Second Report of Special Task Committee on Roadside Design to Reduce Traffic Noise, Dust, and Fumes

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The first report of this committee summarized the 1953 study on what we know, what we do not know, and what research is needed for "Abatement of Highway Noise with Special Reference to Roadside Design."

Part 1 of this 1954 study (second report) outlines ways and means to obtain answers to unknowns on reduction of traffic noise on major highways. Methods, equipment, and units of measurement are reviewed for guidance in field tests initiated to measure and evaluate types of buffer planting and other methods of abatement. Comparative field tests are needed to assist the highway engineer in abating traffic noise that is objectionable to roadside dwellers.

Part 2 of this report presents information available to date regarding traffic fumes on major highways.

Part 1
Reduction of Noise

● ABATEMENT of highway traffic noise requires a sympathetic but critical approach. What are the possibilities of midjudging this factor in the planning, design, and development of new highways and expressways? Is the main question the fact that loud noise sources may be introduced in a quiet residential area? Does the location of heavy traffic in a residential neighborhood have any effect on the value and use of property abutting major highways by reason of the noise factor? What methods of measurement should the highway engineer use to determine the most effective and economical means for abating highway noise to abutters?

Research is needed to find answers to these questions. A forward step toward the development of standards for reduction of noise at the vehicle source was the adoption of a specification for muffler design early in 1954 to establish a maximum permissible noise level and an agreed method of measuring truck exhaust noise.

BERANEK-ARMOUR-ATA METHOD OF NOISE MEASUREMENT IN SONES (EQUIVALENT-TONE)

On March 3, 1954, the Automobile Manufacturers Association Motor Truck Committee announced in a press release that they had adopted the Armour method of truck noise measurement sponsored by the American Trucking Associations as a gauge by which they were going to establish a specification of maximum noise level which no truck would exceed when it comes off the assembly line. This action was taken on the advice of its Truck Noise Subcommittee. David C. Apps, chairman, is head of the Noise and Vibration Laboratory at General Motors Proving Ground. A brochure was prepared by the AMA Motor Truck Committee to explain evaluation of truck noise by the Beranek-Armour-ATA method, described in the press release as follows:

"A major advantage of the (Armour) method, ... is its use of commercially available instruments. These include a high-quality tape recorder and microphone, a set of octave filters, and means for acoustical calibration.

"The proposed (specification for muffler design and performance) calls for a maximum noise level of 125 sones,[1] with the sones measured in each of eight bands covering

[1] "The sone is an arithmetic unit rather than a logarithmic unit, like the decibel, so that a sound of 175 sones is about seven times as loud as one of 25 sones. This type of representation seems to be advantageous in comparing test measurements with results in pyschological tests and is an easier concept than a logarithmic unit for the layman to understand." (SAE Transactions, Volume 62, 1954, p 152, "Measurement and Evaluation of Exhaust Noise of Over-the-Road Trucks," by D. B Callaway)

the frequency ranges form 37 to 9,600 cycles per second, then added to produce the total of 125 or less.

"The AMA committee pointed out that truck manufacturers have made significant advances in muffler design in recent years, but expressed a belief that adoption now of a standard method of measuring results would help stimulate further progress. At the same time, the committee emphasized that other promising methods of noise measurement may, when thoroughly tested, provide an even better standard. Such possibilities will not be overlooked, it said."

What this means in terms of quieting trucks was explained by Lewis C. Kibbee, Chief of the Equipment and Operations Section, American Trucking Associations, before the Kiwanis Club of Akron, Ohio, on April 22, 1954, in his address: ". . . we have roughly taken the noise spread of over-the-road trucks and cut it in half, and we won't have any more of them in the upper half. . . . The trucks that bother people . . . are the ones loud enough to stop conversation, rattle the dishes, and wake the baby. . . . Only about 25 percent of the trucks are in this class even in the West and only five percent here in the East."(7)

TABLE 1[a]
LOUDNESS OF PASSENGER AUTOMOBILES
(At Speeds of 50-60 mph)

Observations made on passenger cars	Relative loudness in sones calculated from octave band levels		
Distance from source on highway pavement (feet)	Maximum loudness approximately (sones)	Average loudness approximately (sones)	Minimum loudness approximately (sones)
30	75	35	22
300	12	6	3
1,000	4	2	1

[a] Table 1 is adapted from Report No. 1, "Noise and Vibration Problems Associated with Traffic on Edens Expressway," Prepared by Armour Research Foundation of Illinois Institute of Technology for the Cook County Highway Department, Chicago, Illinois, April 30, 1952.

The loudness of passenger automobiles reported in Table 1 was not objectionable to residents along the Edens Expressway in Chicago. Observations were made on passenger cars operating at 30 feet and at usual speeds of 50-60 mph. These were made to facilitate comparison with truck and background noises. The report stated that the background noise was five sones for a typical location about 700 feet from the Expressway in the daytime. It can readily be seen from Table 1 above that the average automobile at 300 ft. was just audible, since the average loudness approximating six sones was about the same as the background level of five sones for the typical suburban residential location just mentioned. Table 1 in the 1953 study, however, shows that the city of Chicago traffic backgound noise is of much higher loudness than the average for residential area background noise measured along the Edens Expressway. It shows also that industrial area noise averaged about two times city residential area noise and that background traffic noise in the city of Chicago was relatively louder than industrial area noise.

WIDE-BAND MEASUREMENTS AND EVALUATION OF LOUDNESS IN SONES

During 1954, there was increasing recognition of the need for a "yardstick" to measure and evaluate noise in correlation with the human ear. Table 2 compares three reports on test procedures. A brief description of the use of octave band levels and computation of loudness is given in the April 30, 1952 Research Report No. 1. It is pertinent to point out that the sound level meter indicates sound pressure level without regard to frequency distribution of the sound energy. For this reason, it is first necessary to determine distribution of sound energy with frequency, and then to weight properly the various frequency contributions. These steps are necessary in order to correlate measurement of the physical property of a noise with subjective ear judgments of loudness by individuals. Recent developments and techniques have made possible the calculation of loudness in sones from sound pressure levels in relatively narrow bands of frequencies. The sone is an arithmetic unit such that a loudness of 100 sones sounds twice as loud as one of 50 sones, and 25 sones sound about one half as loud as 50 sones. This comparable unit of measurement was also used in the AMA Research Report No. 2 of January 6, 1954, as indicated in Table 2.

A comparison of the test procedures used in the following three research reports is attempted in Table 2: (1) April 30, 1952, Armour Research Foundation Report No. 1, "Noise and Vibration Problems Associated with Traffic on the Edens Expressway" for the Cook County Highway Department, Chicago, Illinois. (2) January 6, 1954, Automobile Manufacturers Association Report on the "Beranek-Armour-ATA Method of Measuring Truck Noise (Equivalent-tone)," prepared by the AMA Truck Noise Subcommittee, David C. Apps, Chairman Detroit, Michigan. (3) February 1954, Institute of Transportation and Traffic Engineering, University of California, Research Report No. 15, including Appendix 15-A, "Noise Measurements on Expressway-Type Facilities," by Finch and Partridge.

The AMA report of January 6, 1954, (Research Report No. 2 Table 2) describes the equivalent-tone method for determining the loudness of sounds. It is stated that this improved method of rating combines the basic relations of sound intensity, frequency, and ear response, yielding accuracies which are considered adequate from an engineering standpoint. The calculated loudness for most types of noise agrees with individual ear judgments while the overall sound level given by the sound level meter usually does not agree with ear judgments. The February 1954 Research Report No. 3 of the Institute of Transportation and Traffic Engineering, University of California, indicates that

TABLE 2
COMPARISON OF THREE REPORTED TESTING PROCEDURES DESCRIBED

	Research Report No. 1. April 30, 1952	Research Report No 2. Jan. 6, 1954	Research Report No. 3 Feb. 1954
Methods (Distances from Source)	Feet from edge of pavement 30 300 1,000 Loudness of traffic noises obtained by: Measuring sound pressure levels in octave bands. Determining loudness value in sones for each octave band Adding loudness contribution of all octave bands to obtain the total loudness in sones.	Microphone located 5 feet above ground and 50 feet from center of traffic lane used by the vehicle Where this distance cannot be obtained, use the inverse square law for correction for working distance between 30 and 80 feet.	Feet from center line of nearest traffic lane 50 150 300 A graph of the amplitudes of the frequency components was obtained by means of a logarithmic expander and a recording device manufactured by Sound Apparatus Company
Equipment[a]	1. Microphone 2. General Radio Type 759-B Sound Level Meter 3. Recording on magnitic tape Magnecorder Co. Type PT-6JA Unit 4. General Radio Type 1550-A Octave Band Analyzer	1 Microphone 2 A set of octave filters which incorporates a decibel meter and calibrated attenuator 3 A high quality magnetic tape recorder and microphone. 4. A means for accoustical calibration	1 Microphone[b] 2. Three General Radio Co. Sound Level Meters, Type 759-B 3. Recordings on modified Magnecord Amplifier, Model PT6-J. 4. Magnecord Magnetic Tape Recorder, Model PT6-AH. 5. General Radio Co. Sound Analyzer, Model 760, and Sound Level Meter Calibrator, Type 1552-A.
Units of Measurement	Sone (DB levels in octave bands plotted on special graph paper and the loudness computed.)	Sone (Maximum reading on the db meter recorded and the equivalent loudness in sones added to give a single combined reading for the loudness of the truck in sones.)	DB (Decibel) A Scale B Scale C Scale (To simulate to some degree the response of the human ear at the various portions of the frequency spectrum and noise levels

[a] Equipment meeting the standards of the American Standards Association manufactured by. General Electric Company, General Radio Company, Hermon Hosmer Scott, Inc., Western Electric Company, and others.
[b] Equipment described in detail in Appendix A, with complete list in Appendix E. (Feb. 1954 Research Report No. 3)

Figure 1. Planting of highway borders reduces annoyance of traffic to abutters. Liberal 75-ft. width between pavement and frontage road allows ample space for effective buffer planting.

simultaneous readings were made on all three A, -B, -C meter scales to simulate to some degree the human ear response at the various portions of the frequency spectrum and noise levels. Jury appraisals of industrial noises and noises such as these indicate that persons with normal hearing agree reasonably well in evaluating loudness.

The April 30, 1952 Armour Research Report No. 1 points out that this agreement should be interpreted as being within a reasonable range of possibly plus or minus 15 percent. The value of 100 sones should be understood as 100 sones plus or minus 15, thus representing a possible range from 85 to 115 sones, approximating the human tolerance factor in the evaluation of noise.

FIELD TESTS NEEDED FOR EVALUATION OF HIGHWAY NOISE ABATEMENT METHODS

Various methods of reducing traffic noise to abutters have been reported, but specific test measurements are not available. A number of field tests are needed to evaluate the effectiveness of barriers such as walls, embankments, and buffer-planting to abate noise. Uniform test procedures and units of measurement are suggested to simplify comparison of field tests set up for this purpose.

Identical noise sources should be used at highway locations with existing barriers or types of buffer-planting and at similar locations without any barrier or buffer-planting to muffle traffic noise. The effectiveness of the barrier or buffer-planting may be determined in each test by recording the loudness of noise with, and without, a barrier or buffer-planting. Differences would then indicate the effect of the barrier or buffer-planting. Tests would be more satisfactory if done when traffic is light and background noise is not excessive.

In discussing suggested future work, Finch and Partridge urge that an evaluation be made of the effect of various barriers or types of buffer-plantings to muffle traffic noise. Quoting from page 21 of Research Report No. 15, "Noise Measurement on Expressway-Type Facilities:

"The attenuation due to screening is important. Knowing the effect of various heights of and types of screens, several standard types could be designed, and the proper one to be used in any specified case could be determined by balancing the improvement due to its use against cost estimates, as is done in other engineering design work. Screening is perhaps one of the most important solutions to reducing the noise on existing freeways. . . .

"Existing background levels in various sections of a city and of cities and towns of

Figure 2. Frontage roads along this controlled-access highway increase the setback of buildings. Increased setback, together with a narrow buffer planting, reduces traffic annoyance to abutters.

different sizes should be investigated as a basis for determining the effect a freeway would have upon the noise levels of these locations. This work would provide information regarding existing levels near schools, churches, libraries, and the like. The necessary distance between freeways and these locations, or the screening necessary to allow the freeway to pass at a lesser distance could be approximated from such data, assuming that the level be nearly the same as before, or increased to a level which is not deleterious to study or meditation."

CONDITIONS FOR ROADSIDE TESTS TO DETERMINE EFFECTIVENESS IN ABATING NOISE

1. Open highway section without trees or buildings; level, raised, or depressed.
2. Highway section with retaining walls; face of wall bare, and face of wall covered with heavy growth of vines: without any planting above and with planting above.
3. Highway section with buffer-planting; narrow-type, basic-type, and wide-type.

Barriers such as walls and embankments, as well as types of buffer-planting are briefly described and illustrated in the 1953 report.

CONCLUSION

1. Before 1952, little was published on the subject of highway noise. Noise investigators directed their attention mainly to industrial noise until 1952 when the Armour Research Foundation Report, "Noise Problems Associated with Traffic on the Edens Express," (No. 1 in Table 2) was prepared for the Cook County Highway Department, Chicago, Illinois.

2. The 1953 study-survey (First Report by this committee) brought out the fact that, with few exceptions, published data were primarily concerned with industrial noise problems and measurement thereof in decibels, a unit of measurement not always in good correlation with the human ear.

3. This 1954 study (Second Report), with selected references published during 1954, appended, is evidence not only of a broader interest and greatly accelerated progress in noise abatement, but also of increased emphasis on the need for better correlation of noise measurements with jury judgments. The layman finds it easier to understand and comprehend the relative measurement and evaluation of loudness in terms of the human ear, when the sone, an arithmetic unit of loudness measurement, is used instead of the decibel, a logarithmic unit of sound pressure or energy level measurement. The use of the sone seems advantageous in comparing test measurements for different methods of abatement with results of psychological roadside tests, being more easily understood by the average person than use of the decibel, a logarithmic unit.

4. During 1955, the committee recommends the initiation of field tests to measure and evaluate noise abatement methods for reporting in January, 1956, at the next annual meeting.

5. Early in 1956, reports from field tests on practical ways and means of abating highway noise will be of timely value in forthcoming large-scale programs in the United States (Interstate highways, expressways, turnpikes, etc.). Planning of such arterial routes near developed residential communities or through potential neighborhood areas should aim to keep traffic annoyance to abutters to a minimum by:

<u>A. Care in Location.</u> In the consideration of location, the matter of noise is one of the elements in the planning of routes with heavy traffic volumes in the vicinity of residential areas.

<u>B. Adjustments in Highway Design.</u> Adequate right-of-way widths to keep buildings at a greater distance from the traveled way and thereby effect a reduction of traffic annoyance to abutters.

<u>C. Noise Abatement Methods.</u> Adequate barriers and buffer-plantings installed at selected critical locations only (not continuously), such as: (1) erection of barrier structures, walls, embankments, and other structures; (2) installation of buffer-plantings, hedges, trees and shrubs, vines, as outlined in the 1953 study (first report): (a) narrow-type buffer-planting, (b) basic-type buffer-planting, and (c) wide-type buffer-planting; (3) combinations of barriers and buffer-plantings as necessary in special situations.

6. Future Research. In regions where snow is a factor, both the beneficial and the adverse effects of structural barriers and various types of buffer-planting should be weighed.

REFERENCES PUBLISHED DURING 1954 STUDY
(To Supplement Selected References in 1953 Study — with Comments Pertaining to Abatement of Highway Noise.)

1. "Noise May Cause Accidents," A. J. White, Director of Motor Vehicle Research, South Lee, N.Y. November, 1954. Press Release (Univ. of N.H.). — "Noise may be a contributing factor to commercial motor vehicle accidents." This and other facts were revealed at a lecture by A. J. White, Director of Motor Vehicle Research of South Lee, New Hampshire.

Addressing a group of engineers representing insurance companies at the University of New Hampshire, Mr. White pointed out that interior cab noises of certain frequencies may cause fatigue, irritation and predispose truck drivers to become involved in accidents.

"Noise is a contributing factor to accidents if it is of an annoying type," stated Mr. White.

"Acoustical engineering is vital to protect truck drivers against noise values that cause fatigue and strain. A truck operator should be considered in the acoustical design of the operating cab of the vehicle if safety is to be of prime importance.

"The noise or sound level of present commercial vehicle cabs is too high for safety. Repeated exposure merely means tolerance of high noise levels and not elimination of the fatigue factor. Further research in this field is essential," said Mr. White.

"A driver who pilots a large truck and trailer assembly for eight hours should be considered from an acoustical angle because constant noise saps his energy and probably decreases his reaction time."

2. "Easy on the Ears," Sound Barriers of Trees and Shrubs Muffle the Cacophony, The New York Times, Sunday October 10, 1954. By P. J. McKenna. — This illustrated article points up the fact that "Noise is one of the most troublesome by-products of our modern age. In particular, noise resulting from motor vehicle traffic." The use of plants as insulting material to reduce the noise around homes is discussed by P. J. McKenna. "The principle . . . recognized . . . that materials used in noise reduction must be placed near the source of the noise. . . ."

3. "Auto Noises on Way Out," David C. Apps, Head of the Noise and Vibration Laboratory at General Motors Proving Grounds, Milford, Mich. From "The Oregonian," October 23, 1954. — "Chicago (AP) - A noise expert . . . predicted automobile engines will be so quiet that motorists will have to check the oil pressure gauge to tell whether they are running. The day of virtually noiseless engines was described at a national noise abatement symposium by David C. Apps, head of the noise and vibration laboratory at General Motors Proving Grounds, Milforn, Mich. — "Apps told some 300 engineers that modern techniques such as acoustical blankets and firewall treatment, can make engines vartually silent.

"To cut down on other traffic noises produced by automobiles - such as road rumble, axle noise and tire distrubances - Apps suggested more careful gear and tire manufacture and the use of more acoustical material, such as rubber, in construction of cars."

4. "Truck Noise," Noise Abatement News Letter, October 1954, p. 45, National Noise Abatement Council, New York. — "The Automobile Manufacturers Association has recommended to all truck makers the adoption of an industry standard for muffler design, which would apply to original equipment and replacement units. It would establish a permissible noise level and an agreed method of measuring exhaust noise, using the Beranek-Armour Equivalent Tone Method for measuring sound. The AMA asserts that the standard measurement method would stimulate progress in reducing noise. The Truck Noise Subcommittee of AMA, which recommended the standard, has prepared a booklet which explains evaluation of truck noise by the Beranek-Armour Method and includes a description of the required equipment and recommended operating equipment. It has been supplied to all truck manufacturers." (See below References (5) and (9).) Other items of interest are contained in this news letter:

"England Noise Concious . . . is just as alert to industrial noise control as we are here in the United States. . . ."

"Suit Instituted Against Low Flying Airplanes . . . demanding (they) be halted because they interfere unlawfully with property rights and deprive residents of the comfort, convenience and quiet to which they are entitled. . . ."

"Railroad Noise Cited . . . of trains going through the city and railroad officials have instructed trainmen to keep whistle and horn blowing at a minimum while in city limits. They also promised to do something about smoke . . . the noise problem is aggravated . . . (by the numerous grade crossings)."

"National and International. Needless noise, particularly in cities, is receiving much . . . attention . . . ordinances against unnecessary blowing of automobile horns . . . enforced (by police) . . . department . . . alert to those who distrub the peace by being excessively and needlessly noisy."

5. "Fifth Annual National Noise Abatement Symposium" at Armour Research Foundation of Illinois Institute of Technology, October 22, 1954. Vehicle Noise Session: (See Selected Reading Reference (14, 15, 16). "Quieter Automotive Vehicles," David C. Apps, General Motors Proving Grounds, Milford, Mich. "Truck Noise Abatement," Lewis Kibbee, American Trucking Associations, Washington, D.C.

6. "Trees and Shrubs Cut Street Noise," The Washington Post and Times Herald, June 6, 1954. (See Selected Reference (13) also.)

7. "The Truck Noise Reduction Program of American Trucking Associations, Inc.," Lewis C. Kibbee, Chief, Equipment and Operations Section, ATA, Inc., Washington, D.C. Address before Kiwanis Club of Akron, Ohio. April 22, 1954. 11 p. mimeo. —

This is a good background record and history of progress leading to the adoption of the industry standard for muffler design by truck manufacturers (4). Mr. Kibbee discussed also "some widespread misconceptions concerning truck noise, such as muffler cutouts which he has never seen on (any) truck." He summed up the whole philosophy of approach to the truck noise problem by saying that "the quiet muffler program will be a process of evolution and not revolution. . . . As time goes on the standard will be tightened up and commercial vehicles will get quieter and quieter . . . ."

8. SAE Journal, V. 62, No. 4, April 1954. "Industry Hushing Exhaust Noise to Meet Regulatory Demands for Quiet Trucks," pp. 17-21. (Article based on four papers and discussion of them presented at SAE National Transportation Meeting, Chicago, Nov. 1953.) "Measuring Truck Exhaust Noise," D. B. Callaway. (Microphone 50 ft. from road picks up noise as truck climbs 5 percent grade. Hood over mike prevents wind interference. Test location free of buildings, reflective banks, and off-road noise sources. Noise recorded on tape-recorder.) (See Selected References (7 and 8).)

9. AMA Truck Noise Subcommittee, David C. Apps, Chairman, Jan. 6, 1954. 4 p. "Beranek-Armour-ATA Method for the Evaluation of Truck Exhaust Noise." — The information in this reference is equivalent to a specification covering the specialized techniques for measuring and evaluating truck noise. It gives a brief outline of equipment required, procedures for vehicle operation, microphone location, recorder operation, laboratory procedure, etc. This is a most useful reference for the engineer interested in setting up field tests for measuring the effectiveness of barrier and buffer types of structures and foliage, and combinations of each, in order to evaluate the various methods of abating noise on and along highways. In general, good instrument practices are to be followed and should be adapted to the needs of the field test set up.

10. "Noise Measurements on Expressway Type Facilities," Research Report No. 15 and Appendix Report No. 15-A, Finch and Partridge, Institute of Transportation and Traffic Engineering, University of California, February 1954. — From Highway Research Abstracts, October 1954, Volume 24, No. 9, p. 15. "Noise Measurements on Expressway Type Facilities," D. M. Finch and W. A. Partridge. — "Acceleration after a stop creates the highest vehicle-noise levels on highways - more, for instance, than large volumes of traffic moving at high speed, or even up a grade.

"The authors collected data at 15 test locations ranging from a site near Vallejo in central California south to the Los Angeles area. Locations were of five types: inclined, intersection, level, elevated, and cut. Noise measurements were taken at 50, 150, and 300 feet from the centerline of the nearest traffic lane.

"In addition to the matter of acceleration, it was found that: (1) automobiles are a less-significant source of noise than trucks; (2) at close distances there is little or no difference between noise coming from cut or level freeway sections; and (3) the noise field is non-uniform near an elevated freeway section. At 50 feet noise levels were lower for the elevated than for the other test sections, but at 300 feet they were higher."

These reported tests were on open sections of highway free of barrier structures or buffer-plantings. These findings are in substantial agreement with those reported by Armour Research Foundation in its Report No. 1 for the Cook County Highway Department, Chicago, Ill. (See First Report, Selected Reference (8).) The noises were measured and compared in these two studies, but it was not expected that a solution would be found for these difficulties, within the scope of these studies. Field tests of methods of abating traffic noise on highways are needed to point up possible solutions in forthcoming programs.

11. "Apparatus for Noise Measurement," Leo L. Beranek. Form 772-A, 10 pp. illus. Acoustics Laboratory, Massachusetts Institute of Technology and Consultant in Acoustics, General Radio Company, Cambridge 39, Mass.

12. "Handbook of Noise Measurement." General Radio Company, Cambridge 39, Mass. References (11) and (12) are standard publications covering the details of techniques for measuring noise. Figures illustrate basic sound-measuring instruments, with various accessories commonly used in acoustics measurements. These two booklets furnish necessary background to the engineer interested in setting up field tests similar to those of April 30, 1952, of January 6, 1954, and of February, 1954, an outline comparison of which is presented in Table 2 of this Second Report on abating noise.

Part 2
Preliminary Report on Reduction of Fumes with Special Reference to Roadside Design

● TRAFFIC fumes are a definite menace to public health. The problem of keeping such fumes to safe levels is becoming increasingly difficult, as more and more motor vehicles crowd our highways and streets. It has been attempted in this part of the 1954 study to discuss briefly the harmful substances in traffic fumes, how they affect the individual, under what conditions they are likely to be most harmful, and what may be done to make them less dangerous.

TOXIC GASES AND SUBSTANCES ASSOCIATED WITH INTERNAL-COMBUSTION ENGINES

There are several harmful or toxic substances associated with internal-combustion engines, manely: carbon monoxide, acrylic aldehydes, benzol, and lead. Of these, carbon monoxide is by far the most common. Carbon dioxide, although a major product of combustion, is not toxic, and has not been considered in this report.

DISCUSSION OF CARBON MONOXIDE

Carbon monoxide is odorless, colorless, and tasteless, and cannot be detected by any of the senses. It is deadly because it replaces oxygen in the blood. When carbon monoxide and air are breathed into the lungs, instead of the hemoglobin combining with

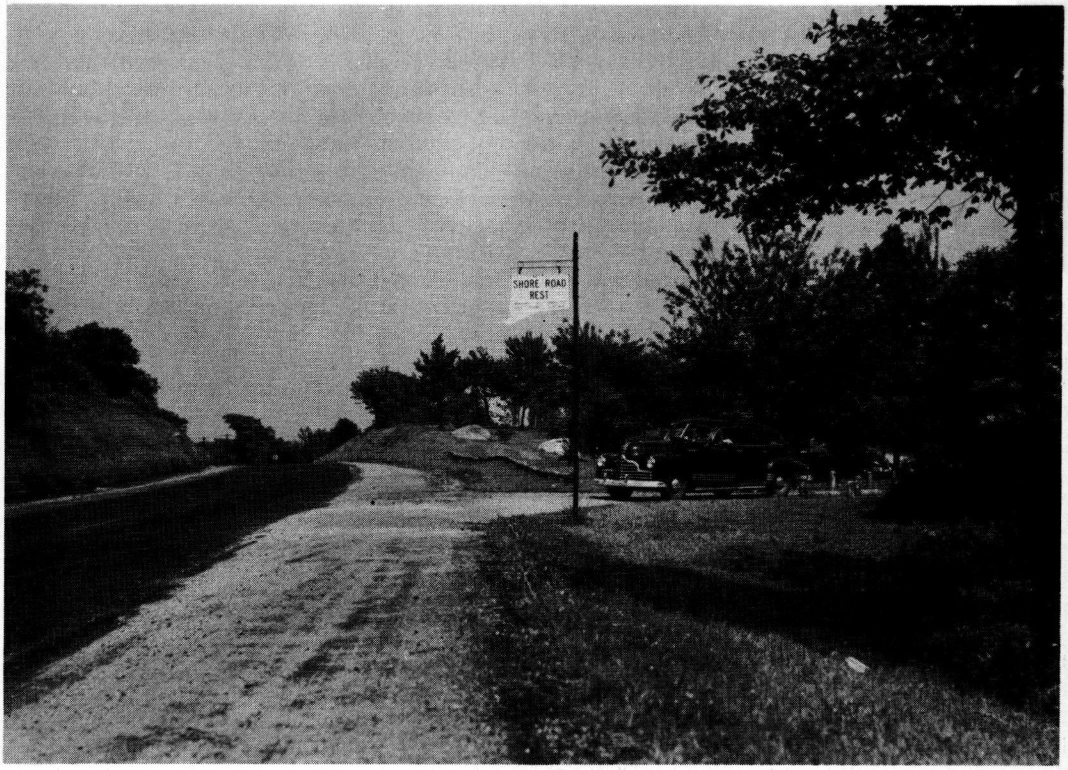

Figure 3. More parking turnouts and rest areas are nedded along heavily traveled highways where motorists may relax, breathe fresh air, and ventilate their cars. Drivers welcome the chance to get away from traffic fumes and rest their eyes. This is an entrance to Shore Road Rest in Connecticut.

Figure 4. A family enjoying the peace and quiet of the same area as Figure 3.

oxygen as it normally does, it combines with carbon monoxide. If the concentration of carbon monoxide is great enough and the time of exposure sufficiently long, death will result.

No one is entirely immune from carbon monoxide but some are much more susceptible to it than others. In general, the very young and the old are most susceptible. Small people are more susceptible than large prople. People with respiratory, thyroid, and heart diseases are particularly affected and should avoid exposure to it.

In some individuals, the body can adjust somewhat to the effects of carbon monoxide by throwing large numbers of red cells into the blood. These individuals can withstand higher concentrations than persons whose bodies have this ability to a lesser degree.

Repeated exposures to carbon monoxide, particularly to high concentrations, generally result in increasing susceptibility and may cause cumulative tissue damage. It behooves everyone to avoid exposure to traffic fumes as much as possible.

Dangerous concentrations of carbon monoxide may be present in motor vehicles on open highways in both light and heavy traffic, in congested city streets, in exclosed places such as garages, bus terminals, and the like. This gas may on occasion, be drawn into office buildings and business places through ventilating systems and open windows.

In California, more than 1,000 vehicles were tested for carbon monoxide after they had been driven over an open highway for five minutes or more. Two percent of the vehicles were found to contain dangerous concentrations that could seriously affect the behavior of drivers. One surprising fact brought out was that vehicles with one or more open windows were generally found to have higher concentrations than vehicles with closed windows. This is contrary to the general belief that open windows are a safeguard against dangerous traffic fumes.

It should be mentioned that exposure to relatively low concentrations of carbon monoxide for long periods, may be as dangerous as exposure to higher concentrations for shorter periods. Temperature and humidity also have a decided influence on the effect of carbon monoxide. Concentrations that would normally be harmless may be dangerous on days of high temperature and high humidity. The American Standards Association considers maximal permissible concentrations as 100 parts per million for periods not exceeding eight hours and 400 parts per million for periods not exceeding one hour, at 25 deg. C and 760 mm Hg. (7)

OTHER TOXIC SUBSTANCES

Acrylic aldehydes are often present in exhaust gases, particularly from engines in poor condition. They are formed by the heating and partial oxidation of oil. They cause a burning sensation to the eyes and nose. Cases have been reported where permanent damage has been caused to the eyes.

Lead and benzol are poisonous substances that are present in many gasolines. It has not as yet been determined what effect they have on the health of human beings at the concentrations found in exhaust fumes.

Freon should be mentioned here although it has nothing to do with exhaust gases. Freon is a refrigerant used in air conditioning systems of automobiles. When exposed to flame, it is converted into phosgene, one of the deadliest of gases known. Ordinarily freon is not exposed to flame, but in an accident, if the tanks holding the refrigerant were punctured and fire were present, results would be disastrous.

CONDITIONS UNDER WHICH TRAFFIC FUMES MAY ENTER MOTOR VEHICLES

1. Faulty exhaust system allowing fumes to escape under the vehicle and seep into it.
2. Fumes coming out of breather pipe from engine in worn condition and seeping into the vehicle.
3. Fumes from car ahead being drawn into ventilating system. This may happen when ventilators are open when driving too close to the car ahead in both light and heavy traffic, and when parking close behind other cars that have motors running.
4. Using the ram-jet type of defroster in which air is drawn in through ventilators.
5. Too short a tail pipe and damage to end of tail pipe causing exhaust fumes to move along with car and possibly seep into it.
6. Vehicles with flat backs such as ranch wagons and trucks with certain body types

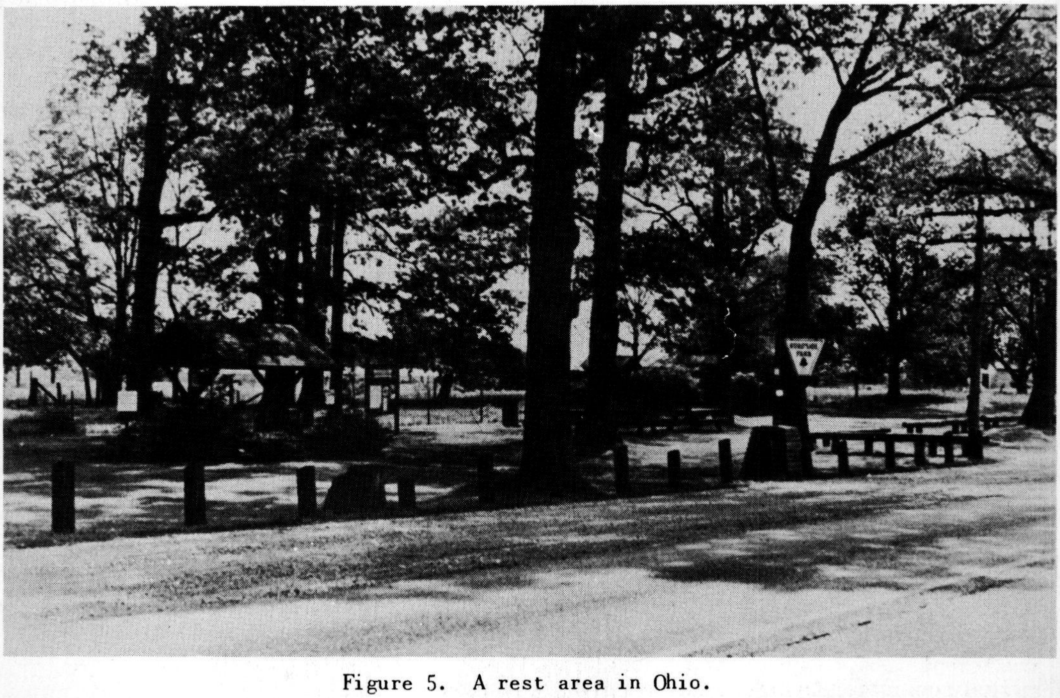

Figure 5. A rest area in Ohio.

Figure 6. A parking turnout at a scenic overlook in historic Virginia. Note the separation of the parking area from the traveled way.

have a greater vacuum drag which may pull exhaust fumes forward so that they may enter the vehicle through open windows and ventilators.

THE EFFECT OF TRAFFIC FUMES IN CAUSING ACCIDENTS

It is not known to what degree traffic fumes contribute to highway accidents. It is known that drivers who are exposed to these fumes may have impaired judgment, slower reflexes, and may even be sufficiently overcome so that they are unable to properly control their cars. It is not unreasonable to presume that exposure to traffic fumes could have been a contributing factor in some of the accidents that are otherwise unexplained.

SUGGESTIONS FOR REDUCING THE DANGERS OF TRAFFIC FUMES[2]

1. Periodically inspect exhaust, ignition, and carburetion systems. An engine burning a proper mixture produces very little carbon monoxide.
2. Make sure tail pipe is undamaged and that it extends beyond the bumper.
3. Keep engines in good repair.
4. Keep 60 feet or more back of preceding vehicle on highways.
5. Close ventilating systems in dense, slow-moving traffic and particularly when standing, as at traffic lights.
6. Keep out of unventilated garages or garages that are not equipped to pipe away exhaust fumes from running motors.
7. Be particularly cautious on hot humid days.
8. Equip motor vehicles with carbon monoxide detectors. Such instruments that safeguard human lives would seem as important as any now furnished as standard equipment.

HOW CAN ROADSIDE DESIGN HELP TO LESSEN THE DANGER CF TRAFFIC FUMES?

There appears to be two methods: (1) Keep dense plantings well back from the traveled way so that exhaust fumes will be more readily dissipated. Distance from pavement as recommended for buffer planting in the 1953 study (first report) should be

[2] Varied recommendations made in cited references.

Figure 7. There is less annoyance from passing traffic where motels are set well back from the highway.

satisfactory. (2) Provide more parking turnouts and rest areas off heavily-traveled highways where motorists may relax, breathe fresh air, and ventilate their cars.

CONCLUSION

It has been attempted in this report to highlight some of the pertinent facts related to traffic fumes; what they are, where they may be in dangerous concentrations, how they affect people, and what may be done to reduce them to safer levels. Carbon monoxide is discussed in much greater detail in the references on traffic fumes.

REFERENCES ON TRAFFIC FUMES

1. "Vermont State Police Check Cars for Carbon Monoxide Concentrations," The Police Chief, January 1954, p. 29. — Describes findings of Vermont State Police after checking cars on bitter cold days when windows were closed and heaters were operating at full capacity.

2. White, Andrew J., "Carbon Monoxide," Copyright 1952. — This pamphlet of 35 pages discusses carbon monoxide very thoroughly, as well as other toxic substances related to motor vehicles. Ways and means to reduce toxic fumes are suggested.

3. "Governmental News," October 1952, p. 32. — This article describes an automatic system installed in New York City's omnibus garage. An alarm sounds when concentration of carbon monoxide reaches a certain level.

4. "C O Rings the Bell in Cincinnati," Public Safety, January 1952, p. 7. — This article describes the automatic system at the Motor Vehicle Testing Lanes, Cincinnati, Ohio. When the concentration of carbon monoxide reaches a certain level, red lights flash, claxons sound, overhead doors open and exhaust fans speed up.

5. Lindsley, Charles H. and Yoe, John H., "Acidimetric Method for Determination of Carbon Monoxide in Air," Analytical Chemistry, April 1949, pp. 513-515. — Description of method used in determining low concentrations of carbon monoxide.

6. "Carbon-Monoxide Detector," Compressed Air Magazine, June 1947, p. 156. —

Describes a small inexpensive device about the size of a pencil that an inexperienced person can use.

7. "Carbon Monoxide: Its Toxicity and Potential Dangers," Reprint No. 2242 from Public Health Report. (1941) — This report defines maximal permissible concentrations of carbon monoxide and discusses the subject generally.

8. California Highway Patrol - "Carbon Monoxide Survey," Reprinted, September 1939. — This report describes findings in testing more than 1,000 vehicles. Gives valuable information on effect of carbon monoxide on behavior of drivers and discusses carbon monoxide in general. A bibliography is included.

9. "Ventilation of Vehicular Tunnels," Report of U.S. Bureau of Mines to New York State Bridge and Tunnel Commission and New Jersey Interstate Bridge and Tunnel Commission - Fieldner, A.C., Henderson, Y., Paul, J.W., Sayers, R.R., and others. Reprinted New York, February 1927, from Journal of American Society of Heating and Ventilating Engineers, January-December 1926.