Noise Pollution a Study in Kalamazoo, Michigan

William Thomas Williams

Western Michigan University

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NOISE POLLUTION
A STUDY IN KALAMAZOO, MICHIGAN

by

William Thomas Williams

A Project Report
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Specialist in Arts Degree

Western Michigan University
Kalamazoo, Michigan
August 1974
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CHAPTER I: CURRENT INFORMATION

Introduction

Noise is the name given to one of the many pollutants that affect people. Other pollutants that affect air, water, and land generally have received more publicity, but noise also has its impact. This report is aimed at showing the importance of noise pollution.

Noise differs from other pollutants in that it deteriorates rapidly. Also it is difficult to demonstrate physiological and psychological effects because of the length of time it takes for noise to affect persons.

Noise has been defined as "unwanted sound." This definition makes the term "noise pollution" less accurate, for the deleterious effects of sound may come from both unwanted and the so-called "wanted" sound. Other terms that could be used might be "dangerous decibels," "freaky frequencies," or "dangerous sound," but none of these would attract the attention that the term "noise pollution" tends to demand. The use of the word "pollution" tends to accentuate the phenomenon. So then, "noise" should be redefined. Noise, in this report, is sound that is unwanted and/or causes some deleterious health effects, either physically or mentally, to man or any plant or animal that is important to man.

1
Organization

This report brings together many aspects of noise that other authors have previously isolated. In the following sections sound will be described, its effects on the ear and other parts of the body, both physiological and psychological, and what is being done, or can be done, to minimize noise and therefore minimize its effects. Recent legislation on noise and the economics of noise will also be discussed. The descriptions will be phrased so that persons lacking technical training can understand them but not so simply that their usefulness is limited only to such persons. A limited study of noise in Kalamazoo will also be described. The study is based on specifications listed in the Kalamazoo Noise Ordinance related to transportation noises. As of this writing the ordinance is not enforced. Consequently this study may be a basis for comparison with any future study after enforcement begins.

This report ends with a chapter on how the materials included in it could be used in community college teaching.

Sound

Sound exists as a three-part phenomenon--source, transmission, and effect. Source and transmission will be discussed in this section, effect as part of a later section.
Sound is produced by an object vibrating in or on an elastic medium. The medium may be air, with which people are most familiar because of human speech, or it may be water, wood, metal, or any other elastic substance. The vibrating object may be, among others, a string or wire stretched tightly between two points, a rock or tree that has fallen, or a piece of leather stretched over the end of a hollowed log.

A vibrating object will make no sound if the transporting (elastic) medium is absent. An alarm clock placed in a vacuum under a bell jar will "go off" but it cannot be heard even at a close distance.

Will a tree make a sound if it falls in the forest with no one around to hear it? Often it has been said that something or someone must hear it for there to be sound, but the ear is not a necessary requirement for sound to cause damage. On this premise, one may conclude that the ear is not a prerequisite for sound. Of Webster's many definitions for the word sound the one that seems most appropriate for this study is "mechanical radiant energy that is transmitted by longitudinal pressure waves in a material medium (as air) and is the objective cause of hearing."

This definition fits in well with the definition of noise as cited earlier and is the one that will be used in this paper.

The ear does receive the vibrations, and if damaged,
the reception may be disrupted. The ear is not sensitive to all frequencies (the number of vibrations per second.) Some do not produce audible sound but do leave physiological or mental effects. The frequencies heard by people with normal hearing range from 20 to 20,000 cycles or vibrations per second (Parkin and Humphreys, 1969, p. 27). The vibrations must also have enough force or intensity to be heard. The more intense the vibrations, the louder the sound. Intensity is one of the aspects of sound that affects the human body.

When an object vibrates, it produces in the transporting medium a series of compressions and noncompressions (rarefractions) (Figure 1). The more intense the vibrations, the more dense the compressions. The increased intensity is produced as the vibrating object travels through a greater distance during each vibration collecting more atoms or molecules to compress. These move outward in all directions from the source, their energies dissipating as they go. Every time the distance is doubled, the area over which the sound energy is spread increases by a factor of 4; the radius has doubled so the area is quadrupled. This is known as the Inverse Square Law and will be important in understanding later discussions.

One must keep in mind that the atoms and molecules do not move outward with the sound. They only vibrate or move far enough to move the next one a short distance.
Figure 1. Sound moves outward in all directions from the source, the energy dissipating as the sound moves.

Sound travels at velocities that vary according to the density, temperature, and composition of the medium. For any medium under a given set of conditions the velocity is constant. If the number of cycles per second (hertz) changes, then the distance between each compression or rarefaction
(wavelength) changes. The relationship that exists among velocity, wavelength, and frequency is as follows: Velocity equals wavelength x frequency (Parkin and Humphreys, 1969, p. 25). The intensity of sound has no effect on its velocity.

In air sound travels at an average velocity of approximately 760 miles per hour.

Measurement of Sound

The most common unit of the measurement of sound is the decibel (dB). This unit measures the loudness of sound with respect to some other sound—namely the softest sound audible to the "average" human ear. Zero decibels, therefore, is an arbitrary number. The power level intensity or rate of energy flow per unit area for this arbitrary number is $10^{-12}$ watts/square meter (NCASI, Dec., 1970, p. 1). The loudness of any given sound is defined as ten times the log of the ratio between the power of the given sound and the power of the barely audible (softest) sound. In mathematical terms it can be written:

$$\text{loudness (dB)} = 10 \times \log_{10} \frac{\text{power of the given sound}}{\text{power of the barely audible sound}}$$

(Turk, 1972, p. 195). The decibel scale does not take into account the tones being registered, namely, the frequency of the sound waves being propagated. Some disagreement exists among scientists in weighting factors for accurate
registration of the ways that noise sounds to humans. There is agreement that high-pitched tones are more annoying than low tones and therefore they are given more weight in an instrument designed to measure sound pressure level. This instrument is called a sound-level meter, or more commonly, a noise meter.

The sound-level meter contains three scales labeled A, B, and C. The A scale is weighted and discriminates against low frequencies. It "hears" mainly the high frequencies. Since the ear is more sensitive to high frequencies, the A scale reading will give an indication of annoyance or probable irritation. The C scale masks the annoyance since it responds to the low frequency noises. A combination of C scale reading and A scale reading gives a rough indication of the amount of low and high frequency noise present (NCASI, Dec. 1970, p. 5). The B scale moderately discriminates against the low frequencies (Figure 2). The three scale reading may be labeled dB(A), dB(B), or dB(C) as the case may be.

The dB change can be computed from any reference point using the same basic formula:

\[
\text{dB change} = 10 \times \log_{10} \frac{\text{power of given sound}}{\text{power of sound at reference point}}
\]

If the intensity of the sound present is doubled, the intensity ratio is increased by 2. The log of 2 is 0.3, so ten times the log of the ratio is 3. Thus, when the
sound intensity in any region is doubled, the increase is 3 decibels. This increase occurs no matter where one starts. This increase is barely detected by the human ear and can work to one's advantage if he wished to add an equally noisy piece of machinery to one already present. It can be disadvantageous if it is necessary to reduce substantially the noise since the noise intensity must be reduced by 50 percent in order to get a 3 dB decrease in sound.

If the distance from a noise source is doubled, the surface over which the sound energy is spread increases by
a factor of 4. The logarithm of 4 is 0.6 and 10 times the log is 6. Thus doubling the distance decreases the sound level by 6 dB. This is advantageous near the source of sound, but has less effect farther from the source (NCASI, Dec., 1970, pp. 2-3).

**SOME TYPICAL SOUND LEVELS - DECIBELS**

(A-Weighted Scale)

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<tr>
<th>Sound Description</th>
<th>Intensity Level</th>
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<tbody>
<tr>
<td>Jet take-off (200 ft.)</td>
<td>130</td>
</tr>
<tr>
<td>Loud motorcycle (50 ft.)</td>
<td>120</td>
</tr>
<tr>
<td>Street corner in a large city</td>
<td>110</td>
</tr>
<tr>
<td>Accounting office</td>
<td>100</td>
</tr>
<tr>
<td>Threshold of pain</td>
<td></td>
</tr>
<tr>
<td>Unmuffled diesel truck (50 ft.)</td>
<td></td>
</tr>
<tr>
<td>USAF recommended max.</td>
<td></td>
</tr>
<tr>
<td>Normal speech (1 ft.)</td>
<td></td>
</tr>
<tr>
<td>Residential area at night</td>
<td></td>
</tr>
<tr>
<td>Broadcasting studio</td>
<td></td>
</tr>
<tr>
<td>Threshold of hearing</td>
<td></td>
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</tbody>
</table>

Figure 3. Intensity levels, measured in dB(A), for a number of familiar sounds. (Anthrop, 1973, p. 13).
Considerations When Making Noise Level Measurements

Noise intensity measurements are easily made, but unless certain factors are taken into consideration, the measurements may have little or no value.

Noise sources are directional although the total noise at any one place may be randomized. Noise from a transportation vehicle is directional, but the direction may change constantly. In determining the levels of sound emitted by either a stationary or moving source one needs to consider several factors. The first of these is distance, as noted earlier, in terms of the Inverse Square Law. Another factor that causes sound intensity to decrease with distance is the type of ground cover. Concrete attenuates sound little if at all, whereas grass, trees, and other similar ground covers tend to decrease sound propagation (Figure 4).

Molecular absorption over distances also decreases sound intensity. This absorption varies with temperature and relative humidity, but is only significant at frequencies of 1000 Hertz and upwards (Figure 5).

Wind reduces the intensity of the sound upwind and increases it downwind. It can also affect the microphone of the noise meter. This effect can be minimized by completely enclosing the microphone with a protective cover such as nylon netting or a hollowed out soft sponge ball.

A wall or high bank opposite the direction of the
Figure 4. Noise reduction with and without trees. (Transportation Noise and Its Control, June, 1972, p. 15).

Figure 5. Typical atmospheric absorption of sound. (Transportation Noise and Its Control, June, 1972, p. 17).

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source might cause the sound to echo and therefore the sound level as indicated by the meter would increase. If the wall is between the source and the noise meter, the sound level will be reduced because of the greater distance the sound travels around or over the structure and its associated ground attenuation.

Wind and ground attenuation do not affect the propagation of sound in the vertical direction nor are they important as long as the path between the aerial source and the ground subtends an angle at the ground of more than 10°.

Measurements of sound intensity, in order to be valid, must be taken fairly near the source. In general, the distance should be about 3 or 4 times the greatest dimension of the source and not more than 60 meters away. Also, if possible, the measurement should be taken at several positions in order to get a complete picture of the noise source, although this may not be possible when measuring the sound level of a moving vehicle.

When using the hand-held noise meter, care should be taken to prevent sound from echoing from the body of the operator. The meter should be held away from the body, about ear level, and to the side. The meter should not be between the source of noise and the person taking the reading.

When making noise level measurements of moving vehicles, background noise should be considered. If the
measurement of the source and the background is less than three dB greater than the measurement of the background alone, the noise level of the source is less than the background. If the background noise is appreciably less than the source it can usually be disregarded. Therefore in measuring noise levels of vehicles, if two are close and one is not appreciably more intense than the other, the noise values may not have any meaning.

Measurements of the noise levels of vehicles should be made in such a way that they will be upheld in a court of law if the need arises. The following is a summary of how measurements are to be taken under British law.

1. At the time when the noise emitted by the vehicle is measured, the microphone of the apparatus shall be so placed that the top of the microphone is set at a height of not less than 3 feet 9 inches and not more than 4 feet 1 inch above a point at ground level which is not less than 17 feet away from the nearest part of the carriageway on which the vehicle is being used.

2.--(1) For the purposes of this paragraph, the area in the vicinity of the microphone shall be treated as comprising areas the situation and extent of which shall be determined by reference to a line joining a point at ground level above which the microphone is placed to the said nearest part of the carriageway and in accordance with the diagram at the end of this Schedule respectively referred to as the areas so marked.

(2) At the time when the noise is measured there shall not be:--

(a) in the area marked I, any physical object higher than 2 feet above ground level;

(b) in the area marked II, any physical object higher than 3 feet above ground level; and
(c) in the areas marked III or IV, any physical object higher than 5 feet above ground level;

Provided that the requirements at (c) above shall not apply in relation to the following objects or to any of them, that is to say—

(i) to plants, shrubs, trees or any other kind of vegetation, or

(ii) to any physical object of which a continuous surface less than 1 foot wide over all its height would be visible in daylight, to a person looking at it from the point above which the microphone is placed and whose eye level is at the height of the microphone.

(3) For the purpose of sub-paragraph (2) of this paragraph, neither the vehicle nor any part thereof, nor any person nor thing in or on the vehicle, nor the apparatus nor any part thereof, nor any persons being less than 3 in number attending the apparatus, shall be taken into account.

3. At the time when the noise emitted by the vehicle is measured, the vehicle shall be wholly or partly on a part of the road which falls within the area marked IV on the said diagram.

4. As soon as the vehicle has left the area marked IV on the said diagram the apparatus shall be used to measure the sound level (A weighting) in decibels of such noise as is then capable of affecting the sound level indications of the apparatus, such measurement being carried out in the manner in which the measurement of the sound emitted by the vehicle was carried out and under the conditions applicable under the foregoing provisions of this Schedule, excluding paragraphs 2 (2) (c) and 3.

DIAGRAM DIRECTIONS (including Key and Dimensions)

M = a point at ground level above which the microphone is placed.
P = the nearest part of the carriageway to the microphone.
The area marked I consists of the triangle MSU.
The area marked II consists of so much of the circle of radius 10 feet with centre at M as does not enclose any part of the area marked I.
The area marked III consists of so much of the rectangle RSUQ as does not enclose any parts of the areas marked I or II.
The area marked IV consists of the rectangle STWU.

DIMENSIONS

The distance MP is not less than 17 feet.
The lengths of SR, and UQ are each 35 feet.
The lengths of TW, SU, and RQ are each 50 feet.
The lengths of SP, and PU are each 25 feet.
The lengths of TS, and WU are each 30 feet.

Anatomy of the ear

The ear consists of three regions, the outer or external ear, the middle ear, and the inner ear (Figure 6).

![Diagram of the ear with labels for various parts]

Figure 6. The Human Ear. (Scheibel, 1972, p. 30).

The outer ear is bounded externally by the auricle or the ear flap, and internally by the external layer of the eardrum. Between is the external auditory canal. The outer ear receives sound and directs it through the auditory canal to the middle ear.

The middle ear is bounded externally by the inner layer
of the eardrum and internally by the mucous membrane that covers the bony wall just external to the inner ear. Within the middle ear cavity are the three ear bones, the hammer (incus), anvil (malleus), and stirrup (stapes); and two small muscles, the stapedius and the tensor tympani. The stapedius muscle is attached to the stirrup. The tensor tympani is attached to the handle of the anvil. The middle ear cavity has five openings, (1) the opening covered by the eardrum; (2) the opening to the auditory tube; (3) the opening into the mastoid cavity; and (4) and (5) the oval and round windows. The oval window is a small opening located just below and in front of the round window. It is covered by a thin membrane which resembles the eardrum.

The middle ear has three functions, (1) to transmit energy from the sound vibrations in the air column of the external auditory canal across the middle ear and into the fluid contained within the cochlea which is accomplished primarily by the three bones, (2) to act as a protective device by reflexively tensing the eardrum and bony chain, thereby reducing in amplitude the very large vibrations that accompany intense sounds of low frequency and minimizing shock to the inner ear, and (3) to equalize through the auditory tube the air pressure acting on both surfaces of the eardrum.

The inner ear consists of two main parts, (1) the
semicircular canals that contain one part of the body's balance mechanism, and (2) the cochlea.

The cochlea is a membraneous device formed of coiled tubes. The three tubes, lying side by side, are filled with fluid and separated from each other by membranes. The membrane between the *scala vestibula* and *scala media* is so thin that it never obstructs the passage of sound waves. Its function is to separate the fluid of the *scala media* from that of the *scala vestibula*. The membrane separating the *scala media* from the *scala tympani*, called the basilar membrane, is a strong structure that impedes the sound waves. This supports the organ of Corti which in turn is supported by about 25,000 reed-like, stiff, thick spines that project into the membrane from one side. The basilar fibers stretch most of the distance across the membrane. Located on the surface of the basilar membrane are the sound receptor cells, the hair cells (Figure 7).

An inward movement of the stirrup at the oval window produces an outward movement of the round window membrane. The flexibility of the coverings of these windows allows waves to travel back and forth in the fluid of the spiral canal. These waves in turn produce a fluid wave in the closed membranous canal. The resulting wave-like movement produced in the organ of Corti produces nerve impulses that travel on the auditory nerve to the brain for interpretation (Guyton, 1969, pp. 299-305).
The Way Sound Damages the Ear

If sound incident on the ear is too intense, the eardrum may rupture, but more often, sound damage is a slow process that may or may not be noticeable before irreparable damage has been done.

Exposure to noise of great intensity for long periods can produce detrimental changes in the inner ear (Figure 8). Some of these changes are temporary and last for minutes, hours, or days after the termination of the noise. After recovery from the temporary effects, residual permanent effects on the ear and hearing may persist throughout the remainder of life.

The hearing changes that follow sufficiently severe exposures to noise include distortions of the clarity and quality of auditory experience and partial loss of the
ability to detect sound. These changes vary in degree, from only slight impairment to nearly total deafness.

The primary site of auditory injury produced by excessive exposure to noise is the receptor organ of the inner ear, the organ of Corti. The sensory cells of hearing are the hair cells in the organ of Corti and the fibers of the auditory nerve. It is thought that severe mechanical stress on the hair cells causes them to become fatigued and unable to transmit impulses to the auditory nerves.

In 1968, Dr. David Lipscomb of the University of Tennessee exposed guinea pigs to 90 hours of loud rock music. (He had recorded it at a Knoxville discotheque). On examination of the cochlea, he found that the hair cells had
collapsed and shriveled (Figure 9). This would suggest a mechanism for hearing loss (Berland, 1970, pp 43,44).

Collapse of organ of Corti-
hair cells absent - accessory cells swollen and distorted

-nerve fibers reduced
-in number

Figure 9. Severely injured organ of Corti. (USEPA, Dec. 31, 1971, p. 1-7).

Some researchers are finding that loud noises cause the small blood vessels of most of the body to constrict. This may be another factor in the hair cells becoming fatigued or destroyed because of the reduced supply of blood to the cochlea. Once the cells are destroyed they do not automatically regenerate nor can they be stimulated to regenerate.

Other Effects of Sounds on the Body

Some of the effects of noise on the human body, other than hearing loss, can be demonstrated. The interference with speech communication is one demonstrable effect whether it is due to impairment of hearing or not. Distraction of
people from work requiring concentration is another. It can also be demonstrated that noise interferes with sleep.

Among the situations that noise has been blamed for is the high divorce rate, social conflicts, indigestion and other organic disabilities, nervous breakdowns, high blood pressure, heart failure, and insanity. These are not readily demonstrable.

Physical changes that take place when noises are perceived are dilation of the blood vessels in the brain whereas the blood vessels of the rest of the body constrict. Blood pressure rises, and the heart rhythm changes. The pupils of the eyes dilate. The blood cholesterol level rises. Various endocrine glands pour additional hormones into the blood and the rate of acid secretion changes.

Ulcers, indigestion, "heartburn," gastro-intestinal malfunctions, heart disease—all are generally related to stress, and since noise is interpreted by the body as stress, noise may also be a contributing factor to the incidence of these conditions. Stress also is a factor in mental illness. Although environmental noise alone is not likely to produce mental illness, the continual exposure of an already depressed person to noise cannot be helpful.

Another recent medical discovery is the effect of noise on unborn babies. Previously they were thought to be insulated from the noise stress of the outside world, but physicians currently believe that external noises can and
do trigger changes in fetuses (Baron, 1970, p. 49).

One study of steelworkers indicated that those working in a noisy environment are more aggressive, distrustful, and irritable than workers in a quieter environment (USEPA, 1972).

Defenses by the Body Against Loud Sounds

Natural defenses against noise are few. During the evolution of man, the ability to hear all sounds was essential. There were few, if any, exceptionally loud noises that could be precursors of an evolutionary trend. Thus, no mechanism evolved to protect humans from loud noises.

If noise is sufficiently intense, the eardrum may rupture. This may actually be a protective measure because it prevents further transmission of loud sounds from reaching the cochlea. But some loud sound will have already reached the cochlea and may have caused damage.

As mentioned earlier, two muscles are attached to the bones of the middle ear. They tend to constrict reflexively when loud sounds are transmitted to the brain thereby reducing the amplitude of the sound reaching the cochlea. But damage may occur prior to this reflex (USEPA, 1972).

Sudden loud noises are frightening and may initiate reactions in the body that are protective. The reactions include the release of adrenalin that may cause man to flee or fight.
The mobility of man may be considered a defensive factor. He may simply migrate from a noisy environment.

Noise Reduction

There is always a need for noise protection and this can be provided in two ways. Noise can be excluded by using noise protectors, and humans can isolate the noise by stopping it at the source.

There are two main types of noise protection devices. One is the insert-type plugs made of rubber, plastic, or wax. These can lower the decibel level of the sound entering the ear by 30 or 40 points. The other is muff protectors that are somewhat more effective than the insert-type plugs. Cotton plugs are of little value.

Machinery can be designed so that the noise level is reduced. Noise shields can be placed around them if they are stationary. Cars, mowers, and other mobile machinery can have adequate mufflers installed and insulation placed around the engine compartment. Noise does not necessarily mean power. One lawn mower was taken off the market because it was so quiet it could not be sold, yet it was as powerful as others of the same size (Bragdon, 1971, p. 6). Appliances can be designed so as to reduce noise level. Buildings can also be constructed so that sound is not transmitted from one room to another by installing sound absorbing materials inside each room. Many modern building
codes insure that new houses are quieter. Trees can be planted around the buildings to help absorb sound.

The U. S. Department of Transportation lists some of the methods for design and control that may be used in reducing highway noise. These are:

**Vehicle Design**

- Engine block design to minimize radiation of combustion-induced noise
- Vibration isolation and sound damping of engine block and transmission
- Intake and exhaust silencers
- Fan noise reductions
- Control of auxiliary equipment noise (e.g., refrigeration units, cab air conditioning, etc.)
- Brake system noise reduction
- Body and frame design including insulation and acoustican enclosures

**Tire Design/Use**

- Tire noise reduction along with control of axle loading
- Use of rib-tire designs instead of cross-bar

**Vehicle Operations**

- Speed limits established and monitored
- Limit access of certain vehicles to particular routes by time of day
- Controls on vehicular flows and volume
- Keep traffic flowing to avoid stopping and starting of vehicles
Vehicle Maintenance

Preventive maintenance of vehicle components which degrade with time or use (e.g., mufflers)

Route Design

Pavement specifications

Limitations on allowable grades

Acceleration/deceleration ramp lengths and traffic light controls

Use of depressed roadway

Use of roadside barriers or berms

Route Maintenance

Road surface repairs

Route Locations

Route locations planned to insure maximum separation between roadway and existing noise sensitive areas and to make maximum use of shielding provided by natural barriers

Provide for compatible use of land adjacent to highways (Transportation Noise and Its Control, June, 1972, p. 12).

In the Kalamazoo area multi-residential complexes and schools are being isolated from noise sources by large mounds of dirt (Figure 10). Using these and other methods, people may be able to live close to main throughfares with assurance of relative quiet.

The EPA suggests these hints for a quieter home.

(1) Use noise absorbing materials on floors, especially in areas where there is a lot of traffic.

(2) Hang heavy drapes over the windows closest to outside noise sources.
Figure 10. This berm separates a school from the Interstate. The purpose is to reduce noise in the classrooms.

(3) Put rubber or plastic treads on uncarpeted stairs. They are safer too.

(4) Use upholstered rather than hard-surfaced furniture to deaden noise.

(5) Install sound-absorbing ceiling tile in the kitchen. Wooden cabinets will vibrate less than metal ones.

(6) Install washing machines in the same room with heating and cooling equipment, preferably in an enclosed space.

(7) Use insulation and vibration mounts when installing dishwashers.

(8) Remember that a hand-powered lawnmower does the job and gives you exercise too. If you use a power mower, operate it at reasonable hours.

(9) Use a headset when you are the only one listening to the stereo. Keep the volume down.

(10) Place window air conditioners where their
hum can help mask objectionable noises. However, try to avoid locating them facing neighbor's bedrooms.

(11) Be aware that children's toys need not make intensive or explosive sounds. Some can cause permanent ear injury in addition to getting on your nerves.


The Economics of Noise Pollution

The cost of noise pollution is difficult to assess although the factor exists.

One of these aspects is the deterioration of one's health. Noise is interpreted by the body as stress and this causes chemical, physical, and psychological changes. It can so weaken the body's defense mechanisms so that diseases are more easily contracted. This results from noise placing the body on alert. The repetition of these alerts is exhausting and depletes energy levels, and the phenomenon continues even when one is asleep.

Noise increases errors (Glass and Singer, 1972) which is probably one reason for the high incidence of manufactured products of poor quality. Errors can also be a factor in accidents, including automobile. Noise inhibits the prevention of accidents by obliterating or obscuring warnings or spoken signals and by masking the sounds of mechanical breakdowns. Accidents cost money in time,
earnings and skills lost; medical care, the high cost of death; and the cost of training replacement personnel.

Noise causes work interruptions which mean more time on the job, but less output. Study is also interrupted (Kalamazoo Gazette, September 17, 1972, p. D-12).

Noise decreases the creativity of an individual. The individual may have to move to a quieter place to continue his work. The cost is paid not only by the individual but by those left behind. If the individual cannot afford to move, this creativity is lost.

Noise decreases the value of real estate although the dollar value of the decrease is difficult to assess. Apartments in noisy areas are more difficult to rent and turnover is greater than for apartments in quiet areas. People who can afford it move to quieter areas. The average income per family drops. The area generally begins to deteriorate. Sales in the area decrease because of the lower average income and the fact that people stay out of the noisier area and will not go there to shop.

In addition, there is the cost of soundproofing. At today's inflated prices from 2 to 10% of the cost of the structure may be the cost of soundproofing. The structure must be air conditioned since windows must be kept closed. This adds to the energy consumption.

Noise, because it interferes with sleep, means more sedatives will be bought—and its antilog, more stimulants
will be bought to get one going the next day.

Noise also increases the sale of ear protective de­
vices as people seek to protect themselves from the on­
slaught of noise and the sale of hearing aids for those who
have incurred hearing losses because of noise (Baron, 1970,
pp. 53-116).

Noise decreases production of our domestic animals.
Chickens lay fewer eggs, cows give less milk, and cattle
gain less weight.

Wildlife is also affected. Some, such as the deer,
opposum, and squirrel, can adapt rather well, whereas
others cannot. For example, Canada geese will not breed in

Noise damages man-made structures. The settlement of
sonic boom claims associated with military supersonic flights
from 1956 to 1967 amounted to $1.3 million (Bragdon, 1971,
p. 13).

In 1968 the Veterans Administration spent $65 million
in rehabilitating 90,000 veterans with service-connected
hearing disorders (Baron, 1970, p. 88). This was up con­
siderably from $34 million spent in 1967 for the same pur­
pose (Bragdon, 1971, p. 13).

Noise pollution control has received little attention
if the number of dollars appropriated by the Federal govern­
ment is any criterion. In 1971 $34 million dollars were
designated for noise abatement of which $31 million were
devoted to aircraft noises. The lack of attention is obvious if one compares this expenditure with the $828 designated for water pollution control (Bragdon, 1971, p. 12).

As the total cost of environmental quality is studied further, people may find that noise is something that society cannot afford.

Noise Legislation in the U. S.

Federal noise legislation first appeared in 1968 when Congress directed the Federal Aviation Administration (FAA) to establish rules and regulations to control aircraft noise. At the state and local level, laws tended to treat noise as a public nuisance, and enforcement was difficult and spotty.

The Clean Air Amendments of 1970 called for the establishment of an Office of Noise Abatement and Control in the U. S. Environmental Protection Agency (EPA). The legislation also called for public hearings on environmental noise and a special report to the Congress on the problem incorporating the results of the public hearings and other special studies. Information from this report as well as extensive congressional hearings formed the basis of the Noise Control Act of 1972 that was adopted in the final hours of the 92nd Congress.

The main provisions of the Noise Control Act of 1972 are:
(1) The EPA is directed to develop and publish information on the limits of noise required for protecting public health and welfare as well as a series of reports to identify products that are major sources of noise and to give information on the techniques for controlling noise from such products.

(2) The EPA is required to set noise emission standards for products that have been identified as major sources of noise and for which standards are deemed feasible.

(3) The EPA has authority to require the labeling of domestic or imported consumer products as to their noise generating characteristics or their effectiveness in reducing noise. Manufacturers or importers of non-conforming or mislabeled products are subject to fines of up to $25,000 per day for each violation and to imprisonment for up to one year.

(4) The EPA Administrator also is to prescribe noise-emission standards for the operation of equipment and facilities of interstate railroads, trucks, and buses.

(5) All federal agencies are directed to use the full extent of their authority to insure that purchasing and operation procedures conform to the intent of the law. EPA may certify low-noise emission products for purchase by the federal government.

(6) The EPA is required to conduct an extensive study of noise standards for aircraft and submit proposals. Using this information, they will submit to the FAA proposed regulations to control aircraft noise and sonic booms. After a hearing and further consultation with EPA, the FAA may adopt or modify the proposed regulations. The FAA may reject the proposals if it believes they are unsafe technologically or economically infeasible, or not applicable to certain aircraft. However it must publicly explain its specific reasons for rejection (USEPA, December, 1972)
Any person may start a civil action on his own behalf against any person or the U.S. and any other governmental agency for violation of this act. Similarly, civil action may be brought against the Administrator of EPA or FAA for failure to perform any non-discretionary duty under this law. Rights that a person may have under different statutes or the common law to enforce a noise control requirement are not restricted by this law.

Many cities have devised their own noise-control code, an example being New York City. The sponsors describe this code as being the most comprehensive in the U. S. The law specifies decibel limits on a wide variety of noise sources such as air-compressors, paving breakers, motor vehicles, air conditioners, emergency sirens, car horns, and trash trucks.

Another section of the code limits "unnecessary noises," prohibiting, for example, the blaring of amplifiers from stores into the streets for commercial purposes, and the playing of phonographs and radios on transit facilities. A major provision limits construction in the city, including utilities and road building, but excluding tunneling, to the hours between 7 a.m. and 6 p.m. The penalties provided by the code are a minimum fine of $50 and a maximum fine of $1000.

Chicago has had a noise-control law since July, 1971.
Fines range from $15 to $300 for the first offense, and up to $500 and 6 months in jail for a second. One noticeable effect is the reduction of excessive horn blowing by motorists. San Francisco's new ordinance prohibits "unnecessary, excessive, and offensive noises from all sources." Other cities with or considering similar controls are Los Angeles, Minneapolis, and Dallas.

An incentive now exists for the full employment of noise-control technology that is already available, and the day when quiet is restored appears closer. Now the law is to give the nation the stimulation to do it (U.S. News and World Report, November 6, 1972, pp. 49-52).
CHAPTER II: NOISE LEGISLATION IN KALAMAZOO

The Kalamazoo Noise Ordinance

The noise ordinance for the City of Kalamazoo was adopted in 1973. It was written because of the need to control noise in the city, but, as has happened in so many other cities in the United States, over 500 of them, the enthusiasm that was evident when the ordinance was being written has waned. It is not being enforced at the time of this writing (Spring, 1974). The ordinance appears below.

CITY OF KALAMAZOO, MICHIGAN

ORDINANCE NO. 992

AN ORDINANCE TO REGULATE NOISE WITHIN THE CITY OF KALAMAZOO, TO PRESCRIBE PENALTIES FOR THE VIOLATION THEREOF, AND TO REPEAL SECTION 201 OF THE POLICE AND LICENSE CODE OF THE CITY OF KALAMAZOO.

THE CITY OF KALAMAZOO ORDAINS:

Section 1. The Police and License Code of the City of Kalamazoo, being Ordinance 891, as amended, is hereby further amended by adding Chapter II A (NOISE ORDINANCE) and repealing Sections PL201. through PL201.3 of Chapter II as follows:

"Sec. PL 201. Repealed."
"Sec. PL201.1 Repealed."

"Sec. PL201.2 Repealed."

"Sec. PL201.3 Repealed."

"Sec. PL201A. Purposes:

(a) The making and creation of excessive or unusually loud noises within the limits of the City of Kalamazoo is a condition which has existed for some time and the extent and volume of such noises are increasing;

(b) The making, creation, or maintenance of such excessive or unusually loud noises which are prolonged, unusual or unreasonable in their time, place, and use, affect and are a detriment to public health, comfort, convenience, safety, and welfare of the residents of the City of Kalamazoo; and

(c) The necessity in the public interest for the provisions and prohibitions hereinafter contained and enacted, is declared as a matter of legislative determination and public policy, and it is further declared that the provisions and prohibitions hereinafter contained and enacted are in pursuance of and for the purpose of securing and promoting the public health, comfort, convenience, safety, welfare, and peace and quiet of the inhabitants of the City of Kalamazoo;

(d) In the enactment of this ordinance, however, it is not intended to prohibit, restrict, penalize, enjoin, or in any manner regulate flights of aircraft which are in all respects conducted in accordance with, or pursuant to, federal law, federal air regulations, and air traffic control instructions.

"Sec. PL202A.1 General Noise Prohibition: It shall be unlawful for any person, firm or corporation to make or cause to be made or continued, any excessive or unusually loud noise or any noise, measured or unmeasured, which either disturbs, injures or endangers the comfort, repose, health, peace or safety of any person within the limits of the City of Kalamazoo.

"Sec. PL202A.2 Definitions: As used in this ordinance, unless the context otherwise requires, the following words and phrases shall have the meanings ascribed to them in this section:
(1) "Decibel" is a unit used to express the magnitude of sound pressure and sound intensity. The difference in decibels between two sound pressures is twenty times the common logarithm of their ratio. In sound pressure measurements the sound pressure level of a given sound is defined to be twenty times the common logarithm of the ratio of that sound pressure to a reference pressure of $2 \times 10^{-5} \text{ N/m}^2$ (Newtons per meter squared). As an example of the effect of this formula, a three decibel change in the sound pressure level corresponds to a doubling or halving of the sound intensity, and a ten decibel change corresponds to a ten-fold increase or a decrease to one-tenth the former sound intensity.

(2) "dB(A)" means the sound pressure level in decibels measured on the "A" scale of a standard sound level meter having characteristics defined by the American National Standards Institute, Publication ANSI S1.4 - 1971, for a Type 2 Instrument.

(3) "Ambient" means surrounding or background noise associated with a given environment, usually a composite of sounds from many sources.

(4) "Any person" shall mean a reasonable person of normal sensitiveness.

(5) "Harmonic" or "pure tones" are sounds which have a specific frequency or pitch associated with them.

(6) "Impulsive sounds" are of very short duration, although they may be repeated at regular or irregular intervals, such as gun shots or automobile backfire sounds.

"Sec. PL202A.3 Noises Prohibited: The following acts, among others, are declared to be loud, disturbing noises in violation of this ordinance, but said enumeration shall not be deemed to be exclusive, namely:

(a) Horns, Signaling Devices: The sounding of any horn or signaling device on any truck, automobile, motorcycle, or other motor
vehicle on the street or public place of the city except as a warning signal as pro-

(b) Radios, Phonographs, TV Sets, etc: The using, operating or permitting to be played any radio receiving set, musical instrument, TV, phonograph, or other machine or device for the production or reproduction of sound in such a manner as to disturb the quiet, comfort, or repose of any person. The opera-
tion of any such set, instrument, TV, phono-
graph, machine or device in such a manner as to be in violation of Sec. PL202A.4 shall be prima facie evidence of a violation of this section.

(c) Loud Speakers, Amplifiers for Commercial Purposes: The installing, using or operat-
ing, within the city, of a loud speaker or sound amplifying equipment, for commercial purposes, in such a manner as to disturb the quiet, comfort or repose of any person. The operation of any such equipment or de-
vice in such a manner as to be in viola-
tion of Sec. PL202A.4 shall be prima facie evidence of a violation of this section.

(d) Yelling, Shouting, etc: Yelling, shouting hooting, whistling or singing at any time or place so as to disturb the quiet, comfort, or repose of any person. The occupant or person in charge of any building emitting such noise and the person owning or operat-
ing any vehicle or device emitting such noise shall be deemed responsible therefore and shall be in violation of this provision.

(e) Hawkers and Peddlers: The selling of any-
thing by outcry within any area of the city zoned primarily for residential uses.

(f) Animals: The owning, keeping, having pos-
session or harboring of any animal which, by frequent or habitual howling, barking, meowing, squawking, or other noise, shall disturb the quiet, comfort, or repose of any person.

(g) Exhausts: The discharge into the open air
of the exhaust of any steam engine, stationary internal combustion engine, motor boat, or motor vehicle except through a muffler or other device which will effectively prevent loud or explosive noises therefrom. Modifying any noise abatement device on any motor vehicle or engine in a manner so that the noise emitted by such vehicle or engine is increased above that emitted by such vehicle or engine as originally manufactured shall be a violation of this section.

(h) **Defect in Vehicle or Load:** The use of any truck, automobile, motorcycle, or vehicle so out of repair, so loaded, or in such manner as to create loud and unnecessary grating, grinding, rattling, or other noise.

(i) **Vehicle Repairs:** Repairing, rebuilding or testing any truck, automobile, motorcycle, or other motor vehicle within the city in such a manner as to disturb the quiet, comfort or repose of any person.

(j) **Loading, Unloading, Opening Containers:** The loading, unloading, opening or otherwise handling boxes, crates, containers, garbage containers or other objects in such a manner as to disturb the quiet, comfort, or repose of any person.

(k) **Construction Projects or Repair of Buildings:** The performing of any construction or repair work on buildings, structures, or projects, or the operating of any pile driver, steam shovel, pneumatic hammer, derrick, steam or electric hoist, or other construction-type device in such a manner as to disturb the quiet, comfort or repose of any person, except in cases of unnecessary hardship. In such cases, a permit shall be obtained from the City Manager in accordance with Sec. PL203A.1.

(l) **Schools, Courts, Churches, Hospitals:** The creation of any excessive noise within the vicinity of any school, institution of learning, church or court while the same are in use, or within the vicinity of any hospital or nursing home which unreasonably interferes
with the workings of such institution or
which disturbs or unduly annoys patients in
the hospital, provided conspicuous signs are
displayed on streets within the vicinity
indicating the presence of a school, hos­
pital, court, church or nursing home.

(m) Drums: The use of any drum or other instru­
ment or device for the purpose of attracting
attention by creation of noise to any per­
formance, show or sale, or for any other com­
mercial purpose.

"Sec. PL202A.4 Noise Limitations Based Upon dB(A)
Criteria: Any noises in excess of the maximum decibel
limits according to the following regulations shall be
deemed prima facie evidence of a violation of Sec.
PL202A.1.

(A) Maximum Decibel Limits on Noise Originating
from Private Property:

(1) Noise will be measured at the boundar­
ies of the lot. To be in violation,
the source or sources of noise must be
identifiable in relation to the ambient,
and must exceed the limitations estab­
lished for the districts and times
listed below.

<table>
<thead>
<tr>
<th>ZONES</th>
<th>dB(A) MAXIMUM LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(7 a.m. to 10 p.m.)</td>
</tr>
<tr>
<td>Residential 7, 7A, 8</td>
<td>50 dB(A)</td>
</tr>
<tr>
<td>Commercial 4, 5, 5A, 6</td>
<td>55 dB(A)</td>
</tr>
<tr>
<td>Industrial 1, 2, 3</td>
<td>75 dB(A)</td>
</tr>
</tbody>
</table>

(2) At boundaries between zones, the lower
of the dB(A) levels shall be applicable.

(3) Harmonic or pure tones, and periodic or
repetitive impulsive sounds shall be in
violation when such sounds are at a
sound pressure level of five (5) dB(A)
less than those listed above.
(4) The following exceptions shall apply:

(a) Construction projects shall be subject to the maximum permissible noise levels specified for industrial districts for the period within which construction is to be completed pursuant to any applicable construction permit issued by proper authority, or if no time limitation is imposed, then for a reasonable period of time for completion of the project.

(b) Noises caused by home or building repair and ground maintenance are excluded from these limits between the hours of 7 a.m. to 10 p.m., provided they do not exceed 74 dB(A) at the property line or at a distance of 50 feet (15 meters), whichever is furthest from the source of the noise.

(c) All railroad rights-of-way shall be considered as industrial districts for the purpose of this ordinance and the operation of trains shall be subject to the maximum permissible noise levels for such district. The allowable noise levels at the boundaries of the right-of-way shall be those appropriate within industrial districts without regard for the zone of the abutting property.

(B) Maximum Decibel Limits on Noise Originating from Motor Vehicles: All noise emitted from motor vehicles upon the public right-of-way shall be measured whenever possible at a distance of at least 50 feet or 15 meters from the source of the noise. If measurement at 50 feet (15 meters) is not feasible, measurement may be made at 25 feet (7½ meters), and 6 dB(A) added to the limits provided below. To be in violation, the source or sources of noise must be identifiable in relation to the ambient, and must exceed the limitations listed below.
<table>
<thead>
<tr>
<th>VEHICLE</th>
<th>WEIGHT</th>
<th>dB(A) MAXIMUM LIMITATIONS*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks and Buses</td>
<td>Over 10,000 lbs. Gross Weight</td>
<td>82 dB(A)</td>
</tr>
<tr>
<td>Trucks and Buses</td>
<td>Under 10,000 lbs. Gross Weight</td>
<td>74 dB(A)</td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>Any Weight</td>
<td>74 dB(A)</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>Any Weight</td>
<td>82 dB(A)</td>
</tr>
<tr>
<td>Snowmobiles, Minibikes, and all other motor vehicles</td>
<td>Any Weight</td>
<td>74 dB(A)</td>
</tr>
</tbody>
</table>

*For areas where posted speed limit is in excess of 35 mph, add 4 dB(A).

"Sec. PL202A.5 Enforcement Personnel: In addition to the employees and officers required to enforce city ordinances generally, the City Manager may assign duties of enforcement to personnel trained in noise control techniques and procedures and equipped with calibrated sound level meters of a standard design.

"Sec. PL203A.1 Permits and Standards: The City Manager shall authorize the issuance of a permit to any person which will allow noise in excess of the noise levels designated in this ordinance when he shall find the following facts to exist:

(a) That all of the statements made in the application are true;

(b) That the control and supervision of the production of such noise will be under responsible and reliable persons;

(c) That unnecessary hardships would result if a permit is not issued;

(d) That the public health and safety will not be impaired by the noise permitted.

"Sec. PL203A.2 Permit Requirement: Permits may be granted for a period not to exceed sixty (60) days while the hardship continues and which permit may be renewed for..."
periods of sixty (60) days while said hardship continues. Said permits shall restrict the noise creating activity to within the hours of 7 a.m. and 10 p.m., except in the case of urgent necessity in the interest of public health and safety, in which case a permit may be issued granting permission for such activity between the hours of 10 p.m. and 7 a.m.

"Sec. PL203A.3 Suspension or Revocation of Permit: Upon complaint filed with the City Manager by any person, or upon his own motion, the Manager may suspend the permit of any person or organization granted under this ordinance for good cause shown. "Good cause" shall include:

(a) Any material misrepresentation in the application for a permit or any fraud in its procurement, or failure to carry out any commitment or representation contained in the application or in the rules of this ordinance; or

(b) Any cause which would have prevented the granting of the permit in the first place.

After the City Manager has suspended a permit, the holder of the permit shall have the right to appeal to the City Commission within ten (10) days after receiving notice of such suspension. Such appeal shall be made by filing written notice with the City Clerk.

"Sec. PL204A. Exceptions: The provisions of this ordinance shall not apply to:

1. Law enforcement or governmental agencies when engaged in activities authorized by law;

2. Emergency work performed for the safety, welfare, and public health of the citizens of the City of Kalamazoo. "Emergency work" is work made necessary to restore property to a safe condition following a public calamity or work required to protect persons or property from an imminent exposure to danger or potential danger;

3. Warning devices emitting sound for warning purposes as authorized by law;

4. Parades, fairs, circuses, other similar public entertainment events, sanctioned sporting events, sporting activities taking place
in areas set aside for such activities, or
any activities normally associated with any
of the above.

"Sec. PL205A. Penalties: Whenever in any section of
this ordinance or rule or regulation promulgated hereunder,
the doing of any act is required, prohibited, or declared
to be unlawful and no definite fine or penalty is provided
for a violation thereof, any person, firm or corporation
who shall be convicted of a violation of any such section
shall, for each offense, be fined in the sum of not more
than Five Hundred (500) Dollars or be imprisoned not to ex-
ceed ninety (90) days, or both so fined and imprisoned.

"Sec PL206A. Additional Remedy - Injunction: As an
additional remedy, the operation or maintenance of any
noise source in violation of any provision hereof and which
causes discomfort or annoyance to reasonable persons of
normal sensitiveness or which endangers the comfort, repose,
health, or peace of residents in the area shall be deemed
and is declared to be a public nuisance and may be subject
to abatement summarily by a restraining order or injunction
issued by a court of competent jurisdiction."

Section 2. Severability of Parts of Ordinance: It
is hereby declared to be the intention of the City Commis-
sion that the sections, paragraphs, sentences, clauses, and
phrases of this ordinance are severable and if any section,
paragraph, sentence, clause or phrase of this ordinance
shall be declared unconstitutional or invalid by the valid
judgment or decree of any court of competent jurisdiction,
such unconstitutionality or invalidity shall not affect any
of the remaining section, paragraphs, sentences, clauses,
and phrases of this ordinance, since the same would have
been enacted by the City Commission without the incorpora-
tion in this ordinance of any such unconstitutional or in-
valid sections, paragraphs, sentences, clauses, and phrases.
Section 3. All offenses committed and all penalties, sentences, fines or liabilities incurred prior to the effective date of this ordinance under any ordinance embraced in or modified, changed, or repealed by this ordinance may be prosecuted, enforced and punished, and any action thereon may be completed in the same manner and with the same effect as if this ordinance had not been passed.

Section 4. All ordinances or parts of ordinances inconsistent herewith are hereby repealed.

CERTIFICATE

The foregoing ordinance was adopted by the City Commission of the City of Kalamazoo, Michigan, on the ________ day of ________, 1973, and was duly recorded, posted, and authenticated by the Mayor and City Clerk, as provided by the charter of said city.

GILBERT H. BRADLEY, JR. Mayor

ARLENE R. VANDER ROEST, City Clerk

It is doubtful whether all part of the ordinance can or will be enforced. Examples are the noise limits for trains and noise limits for vehicles on Interstate 94. Another drawback is the the ordinance does not indicate specifically how measurements will be taken. The measurements should be taken under controlled conditions if they are to be acceptable in court.
A Limited Study of Transportation Noises in Kalamazoo

Undoubtedly, the most far reaching noise source in society today stems from transportation operations. Projections into the future suggest that by 1985 there will be more than 430 million aircraft operations per year compared with 80 million operations today, 130 million automobiles in use versus 84 million now, and 28 million trucks compared with 17 million today (Transportation Noise and Its Control, June, 1972, p. 1). Together these portend a great increase in the volume of noise emanating from transportation services.

Kalamazoo has taken steps to control the transportation noise by limiting the amount of noise the vehicles are allowed to produce legally. No attempt is made to control aircraft noise as it is under the jurisdiction of Federal air regulations.

The study was conducted to determine if there was any appreciable violation of the ordinance by vehicles of transportation including passenger cars, motorcycles, trucks, and trains. Some aircraft were also monitored.

Noise from passenger cars has been reduced through the use of generally adequate intake and exhaust quieting devices and relatively quiet tire-tread designs. Under normal operating conditions of around 35 mph, the noise from a car is a composite of about equal contributions from
the noises of the engine-exhaust system and the tire-treadway interaction. As speed is increased, tire noise grows at a more rapid rate than does engine noise. The graph (Figure 11) indicates how noise levels increase with speed and acceleration. The higher acceleration noise levels can be generated virtually independent of the speeds of the cars. Although automobiles are not so noisy as trucks, their large percentage of the total traffic flow makes the cumulative automobile contribution to overall highway noise important. In addition, maximum acceleration maneuvers by automobiles produce noise levels quite similar to the noise level from trucks. Design is generally not important in noise production except for modified sports-car versions of the standard models. Additionally, poorly maintained cars produce more noise than those that are properly maintained.

Figure 11. Passenger Car Noise at 50 Feet. (Transportation Noise and Its Control, June, 1972, p. 13).
The noise level for automobiles was monitored at points X and Y as marked on the map in Figure 12. The day the measurements were taken was relatively quiet. Background noise was approximately 50 to 55 dB(A). Few cars were on the road, and those were spread out. Therefore the cars could usually be checked individually to see if they violated the ordinance. The noise meter used was #1565 B Sound Level Meter manufactured by General Radio Company. It was set on the A scale reading and slow meter response.

Figure 12. Map of area at Howard Street and Stadium Drive intersection that show where noise measurements were taken.

At location X, only the cars that were in the near lane were monitored. The distance from the center of that lane and the noise meter was 100 feet. This was necessary
because of the terrain (ditch) next to the road. Because of the number of cars involved no attempt was made to determine the exact noise level of each car. The primary concern was to determine if any exceeded the noise levels as set by the Kalamazoo Noise Ordinance. Cars were monitored consecutively.

At location X, the speed limit is 40 mph. Therefore $74 \text{ dB (basic maximum)} + 4 \text{ dB (over 35 mph)} - 6 \text{ dB (doubling of distance)} = 72 \text{ dB}$. This would be the maximal noise level acceptable from any one passenger car at 100 feet on that stretch of road. The cars were traveling at a steady speed and most seemed to be moving slower than 40 mph. At this point 136 cars were monitored of which 135 were below the limit and 1 was above.

At location Y accelerating cars were checked. The speed limit at this point is 35 mph. The noise meter was 50 feet away from the center of the lane checked at which point the acceptable noise level should not exceed 74 dB(A). Thirty-seven cars were monitored of which 36 were below the limit and 1 was above. Of the 36 below the limit, 11 were between 65 and 74 dB.

Cars were also monitored at location Z on Interstate 94 (Figure 13). At this point the speed limit is 55 and with the monitoring at 100 feet from the center of the lane, the maximum allowable noise level is 72 dB(A). Here 131 cars were monitored and all were below the limit.
Figure 13. Map of area where noise measurements were taken on Interstate 94.

Presently the source of the greatest highway noise is from trucks. The average heavy truck cruising at 45 mph produces approximately 86 dB(A) at 50 feet although levels above 94 dB(A) are not uncommon. A 3 to 5 percent upgrade in the highway produces 2 dB(A) more noise than a level run, but on a level roadway acceleration produces 5 dB(A) more than steady running conditions.

Trucks tend to operate at a nominally constant RPM so that engine and exhaust noise does not vary appreciably with vehicle speed. At lower highway speeds when the engine-exhaust noise is dominant, quiet trucks with stock mufflers produce 80 to 82 dB(A). Special tandem experimental mufflers under the same conditions can reduce the noise output to as low as 78 dB(A). The noise output without mufflers under these conditions is about 95 dB(A).

At the higher highway speeds, tire-pavement interaction
becomes the major source of noise. Tractor trailers with 18 tires produce high speed tire noise levels that frequently range above 95 dB(A), depending on the tire-tread designs in use on the vehicle. Worn tires usually make more noise than either (Transportation Noise and Its Control, June, 1972, p. 12).

The noise level for trucks was monitored at point Z on the map (Figure 13). These trucks were all semi-trailer trucks. The monitoring methods used were the same as with the passenger cars at this point. The legal limit in the city of Kalamazoo would be 82 dB(A) + 4 dB(A) - 6 dB(A) = 80 dB(A). Fifty trucks were monitored; 41 were below 80 dB(A) and 9 were above. The range was 70 to 84 dB(A). Two buses monitored at the same point had noise levels of 72 and 75 dB(A).

Three trucks were monitored at point X (Figure 12) and had noise levels of 78, 77, and 77. The legal dB(A) limit at this point was also 80 dB(A).

The motorcycle can be as noisy as trucks and are often judged by the public to be even more annoying. The excessive noise levels result from the great variation in engine and muffler designs and, even more frequently, from the removal or modification of mufflers by the users. The noise generated during acceleration is quite high and is nearly independent of speed. The graph (Figure 14) indicates the range of values for the noise produced by the motorcycle.
Figure 14. Motorcycle noise at 50 feet. (Transportation Noise and Its Control, June, 1972, p. 13).

The noise level for motorcycles was monitored at point Y on the map (Figure 12). The speed limit at this point is 35 mph, and the motorcycles were accelerating. The noise meter was 50 feet away from the center of the near lane checked. The noise level should not exceed 82 dB(A). Fourteen motorcycles were monitored and all were below the limits. The dB(A) range was 67 to 80. Three were small motorcycles (range 67 to 71), and the remainder were large with noise levels between 71 and 80 dB(A).

Nine large motorcycles monitored at point X (Figure 12) did not surpass limits for that stretch of street. The data were taken in the same manner as with cars, except at this point, the limit at 100 feet would be 80 dB(A).

As an alternative to the automobile, passenger service
Figure 15. Wayside noise level for transit trains of various lengths. (Transportation Noise and Its Control, June, 1972, p. 17).

...
per doubling of distance (Inverse Square Law), while noise from a long train attenuates at a rate of 3 dB per doubling of distance.

The noise level for trains was monitored at point T on the map (Figure 12). Modern practices are not used extensively at this point. The tracks do not have welded rails and are in disrepair. The distance from the center of the track to the noise meter was 15 meters. At this point there was no right of way line discernible so this distance was used. The data obtained are as follows:

<table>
<thead>
<tr>
<th>Type of Train</th>
<th>Length</th>
<th>Maximum Noise Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger</td>
<td>8 cars</td>
<td>88 dB(A)</td>
</tr>
<tr>
<td>Passenger</td>
<td>6 cars</td>
<td>96 dB(A)</td>
</tr>
<tr>
<td>Passenger</td>
<td>6 cars</td>
<td>100+ dB(A)</td>
</tr>
<tr>
<td>Passenger</td>
<td>6 cars</td>
<td>102 dB(A)</td>
</tr>
</tbody>
</table>

The speed of the trains was estimated at between 30 and 40 mph and the background noise was between 50 and 60 dB(A).

At subsonic flight speeds, namely below the speed of sound in air, pressure waves produced by the motion of an airplane cruising at high altitudes travel away in all directions and are dispersed so that virtually no pressure disturbance that would be perceived as noise reaches the ground. The sound that an observer on the ground hears from the passage of a subsonic airplane is only that of the engine.
Aircraft use full power during takeoff and therefore are at their noisiest in this operation. Aircraft engines produce less noise during landing because lower power is used. The noise that is generated, however, is annoying because of the screech and whine characteristic that predominates during this operation.

The sound level of planes was monitored at point P on the map (Figure 16). The background noise from nearby Interstate 94 ranged from 55 to 60 dB(A).

Figure 16. Map of area near airport where aircraft noise measurements were taken.

Ten planes taking off on runway A were monitored. Of these 8 single engine planes produced readings between
70 and 79 dB(A) and 2 twin engine planes registered 80 and 94 dB(A) respectively. Runway B was monitored from the same point; 3 single engine planes registered 66 or 67 dB(A) and 1 small twin engine aircraft, 74 dB(A). All small craft banked off before reaching a residential area (at point R). No attempt was made to estimate the height of the planes as the height varied and they climbed at different rates.

Conclusions and Comments

Transportation noises are a major source of noise pollution in Kalamazoo due to the vast numbers of vehicles and the volume of traffic.

Fewer than expected violated the noise ordinance. The higher expectation may be attributed to the possibility that people tend to remember the loud cars and not the quiet ones. The ones that were the loudest were cars that were either modified or noticeably in a rundown condition.

It was also expected that many motorcycles would exceed the noise limits but as with automobiles the expectations were not met. The legal noise level is quiet high, and because the motorcyclist is subjected to noise not only from his own vehicle but from other motorcycles since they tend to travel in groups and also from cars and trucks sharing the roadway, damage to hearing is likely to result, especially if the motorcyclist spends much time on the
vehicle and does not wear hearing protectors. A person in a car or truck is protected somewhat from noise because of his being enclosed. The motorcyclist does not have that protection.

Trucks are a major source of noise pollution and are the main violators of the ordinance. The data obtained indicate that on Interstate 94 in Kalamazoo almost 20 percent of the trucks are above the maximum limits allowed by law. This poses several questions. Can Kalamazoo prosecute violators on Interstate 94? Should Interstate 94 be considered an industrial district as railway rights-of-way are?

Trains violate the noise ordinance. Little effort is being made to control the noise from the standpoint of rail upkeep and the warning horns of trains. The horns of trains were blown frequently as they passed by an apartment complex that houses married college students.

Aircraft do not seem to be a major source of noise pollution. The smaller craft appeared to bank off before they reached a residential area and the larger planes are few in number. If passenger service is increased considerably and larger planes are used as planned for the future, this situation could change.
CHAPTER III: THE TEACHING OF NOISE POLLUTION IN THE COMMUNITY COLLEGE

In the community college setting, teaching about pollution may best be achieved by including it as a unit within an environmental survey course. The main purpose of such a unit should be to make the student aware of his noisy environment. Only by being aware of noise will he be able to contribute toward the control.

Awareness can be accomplished by the student's learning about how noise affects him personally and by his identifying problem sources. He should become acquainted with noise measuring equipment and procedures and learn how to use the hand-held sound meter. He should also become familiar with the noise ordinance of the city in which he lives, if it has one, or of a model ordinance if does not.

Chapter I of this report could be used as a summary to provide him with the information indicated above. The use of supplementary references such as those listed in the bibliography and field observations are necessary, however, to gain a broad understanding of noise pollution.

The community college would be appropriate for teaching noise measurement techniques that are used by law enforcement, industrial, and other personnel.

Listed below are eight behavioral objectives for a
unit in noise pollution. Instructors may modify these for their respective teaching situations.

1. The student will learn what sound is and how it travels through materials of different densities.

2. The student will learn which materials allow sounds to pass through them easily, which reflect sounds, and which tend to absorb sounds.

3. The student will learn the units of sound measurement and the meaning of such units.

4. The student will learn how to make meaningful noise level measurements. This can be achieved by field demonstrations and experiences in the laboratory.

5. The student will study research and the ways noise damages the ear and affects other parts of the body.

6. The student will learn how the protective actions of the body reacts to noise.

7. The student will learn how to reduce noise. A field trip to localities where methods described in lectures are being used can help to illustrate ways for noise reduction.

8. The student will learn some of the cost of noise, both evident and non-evident.

The student should make a satisfactory score on a test dealing with the topics covered on noise pollution. The test may be multiple choice, short answer, or essay. Some sample questions are given below.

1. The basic unit for the measurement of sound is the (a) decibel (b) noise meter (c) foot (d) newton A.

2. In making meaningful noise level measurements, you would not need to consider (a) distance to the source of the noise, (b) nearby buildings, (c) background noise, (d) the earmuffs you have on.

3. You are a law officer in charge of making measurements of noise violations. Describe what you must consider when making the measurements in order that they will be

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sufficiently accurate to hold up in court.

4. Name three defenses against loud noise.

5. What are the legal limits of noise allowed in your city? Include limits of different zones and limits for transportation vehicles.

6. As a citizen you are trying to convince your mayor of the need for a noise ordinance in your city. You are good friends and you are doing this while the two of you are enjoying a cup of coffee at a downtown cafe. Make an outline of what you would say in order to get him to agree.

7. Discuss some ways in which you can reduce noise in your home.

8. Cotton plugs will reduce the level of noise by about 15 to 20 dB(A). True_____ False______
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