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ABSTRACT

There is reasonable agreement that hearing impairment is related to noise exposure. This hearing loss due to noise is considered a serious health injury, but there is still difficulty in delineating the importance of noise related to people's general non-auditory well-being and health. Beside hearing loss, noise inhibits satisfactory speech communication in offices, conference rooms, engineering spaces, factories, and ships' compartments, and produces annoyance in residential neighborhoods or multi-family dwellings. Some "noisy" environments can be made more tolerable through architectural design, while in others, machine redesign or ventilation system quieting may solve the problem. In either event, there is an evident need for a U.S. Bureau of Living Standards to work in parallel with the U.S. Bureau of Labor Standards in assuring comfort in our home lives as well as safety and efficiency in our working lives. Noise criteria charts and tables are included. (KK)

NOISE, HEALTH, AND ARCHITECTURE

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Noise--in the sense of "unwanted sound"--has been a problem since Eve first poked Adam in the remaining ribs and told him to stop snoring. Thirty-nine years ago, in May, 1930, the first symposium on noise in this country was held in New York City. At that meeting the Health Commissioner of New York, Shirley W. Wynne, said, "It is doubtful that people even suspect how much noise affects their daily lives. In New York City, there are many who are ill, ... and it is a physician's first thought that noise might in many cases be .... the determining factor of physical--and even of mental--health". In June, 1968, a similar Conference was held in Washington, D.C., under the auspices of the American Speech and Hearing Association titled, "Noise as a Public Health Hazard". This conference dealt with the effects of noise on:

Hearing Threshold

Speech Intelligibility

Psychological State

Physiological State

The noise problem was discussed relative to four areas: Industrial noise and the worker; noise in the community; noise of transportation; and noise in buildings.

When a noise strikes the eardrum, it first travels to the inner ear (See Fig. 1) where it is converted to electrical impulses that travel to the brain. Two principal auditory pathways in the brain are observed. The direct pathway is to the auditory cortex where the sum of the arriving nerve impulses is perceived and interpreted; for example, in the auditory cortex speech sounds are understood. The indirect pathway ends in the reticular formation where the impulses may cause a generalized alerting response, which stimulates internal organs such as the heart, peripheral circulation and the digestive system. Through this indirect system, noise may cause interference with mental work and skill, impairment of sleep, emotional effects, annoyance, and strain on the heart and brain.

In the inner ear, loud noises will interfere with speech communication and enjoyment of music and very loud noises will damage the tiny nerve endings and cause temporary or permanent loss of hearing acuity.

This recent Washington conference demonstrated that there is full agreement in considering hearing loss a serious health injury. But there was great difficulty in the distinction between tolerable and intolerable noise and in delineating the importance of noise related to people's general (non-auditory) well-being and health.

In regard to the sonic boom, it is known from gun shots, which are similar in nature, that a startle effect is observed which causes a blinking of eyelids, pupilary dilatation, and a rise in blood pressure and heart rate. But there are no tests that relate long exposures to startle to the general health of individuals.

Let us now treat in some detail those effects on human beings about which there is reasonable agreement.

HEARING IMPAIRMENT RELATED TO NOISE EXPOSURE

Noise may be rated on several types of scales, some more suited to certain types of noise than others. In this paper we shall restrict ourselves to the most widely used scale known as sound-level A. The units of sound-level A are "decibels-(A)" or "dBA" and measurements of sound-level A can be made with a standard sound level meter switched to "weighting-scale A". When a loud noise is rated by this scale, and the length of exposure of a group of people to this noise is taken into account, the resulting dBA-time-exposure numbers correlate well with the resulting impairment of hearing.

There is also degradation of hearing with age alone, even among people who have never been exposed to industrial or other noises in excess of 80 dBA. Beginning at a noise level of about 80 dBA, increasingly higher noise levels and longer times of exposure create greater amounts of hearing impairment. To illustrate, the curves of Fig. 2 are shown. These curves show the percentage of men whose hearing should be impaired as a result of age and of continuous exposure to noise since age 18. "Hearing impairment" is defined medically as an average "hearing level" in excess of 26 dB. "Hearing level" is the amount by which a person's hearing is deficient as compared to the normal hearing of a young population, which is equated to "zero" at each frequency on a hearing testing device called the audiometer (ISO-1964). To obtain "average hearing level", the hearing levels for a person are averaged at frequencies of 500, 1000 and 2000 Hertz.

We see from Fig. 2 that even for non-noise-exposed groups and for the general population, the percentage of people with hearing impairment increases from 3% at age 25 to 20% at age 55. We further see that if 100 men were exposed to the high noise levels of 100 dBA continuously from age 19, the expected percentage with hearing impairment should be 7% at about age 25 and 45% at age 65.

Based upon data like those shown in Fig. 2, the Bureau of Labor Standards of the U.S. Department of Labor issued on May 20, 1969, an amendment to the Walsh-Healey Public Contracts Act that reads: "Protection [of workers in industry] against the effects of noise exposure shall be provided when the sound levels exceed those in Table I. .... When noise levels are determined by octave-band analysis, the equivalent A-weighted sound level may be determined, from the graph" (See Fig. 3).

TABLE I

BUREAU OF LABOR STANDARDS

Walsh-Healey Public Contracts Act

Amendment of May 20, 1969

Permissible Occupational Noise Exposures in Industry

Duration Per Day, Hours*	Sound Level
8	90 dBA
4	95
2	100
1	105
0.5	110
0.25 or less	115

* When the daily noise exposure consists of periods of different levels, their combined effect in equivalent dBA is determined by a procedure specified in the Amendment.

The Bureau of Labor Standards says that it is not sufficient for an industry to provide ear plugs or ear muffs to reduce the noise below the permissible limits at a man's eardrum. Instead, the Act reads: "feasible administrative or engineering controls [of the excessive noise] shall be utilized. If such controls fail to reduce sound levels within the levels of the table, personal protective equipment shall be provided".

As architects, you must plan with the owner to provide working spaces that will have equivalent noise exposure below the Department of Labor's permissible limits. Design consideration may include the kind, amount and placement of acoustical materials; subdivision of spaces; partial-height sound-absorbing petitions, quiet rooms that workers may step in and out of. But design for quiet is a systems process in which the given complement of machinery must be studied in regard to its noise characteristics. Both the owner and you must have competent assistance. Bargain offers of free design by materials manufacturers may lead to ineffective design, because the solution to the noise problem may lie only in special structures or in machine modifications, or personal ear protection.

The penalties for non-conformance by a manufacturer with the Walsh-Healey regulation, even if violation is found in only one branch of the company, may mean exclusion from government contracting in excess of $10,000 for a period of three years. Obviously noisy industries will automatically be checked by the Bureau of Labor Standards. In other industries, complaints by labor will result in inspection for conformance to the Act. The matter is serious and should be studied in initial designs.

SATISFACTORY SPEECH COMMUNICATION

Satisfactory speech communication is required in many building locations, for example, business offices, conference rooms, foreman's offices, even in factory spaces. Criteria are available for use in architectural design.

Criteria for Large, Relatively Non-reverberant Spaces:

In Table II, the levels of a continuous, steady noise--

measured in dBA without the listener present--that barely permit reliable conversation in non-reverberant spaces at various voice levels and at various separations between a listener and a male talker are shown.

TABLE II

SPEECH COMMUNICATION CRITERIA

(Levels of Interfering Steady Noise Expressed in Readings from A-Scale on Sound Level Meter)

Distance between Talker and Listener in Feet	Voice Levels			
	Normal dBA	Raised dBA	Very Loud dBA	Shouting dBA
0.5	81	87	93	99
1	75	81	87	93
2	69	75	81	87
4	63	69	75	81
6	59	65	71	77
12	53	59	65	71

For example, we see from Table II that if the level of the intruding noise is 80 dBA, the average male talker must shout in order to make himself understood at a distance of 4 ft. In normal voice, he could be understood at 4 ft. only if the level of the noise were 63 dBA or less.

One must use Table II with judgement because it applies to average male voices. The voices of individuals may differ in loudness and precision of articulation. Further, the chart relates to speech material that the listener is not able to anticipate, such as individual words or numbers. Familiar context is more easily understood. However, these numbers have proven acceptable in design for two decades.

Design criteria for specific indoor spaces are given in the following paragraphs. These criteria relate to speech communication, not to damage to hearing.

Criteria for Offices, Conference Rooms, Engineering Spaces, Factories and Ships' Compartments. In private offices or small conference rooms (for 20 or so people), where persons speak at normal voice levels over distances of 10 to 25 ft., the background noise should preferably not have a level of more than 35-45 dBA; one as high as 50 dBA will begin to restrict communication. In large engineering rooms and drafting rooms, where people may be willing to speak in raised voices and to stand not more than about 6 ft. apart, the background noise should preferably not have a level that exceeds 45 to 60 dBA; 65 dBA will barely permit such communication. In factories or ships' compartments, where a restricted vocabulary is common, levels of 70 to 80 dBA are acceptable. Where only warning signals, such as shouts of a very limited vocabulary ("danger") are necessary, at a distance of, say 3 feet, a level of 90 to 95 dBA might be permitted.

Criteria for Homes. In the home, continuous background noise should not exceed a level of 35 to 45 dBA if TV and radio operating at moderate levels are to be understood comfortably.

Criteria for Telephone Communication. Communication by the usual home or office telephone is also susceptible to interference from room noise. For satisfactory telephone intelligibility, the listener should not be in a noise environment with a level of more than about 55 dBA. Levels of 55 to 70 dBA make telephone communication slightly difficult, and 70 to 85 dBA make it difficult. If the listener is in noise with a level above 85 dBA, telephone communication is unsatisfactory, perhaps nearly impossible.

Very Noisy Environments. The maximum noise level at which "mouth-to-ear" communication is possible is a level of about 100 dBA with a separation of 3 to 6 inches.

As we said previously, noise levels may be controlled by architectural design in some instances. In others, machine redesign or ventilation system quieting may be the only possible solution. Expert advice should be sought to determine the direction to follow.

ANNOYANCE OWING TO NOISE

How much noise in a neighborhood or a multi-family dwelling is too much? This important question must be understood by the architect. He and his client must also realize that what is noise for one man may be music for another and that people differ greatly, one from another.

Large social surveys have been conducted in several American cities and in London. Those interviewed have lived both near to and far from military and civilian air bases. The results obtainedfrom 1377 interviews of adults in central

London in 1961 are given in Figs. 4 and 5. Those interviewed were selected by the intersection of a grid laid over a map of London. The questionaire included questions designed to learn whether an individual was more or less susceptible to noise,and which types of noise annoyed the most people.

We see from Fig. 4 that about one-quarter of those interviewed were comparatively insusceptible to their noise environment and about one-tenth were extremely susceptible. Fig. 5 shows which noises of various kinds bothered people and how their answers correlated with the susceptibility ratings of Fig. 4. The correlation is high. Transportation noise was the greatest nuisance, especially to those who are "extremely susceptible".

It seems that about one-fourth of the people can live relatively happily next to elevated train routes, truck routes, aircraft flight paths, or other very noisy activities, while about one-tenth are probably disturbed by almost any noise not of their own making. It was also found from the interviews that the highly susceptible people were dissatisfied with many other things in their environment. Similar results have been found in the United States.

Generally aircraft noise is the most intense and the most troublesome noise for those living near an airport.

It is a complex matter to estimate a neighborhood's reaction to noise of operations to and from an airport. A procedure is however available for estimating total noise exposure of residents of communities surrounding an airport (Bolt Beranek and Newman Inc., 1964). This procedure requires detailed estimates of takeoff and landing information on each runway, including the types, noise ratings, and average number of movements of aircraft during nighttime (10 p.m.-7 a.m.) and daytime (7 a.m.-10 p.m.) periods.

This information is assembled and handled according to charts and formulas. The result is that the area around an airport can be divided into several zones of noisiness, say A, B, and C (Figure 6). Such zones can be used in future land-use planning, e.g., prohibit housing in zones B and C. But for buildings already existing in zones B and C, the necessary sound attenuations in dBA for roof, walls, windows, and doors necessary for the inhabitants' indoor comfort are determined according to need (see Tables III and IV) (Teplitzky and Hirtle, 1968). The sound attenuation requirements presented

TABLE III

Required sound isolation ratings for several building types

Type of Space	Noise Zones A	B	C
Restaurants	N	6	8
Sports facilities indoors	N	5	7
Offices—secretarial	N	4	6
Offices—drafting	N	6	7
Offices—semiprivate, clerical	N	8	9
Residences	N	4	6
Hotels and motels	N	4	6

* N = normal building construction.
NOTE: Numbers are sound isolation ratings of Table IV.

TABLE IV

Typical sound isolation ratings for aircraft noise provided by typical construction materials

Construction Materials	Sound Isolation Ratings
Types of Construction	
Conventional Lightweight	
Windows Open	1—2
Windows Closed	3—4
1/4 in. Glass Sealed in Place	4—5
Walls and Roof	
Weighing 20–40 lbs/sq ft	5—6
Weighing 40–80 lbs/sq ft	6—7
Windows*	
1/8 in. Glass in Double-Hung Wood Frame	0.5—1.5
1/4 in. Plate Glass, Sealed in Place	2—3
Double Windows in Aluminum Frame, Glass Panels Set in Neoprene, 1/4 in. Gaskets, 7/32 in. Panes, 3¾ in. Airspace	5—6
Exterior Walls	
Wood Sheathing or Stucco, etc., on 2 × 4 Studs	
1/2 in. Plaster Board Interior Wall	2.5—3.5
7/8 in. Plaster Interior Wall	3.5—4.5
4½ in. Brick or 6 to 8 in. Lightweight Concrete Block	4.5—5.5
9 in. Brick Wall	6—7
Roofs	
Built-Up Roofing on 1 in. Wood Decking, 1/2 in. Plaster Board on 2 × 8 Joists	1.5—2.5
Built-Up Roofing on 1 in. Decking, 7/8 in. Plaster on 2 × 8 Joists	3.5—4.5
Built-Up Roofing or Shingles on Wood Sheathing, Ventilated Attic Space, 1/2 in. Plaster Board Ceiling	5.5—6.5
Built-Up Roofing or Shingles on Wooding Sheathing, Ventilated Attic Space, 7/8 in. Plaster Ceiling	6—7
Doors	
Noise Zone B Entrance Doors for Residences are 1¾ in. Solid Core Exterior Wood Doors with Heavy-Duty Weather Stripping.	
Noise Zone C, Same as for B, and Add Separate Storm Door with Weather Stripping.	

* These values are to be used in buildings that have window area exceeding 10% of wall area.

in these tables are intended as a guide for general planning and cost estimating; details have to be worked out for each individual house. The specified sound attenuation values are based on the median of acceptability judgements of a large number of persons. Noise sensitive people might prefer better buildings, while insensitive people would probably accept less expensive structures.

For the next decade at airports where noise limits are already in effect, modification of building structure accompanied by year-round air-conditioning promises to be almost the only solution to an owner's demand for substantially quieter indoor life. Obviously outdoor spaces will always be exposed to the noise of aircraft flyovers.

NOISE IN DWELLINGS

Some of the highest-priority items in contemporary architecture seem to be based not on function but on esthetics. Transparency and continuity are two of today's architectural objectives. Spaces are not isolated, but join without barrier through glass, grilles, and gardens. Continuity follows from the flow of space, the open plan, and the flow of forces. But continuous structures and open plans are inimical to quiet living. Many dwellings are acoustical torture chambers!

The noise situation in many new high-rise apartment buildings in New York City has been so unsatisfactory that occupancy rates in them have declined below the profitable point. Potential tenants have been known to bring a portable radio with them when selecting an apartment, and then insist on placing the radio in adjacent apartments and checking the noise isolation with their own ears. Some apartment owners have been forced to embark on expensive additions to walls shared with adjoining apartments, in order to reduce the transmission of noise. For every satisfactorily quiet apartment, many remain as perpetual nuisances to their occupants.

Physical means for controlling noise in dwellings are known. Available are: heavy or multilayered walls between adjacent apartments; floated floors or hung ceilings between vertically oriented units; quiet bathroom fixtures; acoustically designed ventilation ducts; and quiet air-conditioning machinery. At the other extreme, well-designed, air-conditioned apartments (or offices, libraries, and hospitals) may become so quiet that even very faint noises from adjacent rooms or outdoors may be disturbing to the occupants. In these cases, a gentle, steady "sh-sh"sh" type of noise (called white noise), purposely introduced into each room, may provide the noise isolation desired. Thus a new concept is added to our way of living -- noise perfume -- the masking of faint, unpleasant sound by slightly more intense, soothing sound. Noise perfume properly designed is essential in open-plan offices to provide privacy.

The solution of the noise problem in multiple dwellings is hampered by economic and political considerations. Economic, because quiet housing costs more. Political, because it is hard to legislate well-conceived building codes specifying noise and impact isolation. Each of the 6,000 cities and towns (2,500 population and over) in the United States writes its own building code. Labor is slow to adapt to new building techniques. And builders say they are forced to take advantage of the lack of standards to remain competitive. Only New York City has a modern code covering noise control.

The situation is not the same in Europe. A long history of multiple-family dwellings, a basic desire for gracious living in exchange for gadgets, and the rebuilding of millions of dwellings after World War II have led to well-developed acoustical building codes, particularly in Holland, Germany, England, Russia, and Sweden.

Studies reported recently in Holland and England conclude that the sound of radio or TV in a neighbor's apartment is one of the most annoying noises. Another is impact noise, transmitted downward through the ceiling to the apartment below, created primarily by the ordinary moving about of people. Other nuisances, such as talking, piano playing, and household appliances operating, are usually of no greater annoyance than radio, TV, and impact noise.

One might hope that a catalog of walls and floors, with noise ratings appended for each, would be sufficient for the architect or builder to choose from when planning quiet. But the problem is not so simple. Noise can travel from one room to another by devious means: through cracks, ventilation ducts, electrical boxes, pipes, conduit, medicine cabinets, and along continuous walls. Thus sound isolation in building codes must be specified in terms of the difference between the noise level in the room in which the noise originates and that in the receiving room.

The effectiveness of noise isolation between two adjacent apartments is customarily determined from noise measurements made in six octave-frequency bands and the equation,

$$R = L_1 - L_2 + 10 \log_{10} \frac{S}{A_2}$$

The symbol R is called the noise isolation in one of the frequency bands in decibels; L_1 equals the decibel level in the room where the noise originates; L_2 equals the decibel level in the receiving room; S equals the area (in square feet) of the party wall or party floor between the two rooms; and A_2 equals the total amount of sound absorption in the receiving room (expressed in square feet). A_2 is approximately equal to one-third of the exposed area of carpet, draperies, and upholstered furniture,

According to the various codes, the sound isolation between two dwellings is acceptable if the rating figures R in the prescribed bands are equal to or greater than those shown in the Table below.

TABLE V

MINIMUM NOISE ISOLATION RATINGS

IN VARIOUS BUILDING CODES

Mid-frequencies of the Octave-Frequency Bands Used for Rating Party Walls or Floors Hz	Minimum Permissible Noise Isolation Rating of Party Walls or Floors (see Formula) R (Decibels)		
	Netherlands	England Grade I Code	New York
125	--	38	24
250	43	43	34
500	50	48	40
1000	53	53	43
2000	54	56	45
3000	--	56	45

Slightly lower numbers in one frequency band may be compensated for by slightly higher ones in other bands, in a manner detailed in the Codes. The numbers for Grade II Code in England are 5 decibels lower than for Grade I. British surveys indicate that with Grade II structures, many tenants consider the noise from their neighbors to be the worst single factor about apartment house living. It is apparent that the New York Code allows walls or floors that are 5 decibels less satisfactory than even the British Grade II Code. Even so, many existing apartment houses in New York are 10 more decibels worse than the Code.

The amount of impact-noise insulation provided by a floor-ceiling between two apartments is determined by placing a standardization pounding machine* on the floor above and measuring the decibel noise level in the room below. In the Netherland's Code, the values of the noise levels in the room below, with minor corrections for the total sound absorption A_2 in that room, must not exceed 72, 70, 67, and 58 dB, respectively, in the four octave-frequency bands with mid-frequencies of 250, 500, 1000, and 2000 Hz, while in the English Grade I Code, the numbers, respectively, are 66, 65, 62, and 56 dB. The New York Code allows the transmitted impact noise to be

* Such a machine has five hammers, spread about three inches apart, and placed in a line. The hammers fall to the floor in succession at a rate of ten impacts per second. Each hammer weighs 1.1 pounds and falls a distance of about 1.6 inches.

66, 66, 59, and 51 dB, respectively. In the Grade II English Code, the numbers are 72, 71, 68 and 62 dB, very high levels, indeed.

The time is near when we may expect noise codes throughout America. The Federal Housing Administration, HUD, through its Technical Studies Program is supporting a comprehensive study of the control of noise in multiunit dwellings. This study may in time lead to the issuance of a Federal requirement for acceptable noise control in FHA mortgaged or insured housing. Individual cities will undoubtedly follow New York's lead.

Some builders argue that it is not economically possible to provide the degree of quiet enjoyed in many countries of Europe. To do so would require a greater variety of lowcost, lightweight structures, better suited to the skills of American labor, than are presently available.

The conclusions to be drawn are: That research and development are needed to increase the availability of low-cost products for noise control; that designers and builders should be educated in the proper use of currently available products; that building codes are needed to assure use of suitable structures; and that apartment dwellers must clearly make their needs known to owners and builders through intelligent rejection of inferior housing units.

CONCLUSION

I hope to have acquainted you with some of the health and annoyance factors related to modern-day noise exposures. I have also indicated some ways of architecturally helping industrial plant owners, owners of dwellings near airports and owners of multi-family dwellings everywhere.

My parting message is that we need a U. S. Bureau of Living Standards to work in parallel with the U. S. Bureau of Labor Standards to assure comfort in our home lives as well as safety and efficiency in our working lives.

CAPTIONS TO FIGURES

Figure 1. The physiological organization of the auditory pathways in the brain, and their relation to the effects of noise on man. (After E. Grandjean, Swiss Federal Institute of Technology.)

Figure 2. The percentage of men in an age group who should sustain impaired hearing after exposure continuously to the noise levels given on the abscissa since age 19.

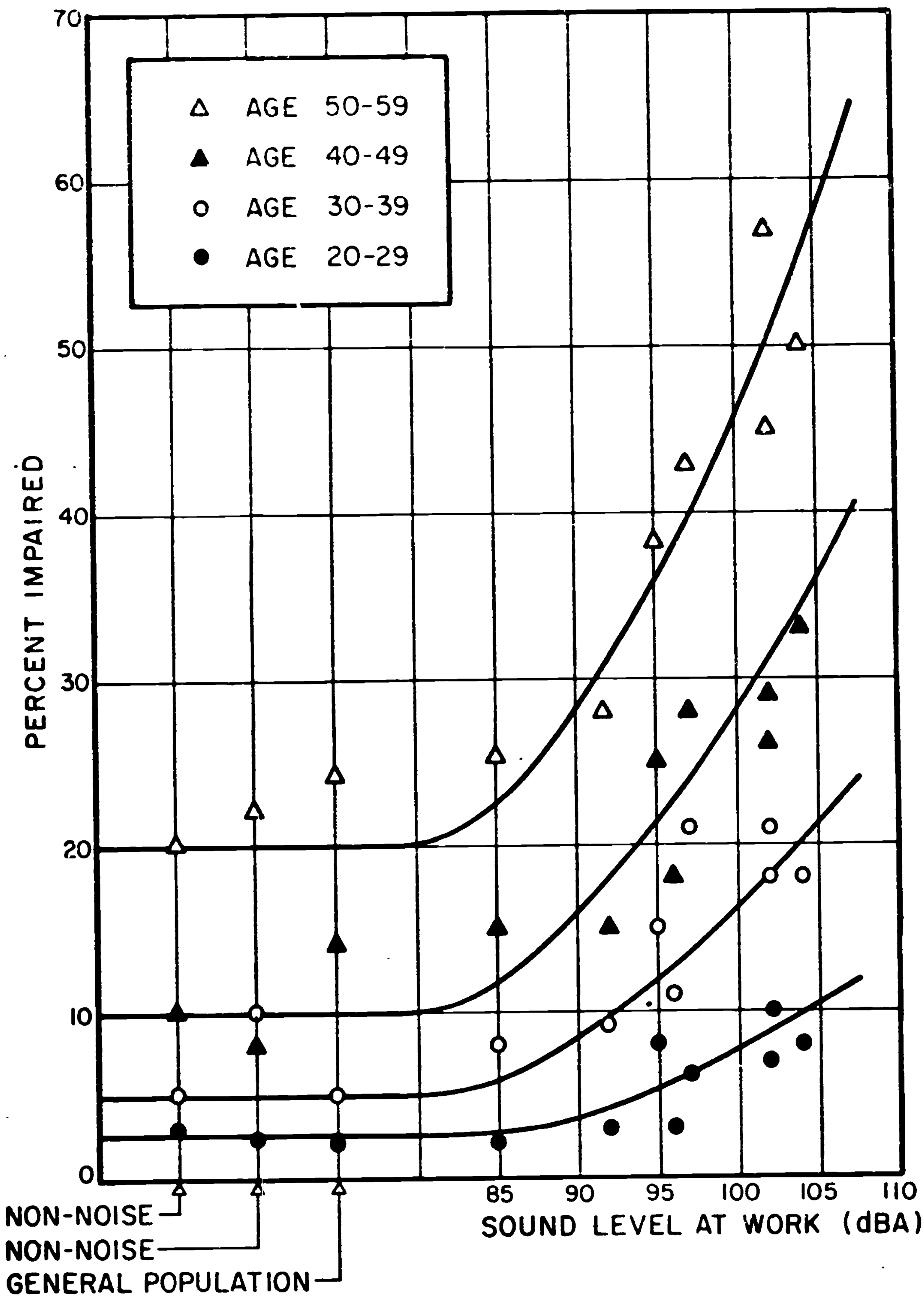
Figure 3. Equivalent sound level contours. Octave band sound pressure levels may be converted to the equivalent A-weighted sound level by plotting them on this graph and noting the A-weighted sound level corresponding to the point of highest penetration into the sound level contours. This equivalent A-weighted sound level, which may differ from the actual A-weighted sound level of the noise, is used to determine exposure limits from Table I. (From the Walsh-Healey Public Contracts Act)

Figure 4. Bar graph showing the percentage of 1377 adults interviewed in depth in a 1961 Central London Survey for each of five categories of noise susceptibility rating. The

susceptibility rating was derived from the answers to six questions on a 40-item questionnaire that evoked statements from the interviewees about their sensitivity to noise.

Figure 5. Bar graphs showing the percentage of the 1377 adults interviewed in Central London who said they were bothered by particular outdoor noises that they heard when they were in their homes as related to their susceptibility rating to noise. The survey concluded traffic noises are most disturbing to residents and that the extent of annoyance both with noise in general, and with particular noises, is very strongly related to the susceptibility rating.

Figure 6. Regions of noise exposure around an airport with takeoff and approach flight paths. Zone A: Aircraft noise may not constitute a problem for many types of buildings. Zone B: Occupants of buildings in this zone may find aircraft noise a problem. Zone C: Occupants of buildings in this zone will find aircraft noise a severe problem.



AGE 50-59
AGE 40-49
AGE 30-39
AGE 20-29
PERCENT IMPAIRED
0
10
20
30
40
50
60
70
85
90
95
100
105
110
SOUND LEVEL AT WORK (dBA)
NON-NOISE
NON-NOISE
GENERAL POPULATION

FIG.2

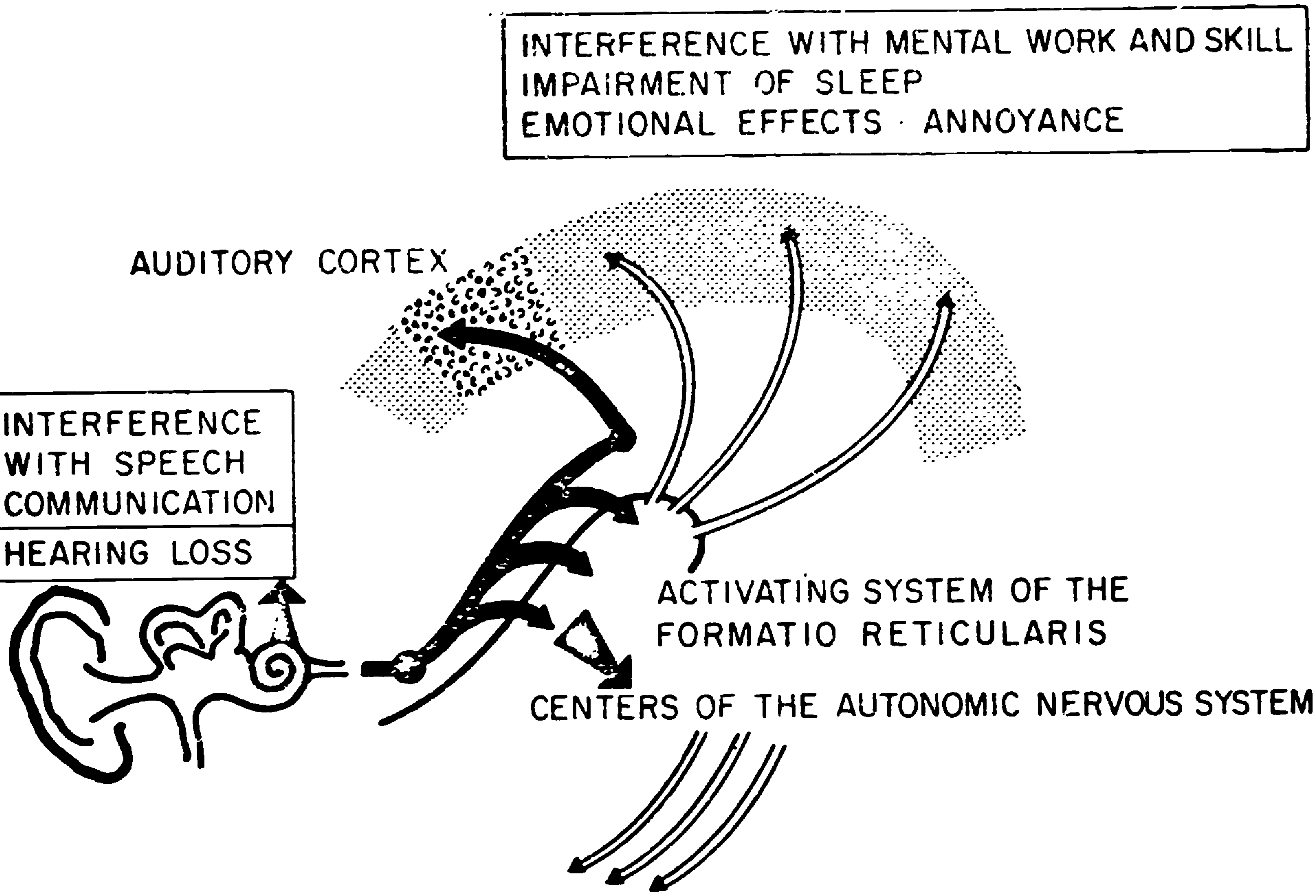

INTERFERENCE WITH MENTAL WORK AND SKILL
IMPAIRMENT OF SLEEP
EMOTIONAL EFFECTS · ANNOYANCE
AUDITORY CORTEX
INTERFERENCE WITH SPEECH COMMUNICATION
HEARING LOSS
ACTIVATING SYSTEM OF THE FORMATIO RETICULARIS
CENTERS OF THE AUTONOMIC NERVOUS SYSTEM

FIG. 1

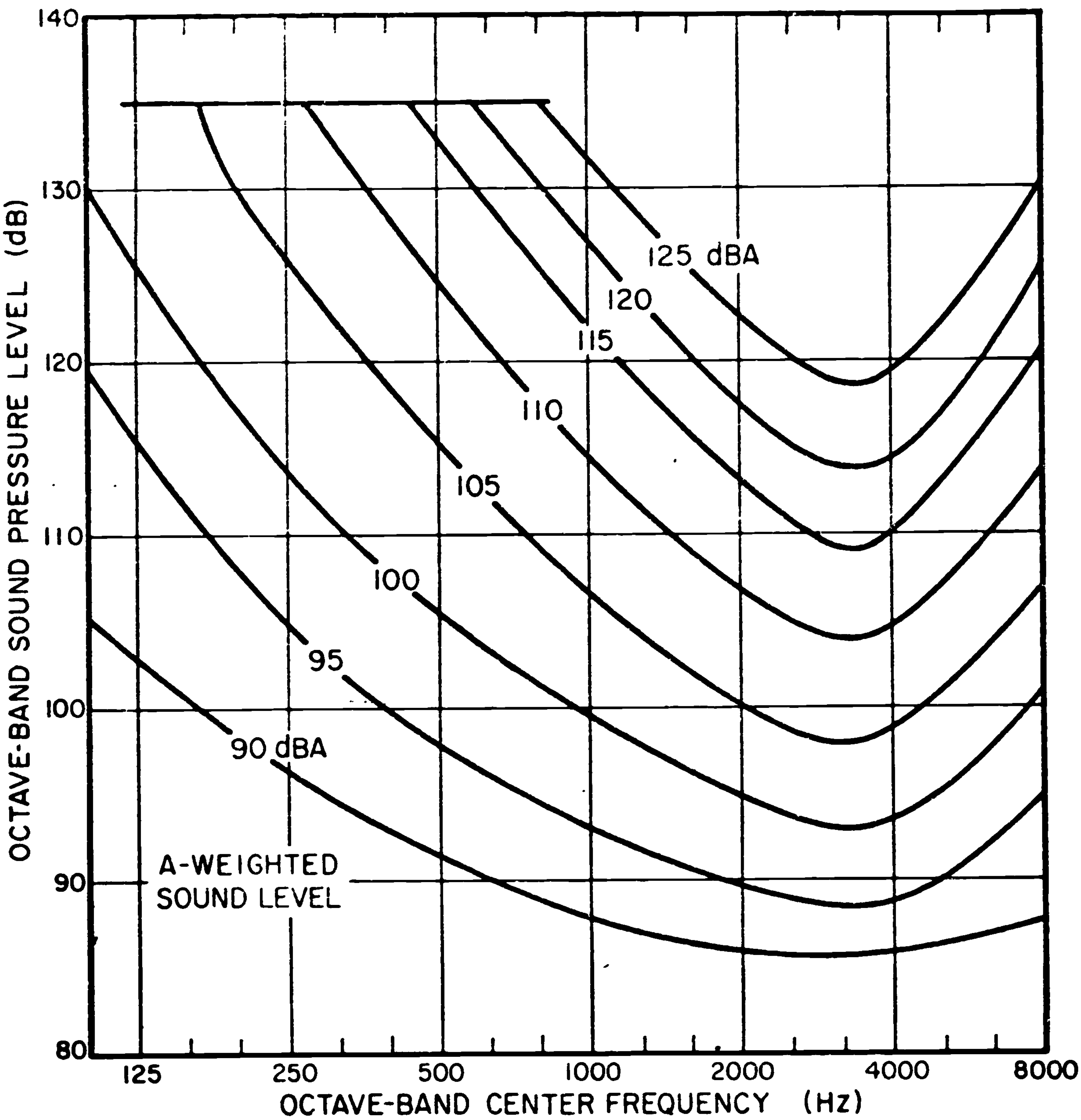

140
130
120
110
100
90
80
125 dBA
120
115
110
105
100
95
90 dBA
A-WEIGHTED
SOUND LEVEL
125
250
500
1000
2000
4000
8000
OCTAVE-BAND CENTER FREQUENCY (Hz)
OCTAVE-BAND SOUND PRESSURE LEVEL (dB)

FIG. 3

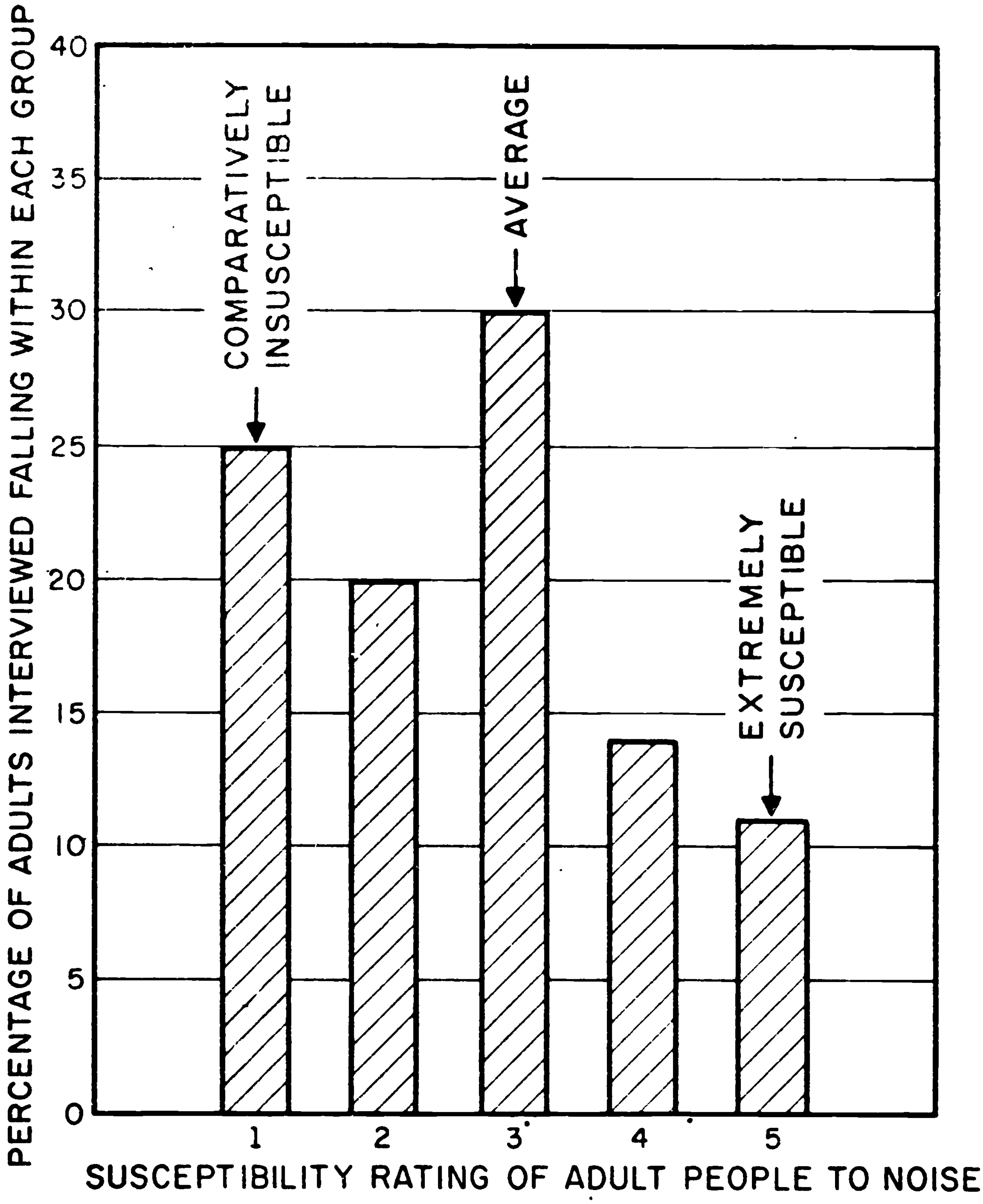

PERCENTAGE OF ADULTS INTERVIEWED FALLING WITHIN EACH GROUP
0
5
10
15
20
25
30
35
40
COMPARATIVELY INSUSCEPTIBLE
AVERAGE
EXTREMELY SUSCEPTIBLE
1
2
3
4
5
SUSCEPTIBILITY RATING OF ADULT PEOPLE TO NOISE

FIG. 4

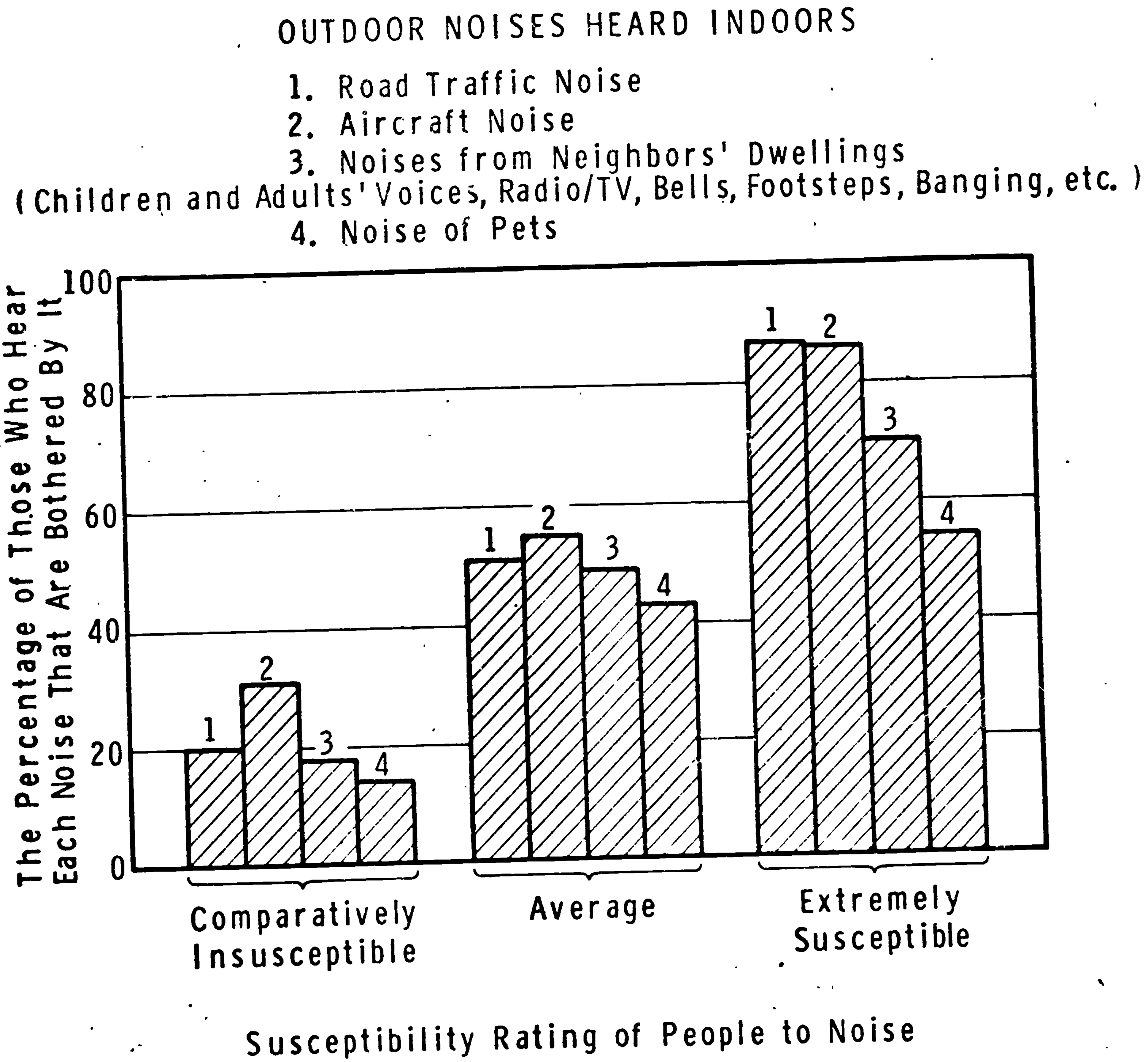

OUTDOOR NOISES HEARD INDOORS
1. Road Traffic Noise
2. Aircraft Noise
3. Noises from Neighbors' Dwellings
(Children and Adults' Voices, Radio/TV, Bells, Footsteps, Banging, etc.)
4. Noise of Pets
The Percentage of Those Who Hear Each Noise That Are Bothered By It
100
80
60
40
20
0
1
2
3
4
Comparatively Insusceptible
Average
Extremely Susceptible
Susceptibility Rating of People to Noise

FIG. 5

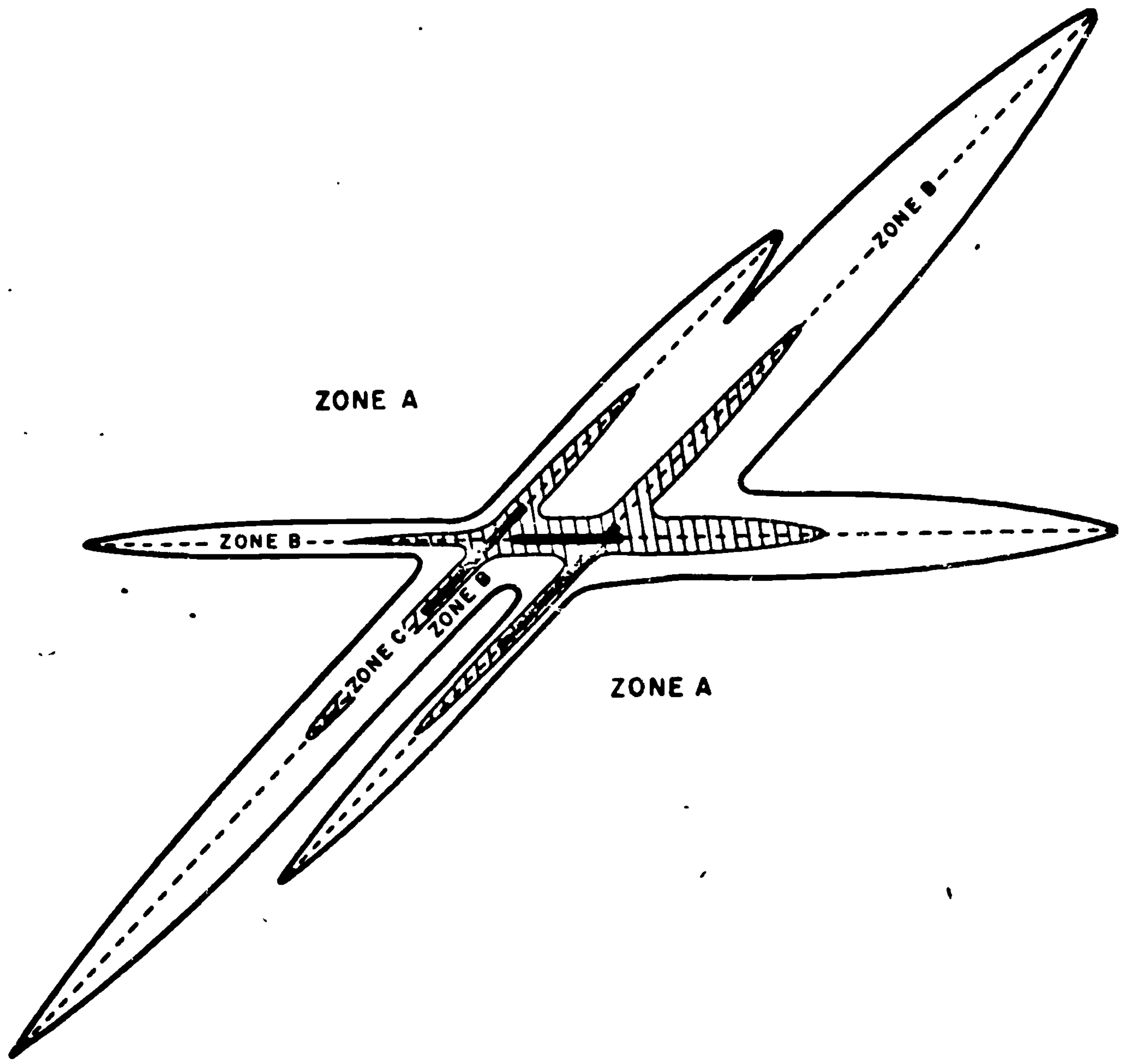


FIG. 6