday data could be collected. The sampling sequence is shown in Fig. 1.

The stations chosen fell into three categories. Stations 1 and 2 were in high traffic areas, stations 3 and 4 were in moderate traffic areas, and stations 5 and 6 were in light traffic areas. The rows in the chart show that on each day two stations of the six selected were sampled during the three weeks allocated. The columns show that each station was sampled twice in two of the sampling weeks and once in the remaining week.

Sample Location

Factors that were taken into account in selecting the sites included the area of neighborhood, the type and location of nearby industry, location of nearby thoroughfares, density and continuity of traffic flow, electric power availability, shelter, space for instruments, prevailing wind, and direction and location of barriers and buildings. The sam-

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Table I—Traffic Density, Vehicles per Minute

Sampling Day	Station: Heavy Traffic 1	Heavy Traffic 2	Moderate Traffic 3	Moderate Traffic 4	Light Traffic 5	Light Traffic 6
Thurs.	61	45	13	14	2	3
Fri.	69	45	15	16	2	1
Sat.	52	39	12	12	2	2
Sun.	42	23	8	7	1	1
Mon.	61	63	14	13	2	3
Over-all Station Avg	57	43	12	12	2	2

Table II—Range of Traffic Density, Vehicles per Minute

Sampling Day	Station: Heavy Traffic 1	Heavy Traffic 2	Moderate Traffic 3	Moderate Traffic 4	Light Traffic 5	Light Traffic 6
Thurs.	55–70	32–70	11–22	9–17	1–4	1–5
Fri.	60–99	38–56	10–20	13–18	1–3	1–2
Sat.	32–68	30–46	9–14	9–15	1–3	0–4
Sun.	38–54	16–30	5–11	3–10	0–2	1–3
Mon.	49–79	32–79	10–17	9–21	1–4	1–5
Station Range	32–99	16–79	5–22	3–21	0–4	0–5

Table III—Lead Concentration, mmg/cu m

Sampling Day	Station: Heavy Traffic 1	Heavy Traffic 2	Moderate Traffic 3	Moderate Traffic 4	Light Traffic 5	Light Traffic 6
Thurs.	4.74	2.60	1.61	1.31	0.20	0.33
Fri.	3.61	1.91	0.98	0.64	0.55	0.73
Sat.	2.80	2.03	1.50	0.99	0.77	<0.1
Sun.	0.61	0.65	0.60	0.70	0.49	0.61
Mon.	0.77	1.91	1.30	1.05	0.16	0.50
Over-all Station Avg	2.51	1.82	1.20	0.94	0.43	0.43

Table IV—Carbon Monoxide Concentration, ppm

Sampling Day	Station: Heavy Traffic 1	Heavy Traffic 2	Moderate Traffic 3	Moderate Traffic 4	Light Traffic 5	Light Traffic 6
Thurs.	16	6	3	2	1	<1
Fri.	9	4	2	1	<1	<1
Sat.	8	4	<1	2	<1	1
Sun.	1	<1	<1	1	<1	<1
Mon.	5	8	2	2	1	<1
Over-all Station Avg	8	4	1	2	<1	<1

plers were set up 30–50 ft from the nearest traffic at about 4 ft above ground level.

Results

The traffic density was averaged from 17 5–10 min traffic counts during the eight-hour day, and the results are shown in Table I.

It is interesting to note the variation in traffic flow for the days of the week. On Sundays, the average traffic flow is reduced by one-third to one-half of the over-all station average. During the weekdays, the average traffic density remains fairly constant.

The ranges of traffic densities are tabulated in Table II. The ratio of the upper to the lower traffic count varies from 1.4:1 to as much as 5:1. For obvious mathematical reasons, these ratios do not consider the ranges with 0 vehicles per minute as the lower limit. The average ratio of range extremities is 2.5:1. The peak traffic flows were generally reached from 4:00–5:30 PM, while the lows were recorded usually from 6:00–6:30 PM.

Lead

The particulate lead concentrations obtained during the sampling program are presented in Table III. These concentrations represent eight-hour averages.

The <0.1 value shown for Saturday at Station 6 was assumed equal to 0 mmg/cu m for calculation purposes. A regression of lead levels on traffic density using the 30 data points obtained yielded the following relation which is positively correlated at greater than 99% significance

$$\mathrm{Pb} = 0.444 + 0.0363T \quad (1)$$

where

Pb = lead level, mmg/cu m
T = traffic density, vehicles per minute past the sample location

Equation (1) plus the corresponding 95% confidence limits for the regression of lead concentration on traffic density data are plotted in Fig. 2.

Carbon Monoxide

The carbon monoxide concentration averaged during the day is tabulated in Table IV.

The trend of the 30 data points shows that increased car population is related to increased carbon monoxide content in the air. The regression of average carbon monoxide level obtained each day at each station on the corresponding average daily traffic density gave the following highly correlated relation at greater than 99% significance. For calculation purposes, <1 values in Table IV were assumed equal to 0 ppm.

$$\mathrm{CO} = -0.281 + 0.136T \quad (2)$$

where

CO = carbon monoxide, ppm
T = traffic density, vehicles per minute past the sample location

A plot of equation (2) with the corresponding 95% confidence limits for the regression of atmospheric carbon monoxide concentration on traffic density are given in Fig. 3.

The carbon monoxide concentration ranges obtained during the day at each station are shown in Table V. The range of those concentrations with a lower limit of one or greater had a ratio of upper to lower level which varied from 2:1 to 12:1. The average ratio was 4:1. These range figures compare closely with the traffic density ranges described previously.

A further study of the data obtained for carbon monoxide and lead concentrations suggests the possible relation between these variables. The corresponding data in Tables III and IV yielded the following highly correlated regressions of CO on lead and lead on CO.

$$\mathrm{CO} = -1.169 + 3.111\ \mathrm{Pb} \quad (3)$$

and

$$\mathrm{Pb} = 0.516 + 0.268\ \mathrm{CO} \quad (4)$$

These regressions are plotted in Fig. 4.

In the above case, carbon monoxide and lead would be expected to be related only through the fact that they are

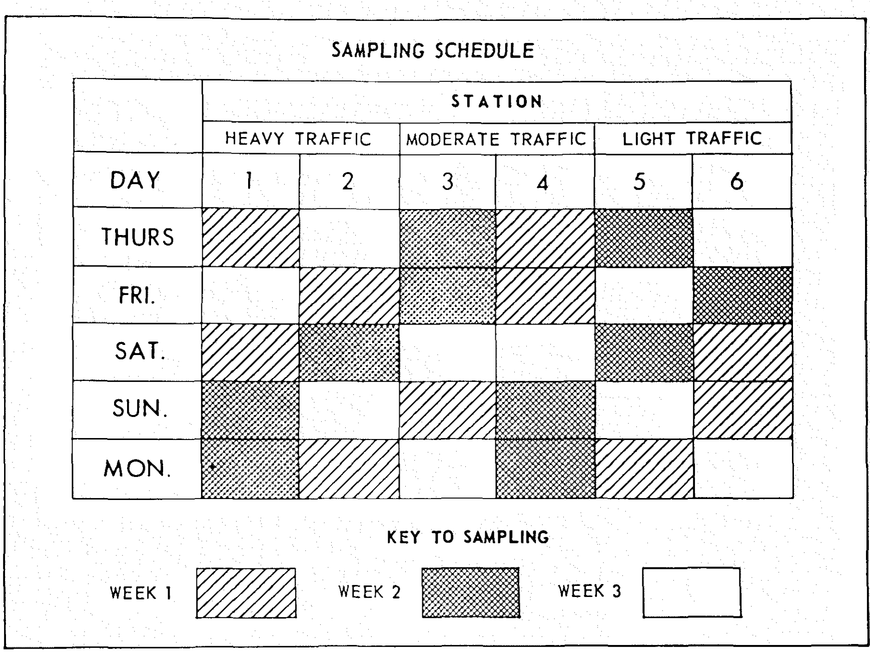

Fig. 1.

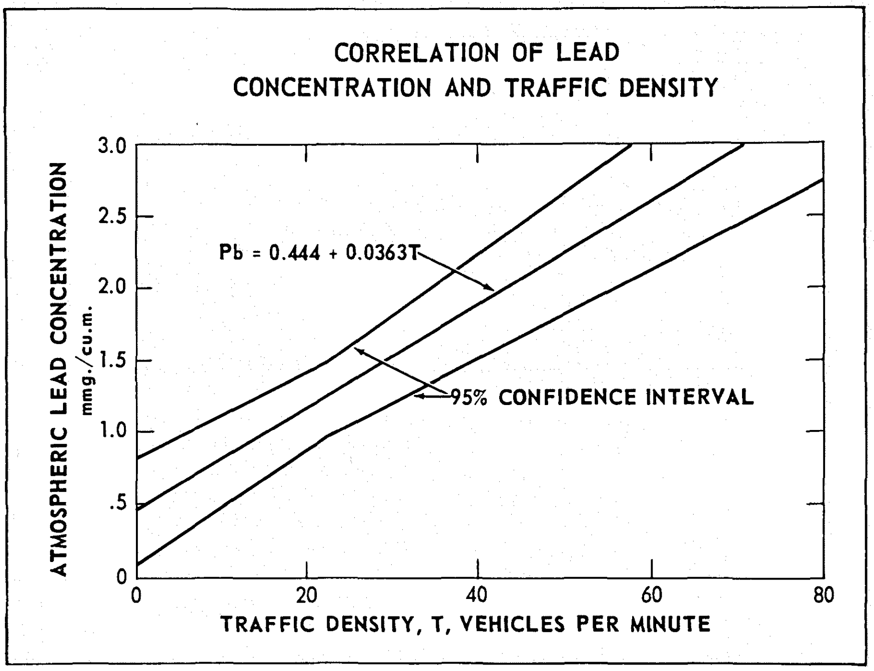

Fig. 2.

emitted from the same source, the automotive engine. The incomplete combustion of gasoline, as in an engine, is a recognized source of carbon monoxide, but unless lead is present in the consumed gasoline, lead would not be expected to be exhausted. However, the fact that most commercially available gasolines do contain tetraethyl lead is evidence a priori of the presence of lead in the exhaust gases from automobiles.

The developed regressions for carbon monoxide and lead then are indicative of air pollution from automobiles consuming leaded-gasolines.

Discussion

Before proceeding with the discussion it is important to remember that the data, the correlations drawn, and the 95% confidence intervals for regressions calculated are all based on tests conducted in one northeastern United States' city. The extent to which the correlations and confidence intervals can be generalized will vary with such factors as meteorology, type of traffic flow, and sampler location.

Weather Effects

Because the testing was done in the summer, the air temperature was generally 80–90°F. At other temperatures, convective currents could be different and might possibly alter the levels obtained. It is expected, however, that the temperature effect would be minimal compared with the others to be discussed.

The wind conditions were generally variable. It is suspecied that over the course of three weeks, the direction and velocity ran the gamut of meteorological patterns at the location of the samplers, four feet above the ground. No meteorological data were obtained during the study. Wind direction and velocity obtained from the Weather Bureau were not considered to be directly applicable. Under conditions of high wind turbulence and maximum dilution (not experienced during the tests), the slope of the correlation curves could be lessened so that even under conditions of high traffic density, the levels of lead and carbon monoxide might be less than the lower confidence limits. On the other hand, in an area with predominantly calm wind conditions, the slope of the correlations might be greater than that shown.

The distance the sampler is placed from the traffic stream is an important factor in the detection of air contaminant levels. In the subject study, 30–50 ft was used. At other distances, correlations would still be expected to evolve but with the location and slope of the curve changed.

Traffic Effects

Traffic patterns are also quite important. Little congestion was found to exist at the six stations tested; that is, traffic flow was relatively free flowing, and therefore, density measurement in cars per minute should be representative of the number of cars exhausting in the proximity of the samplers. If in another area it was found that traffic pile-up was commonplace, cars per minute past the sampler might not be truly indicative of the number of car exhausts near the sampler. In this case, a more proper assessment of traffic density might be cars per 1000 ft^2 near the sampler. This type of count would be very difficult to obtain. Time-lapse photography might be used to collect such data.

To generalize, the results of this study point out the importance of traffic density in relation to the lead and carbon monoxide in the atmosphere. More detailed generalizations, without accounting for the factors discussed above, might suggest erroneous levels of lead and carbon monoxide based on traffic data. Perhaps if more data were available, the correlation developed in the one city tested could be adjusted for these factors. Therefore, for a full-scale assessment of traffic and its relation to contaminant levels in the atmosphere, more data are necessary. It would be advisable that future work in this field include traffic density data, along with the information on the factors discussed, when reporting possible vehicle-related atmospheric contaminants.

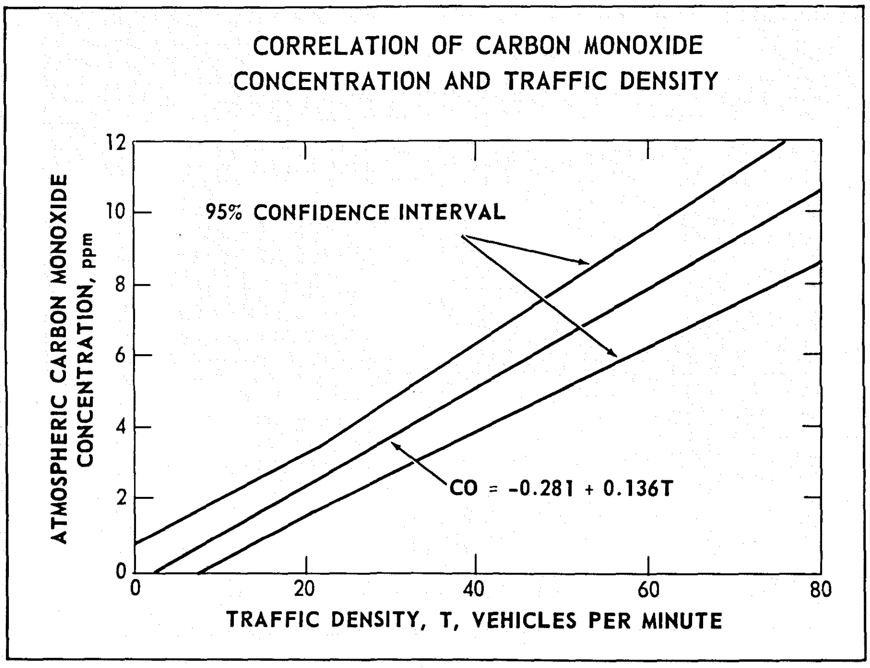

Fig. 3.

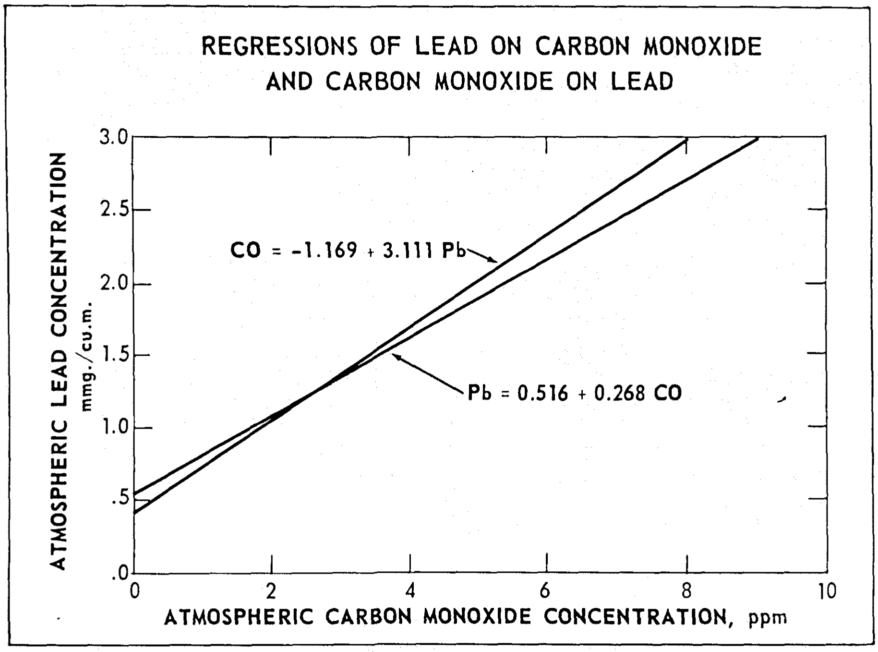

Fig. 4.

Data from Literature

Many authors have pointed out that carbon monoxide and lead are directly related to traffic. Unfortunately, the data presented are usually only qualitative. However, some authors have presented actual data which will now be discussed.

Lykova[22] compared traffic density with carbon monoxide concentration in the street air of certain Soviet cities. The data Lykova presented are 5, 11, and 22 ppm carbon monoxide for <17, 17–25, and 25–50 vehicles per minute, respectively. The mean levels of carbon monoxide obtained in the Soviet cities tested were about two to three times higher than those obtained during the subject study. Lykova's work being done in 1953 in the Soviet Union could reflect differences in Soviet vehicles and gasoline from the automotive situation in the northeastern United States' city tested in 1959. Further evaluation of the variance suggests that the sampler location, being closer to the traffic in the Soviet cities, could contribute to the explanation of the differences noted.

Berlin

Effenberger[10a] found that carbon monoxide at the breathing zone of customs officials and traffic density at border crossing points in Berlin are highly correlated. Regressions of carbon monoxide on traffic density at two different locations gave the following relations:

$$CO = -37.2 + 30.0T$$
$$CO = +6.6 + 20.2T$$

where

CO = carbon monoxide concentration, ppm
T = traffic density, cars/min

Effenberger points up the differences in these regressions to differences in meteorology that existed at the time of the sampling and to the types of buildings near each location.

In periods of heavy traffic with little wind, peak values of 220–240 ppm CO were measured. Average values of about 78 and 130 ppm CO were encountered at the two stations tested. The range of traffic densities encountered in Effenberger's study was from 1–8 cars/min. The differences in the levels of CO obtained by Effenberger and obtained in the subject study can be almost wholly attributed to the distance between the CO sampler and the automobile. Customs officials in processing the cars through their check points stood in quite close to the vehicles. The fact that the cars were idling while awaiting customs processing would also tend to increase the levels of CO.

Detroit

Clayton[9a,9b] collected data in Detroit on carbon monoxide, traffic density, and meteorological conditions. Statistical treatment of these data is now being made to develop, if possible, a mathematical model which would include carbon monoxide, wind speed, air temperature, traffic density, inversion information, and time of day.

Chicago

Tufts[34] compared lead concentration with street traffic density. The air was sampled with Millipore molecular sieve paper in a small shopping district in Chicago. Samples which were obtained were treated for microscopic examination, and the lead particles collected were counted and sized. Sampling was done in 10-min intervals over about a two-hour period. An estimate was made of the mass of lead collected (based on lead chloride) in each sample from the particle count and size distribution. The results in mmg/cu m were compared with traffic counts which varied from four to seven vehicles/minute. The lead levels obtained by these calculations were considerably higher than would be expected from the correlation of lead level in traffic obtained in the subject study. It should be noted, however, that Tufts sampled within two feet of the traffic at about three feet above the ground. The close proximity to the traffic could explain the higher level obtained. Possible

Table V—Carbon Monoxide Concentration Range, ppm

Sampling Day	Station: Heavy Traffic 1	Heavy Traffic 2	Moderate Traffic 3	Moderate Traffic 4	Light Traffic 5	Light Traffic 6
Thurs.	7–47	2–13	1–5	1–4	<1–1	<1
Fri.	7–14	2–6	1–3	<1–2	<1–1	<1–1
Sat.	3–16	2–7	<1	1–2	<1	<1–1
Sun.	1	<1	<1–1	<1–6	<1–1	<1–1
Mon.	1–12	5–13	1–3	1–3	<1–1	<1
Station Range	1–47	<1–13	<1–5	<1–6	<1–1	<1–1

errors in the estimation technique used could also contribute tó the deviation noted in Tufts' results.

In the city tested, there was no apparent industrial source of carbon monoxide or lead. If such a source is present, e.g., a lead smelter, obviously the atmospheric level of the contaminant could be expected to increase beyond vehicle exhaust producted levels. Sources other than vehicle exhaust must then be considered in any analysis of data relating the particular variables discussed in this report.

Summary

Atmospheric levels of lead and carbon monoxide were studied at six locations in a northeastern United States' city, wherein the traffic density varied from 0–99 vehicles/min. Positive correlations have been developed between lead and traffic density and between CO and traffic density. The correlations obtained conclusively point to vehicle exhaust as a source of lead and carbon monoxide in the atmosphere.

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(Continued on p. 413)

CALIFORNIA BEGINS ANTI-SMOG DRIVE; VEHICLE FUME-SUPPRESSORS REQUIRED

Smog-saturated Californians are seeking new means of alleviating their atmospheric problems. A law was passed last April by the California legislature requiring every new car registered in the state to be equipped with an anti-smog device within a year after the state's Motor Vehicle Pollution Control Board tests and approves at least two such devices. The law is designed to curb air pollution by automobile exhaust fumes.

The new legislation also provides that within three years practically all cars and trucks in the state must have the fume suppressors. The principal exception to the law—put in on behalf of smog-free rural areas in California—is that county governments may exempt used cars in those counties that rule they have no smog problem.

California's climate is partly responsible for its smog problem. Smog is principally the product of a photochemical reaction of intense sunlight, atmospheric temperature differences, weak winds, and unburned hydrocarbons in the air. Such smog stings the eyes, irritates the lungs, and damages vegetation.

The automobile long was suspected as an important contributor to air pollution. With the rapid growth of Los Angeles and the great increase in population and in the use of motor vehicles, a new type of air pollution has arisen, called photochemical smog. More recently, this type of smog has been noticed in other West Coast cities, as well as in some Eastern areas. Factory smokestacks and outdoor incineration also play a big part in creating smog.

Since a considerable amount of this air pollution is a result of gases from automobiles, an increasing number of manufacturers in the last few years have been trying to develop a device for a car's exhaust system that will burn or oxidize vapors before they reach the air.

Good Market Potential

If the procedures are successful, the market for these devices could be tremendous. For instance, California has the largest number of autos of any state with 7,500,000 registered vehicles, of which at least 6,500,000 may be required to use the smog-control apparatus.

Trade sources predict that sales of such anti-smog devices over a three-year period after they become manditory in California could amount to almost $700,000,000. They estimate the average cost of a smog-suppressor at $100.

However, these sources say that this would be only the beginning of a burgeoning new anti-smog-device industry. In time, they add, the devices might become mandatory in many other American cities that are plagued with air pollution problems. They believe sales could soar to billions of dollars a year.

Manufacturers working on anti-smog devices—automobile parts producers, chemical concerns, research companies, and a host of others—are concentrating on two main types.

One is an afterburner that uses a pilot flame. The other is a catalytic converter. To a great extent, both resemble and replace the muffler and are locked to the exhaust pipe or are placed under the car's hood.

Afterburners require only a brief warm-up time and have the advantage of longer wear. The catalyst or chemical agent in most converters must be replaced or revitalized after 12,000 to 15,000 miles of driving.

Estimates on the cost of an effective anti-smog car unit vary from $75 to $300 and more. Some Detroit retail cost estimates on either a catalyst converter or afterburner have been between $130 and $150 a unit on a new car.

The big problem in producing smog mufflers is how to cut manufacturing costs.

The present high cost of anti-smog devices results from the materials used in producing them. Many converters use catalyst made with platinum and most afterburners utilize expensive, heat-resistant steel or ceramic materials.

100 Companies Involved

About 100 companies are actively engaged in the study or development of anti-smog car devices or components.

Among these are the American Cyanamid Company. New York; American Thermocatalytic Corporation, Mineola, L. I.; Arvin Industries, Inc., Columbus, Ind.; Engelhard Industries, Newark, N. J.; Chromalloy Corporation, New York; Norris-Themador Corporation, Los Angeles; Oxy-Catalyst, Inc., Berwyn, Pa.; Thompson Ramo Wooldridge, Inc., Cleveland; Union Carbide Corporation, New York; Universal Oil Products Company, Des Plaines, Ill., and all of the major auto producers, much of whose work is co-ordinated by the Automobile Manufacturers Association.

The Studebaker-Packard Corporation is installing a smog-reducing apparatus in its 1961 Lark six-cylinder engines destined for delivery in California.

AIRCRAFT CLEARED

(*Continued from p. 411*)

results, but also because of the difficulties and hazards involved in securing the information.

Necessity of sampling jet exhaust during actual operation required APCD personnel to work near areas where the jet blast emerges at a speed of 700 miles per hour and at a temperature of 700 degrees.

Authors of the report which bears the title "Air Pollution from Commercial Jet Aircraft in Los Angeles County," are: Ralph E. George, Senior Air Pollution Engineer and Ralph M. Burlin, Senior Air Pollution Engineer. The test team was headed by Robert L. Ramlo, Air Pollution Engineer and William Oaks, Testing Assistant.

NEW AP PROGRAM STARTED BY USPHS

The Public Health Service and the Weather Bureau have begun an experimental program of forcasting air pollution potential in all areas east of the Rockies. The forecasts will be issued only when meteorological conditions favor build-up of pollutants in an area; hence, "No news will be good news," USPHS says. The forecasts will be developed at Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, and will help local pollution control and research units in setting up special studies of their problems.

Traffic Correlation Study

(*Continued from p. 388*)

ulate Lead Content in Air. Results of Tests in City Traffic," *Anal. Chem.* **31**: 238–41 (February, 1959).

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36. W. P. Yant, E. Levy, H. W. Frevert, and K. L. Marshall, Carbon Monoxide and Particulate Matter in Air of Holland Tunnel and Metropolitan New York. U. S. Bur. Mines Report Invest. 3585, 69 pp. (1941).

NOTICE

NEW DATES FOR 54th ANNUAL MEETING OF APCA

JUNE 11-15, 1961

These new dates have been obtained by popular demand of APCA membership through the co-operation of the Hotel Commodore management.