IMPACT OF NOISE ON PEOPLE

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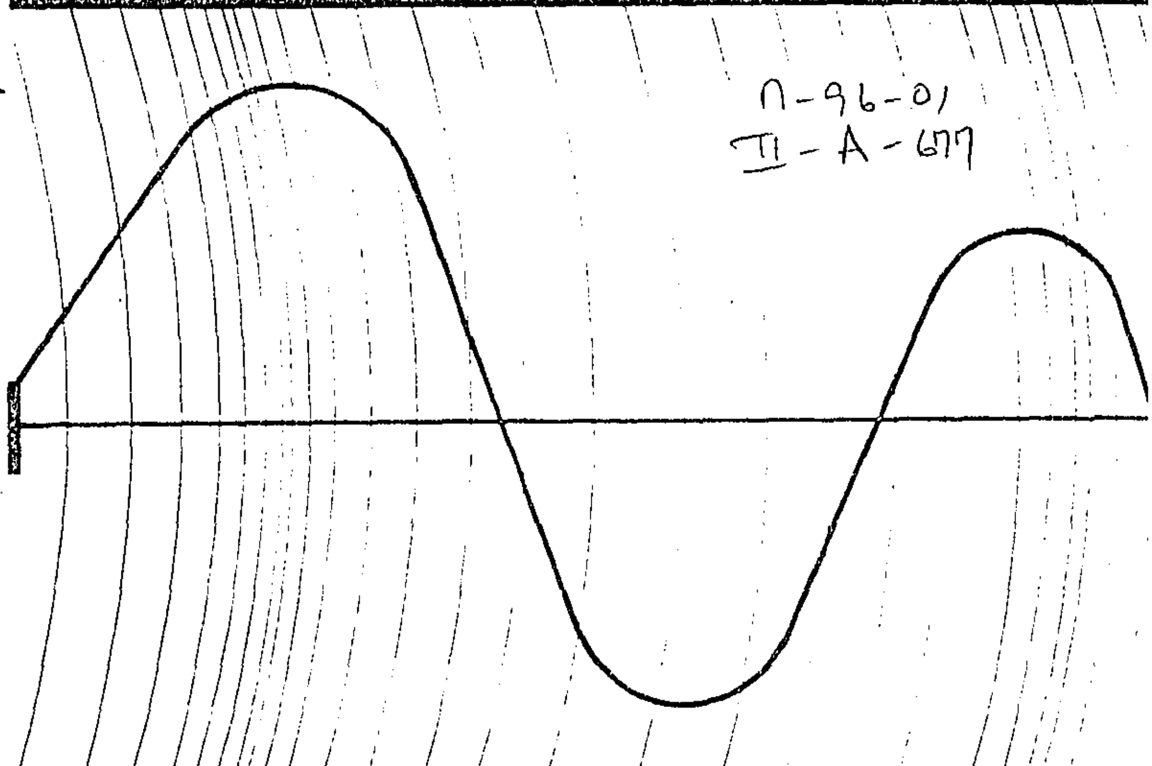

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MAY 1977
U.S. DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Office of Environmental Quality

FOREWORD

Aviation noise significantly impacts approximately six million people in urban areas. In an effort to explain the impact of noise on these citizens, the Federal Aviation Administration (FAA) presents this brochure. Included are aircraft noise indices, information on human response to noise, and criteria for land use controls. Additionally, hearing damage and occupational health standards for noise are described.

FAA presents this information in an effort to enhance public understanding of the impact of noise on people and to answer many questions that typically arise.

We hope you find this information useful.

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Distribution

W-3; FAS-1 (Min); Regional Planning Offices (200 copies each); ZMS-348I; ZEQ-424; ZEQ-427

IMPACT OF NOISE ON PEOPLE

How people perceive loudness or noisiness of any given sound depends on several measurable physical characteristics of the sound. These factors are:

a. Intensity - in general, a ten decibel increase in intensity may be considered a doubling of the perceived loudness or noisiness of a sound; however, recently obtained psychoacoustic evidence suggests that a greater than 10 decibel increase in peak level of airplane flyover noise is required to produce a perceived doubling of loudness.

b. Frequency content - sounds with concentration of energy between 2,000 Hertz and 8,000 Hertz are perceived to be more noisy than sounds of equal sound pressure level outside this range.

c. Changes in sound pressure level - sounds that are increasing in level are judged to be somewhat louder than those decreasing in level.

d. Rate of increase of sound pressure level - impulsive sounds, ones reaching a high peak very abruptly, are usually perceived to be very noisy.

The task of quantifying the environmental impact of noise associated with any noise source requires the application of statistics. This approach is necessary because individual human response to noise is subject to considerable natural variability. Over the past 25 years researchers have identified many of the factors which contribute to the variation in human reaction to noise.

Knowledge of the existence of these individual variables helps to understand why it is not possible to state simply that a given noise level from a given noise source will elicit a particular community reaction or have a particular environmental impact. In order to do this it will be necessary to know how much each variable contributes to human reaction to noise. Research in psychoacoustics has revealed that an individual's attitudes, beliefs and values may greatly influence the degree to which a person considers a given sound annoying. The aggregate emotional response of an individual has been found to depend on:

a. Feelings about the necessity or preventability of the noise. If people feel that their needs and concerns are being ignored, they are more likely to feel hostility towards the noise. This feeling of being alienated or of being ignored and abused is the root of many human annoyance reactions. If people feel that those creating the noise care about their welfare and are doing what they can to mitigate the noise, they are usually more tolerant of the noise and are willing and able to accommodate higher noise levels.

b. Judgment of the importance and of the value of the primary function of the activity which is producing the noise.

c. Activity at the time an individual hears a noise and the disturbance experienced as a result of the noise intrusion. An individual's sleep, rest and relaxation have been found to be more easily disrupted by noise than his communication and entertainment activities.

d. Attitudes about environment. The existence of undesirable features in a person's residential environment will influence the way in which he reacts to a particular intrusion.

e. General sensitivity to noise. People vary in their ability to hear sound, their physiological predisposition to noise and their emotional experience of annoyance to a given noise.

f. Belief concerning the effect of noise on health.

g. Feeling of fear associated with the noise. For instance, the extent to which an individual fears physical harm from the source of the noise will affect his attitude toward the noise.

A number of physical factors have also been identified by researchers as influencing the way in which an individual may react to a noise. These other factors include:

a. Type of neighborhood - instances of annoyance, disturbances and complaint associated with a particular noise exposure will be greatest in rural areas, followed by suburban and urban residential areas, and then commercial and industrial areas in decreasing order. The type of neighborhood may actually be associated with one's expectations regarding noise. People expect rural neighborhoods to be quieter than cities. Consequently, a given noise exposure may produce greater negative reaction in a rural area.

b. Time of day - a number of studies have indicated that noise intrusions are considered more annoying in the early evening and at night than during the day.

c. Season - noise is considered more disturbing in the summer than in the winter. This is understandable since windows are likely to be open in the summer and recreational activities take place out of doors.

d. Predictability of the noise - research has revealed that individuals exposed to unpredictable noise have a lower noise tolerance than those exposed to predictable noise.

e. Control over the noise source - a person who has no control over the noise source will be more annoyed than one who is able to exercise some control.

f. Length of time an individual is exposed to a noise - there is little evidence supporting the argument that annoyance resulting from noise will decrease with continued exposure, rather, under some circumstances, annoyance may increase the longer one is exposed.

Aircraft Noise Indices

There are two basic schemes for quantifying the noise associated with aircraft operations. One method considers the noise generated by all aircraft over a cumulative twenty-four hour period, while the other quantifies the sound levels of single aircraft flyover measured at various points on the ground. The latter scheme may employ either the effective perceived noise level (EPNL) or the "A" weighted sound level (dBA). While the EPNL and dBA both involve acoustical frequency weightings, only the EPNL employs a correction factor which considers the duration of the noise event.

A number of cumulative noise exposure techniques have been developed in the United States, including the Noise Exposure Forecast (NEF), Composite Noise Rating (CNR), Day/Night Sound Level (Ldn), and Aircraft Sound Description System (ASDS).*

A primary noise metric is NEF, based on the EPNL expressed in units of EPNdB. The NEF analysis involves construction of contours which link together points of equal cumulative noise exposure. The contours are generated by a computer technique based on the following input data: airport flight patterns, number of daily aircraft operations

*There are equivalencies among the various cumulative noise indices. Any given NEF is equivalent to Ldn minus 35, plus or minus 3. For example, NEF 30 is approximately equal to Ldn 65. Between NEF and CNR there is a non-linear relationship. The general equivalencies are shown below (Ref. 1).

NEF	20	=	CNR	85	=	Ldn 55
NEF	30	=	CNR	100	=	Ldn 65
NEF	40	=	CNR	115	=	Ldn 75

by type of aircraft, weight and time of day, noise characteristics of each aircraft in terms of EPNL during takeoff and landing and typical runway utilization patterns in terms of percentage of use.

It is important to keep in mind the assumptions and limitations when comparing sound levels of different aircraft at any given point. The difference in sound levels between two aircraft under comparison will not usually be the same at different locations on the ground. This reflects the differences in their rates of climb, climb gradients, flight paths, thrust settings, and acoustical spectra.

In order to convey the intensity and relative impact of single event noise in A-weighted levels, Table I describes typical dBA values of noise commonly experienced by people.

Quantifying Human Response to Noise

The inherent variability in the way individuals react to noise makes it impossible to predict accurately how any one individual will respond to a given noise. However, considering the community as a whole, trends emerge which relate noise to annoyance. In this way it is possible to correlate a noise index (cumulative or single event) with community annoyance. This index will represent the average annoyance response for the community.

TABLE I

Comparative Noise Levels

Typical decibel (dBA) values encountered in daily life and industry

	dBA
Rustling leaves	20
Room in a quiet dwelling at midnight	32
Soft whispers at 5 feet	34
Men's clothing department of large store	53
Window air conditioner	55
Conversational speech	60
Household department of large store	62
Busy restaurant	65
Typing pool (9 typewriters in use)	65
Vacuum cleaner in private residence (at 10 feet)	69
Ringing alarm clock (at 2 feet)	80
Loudly reproduced orchestral music in large room	82

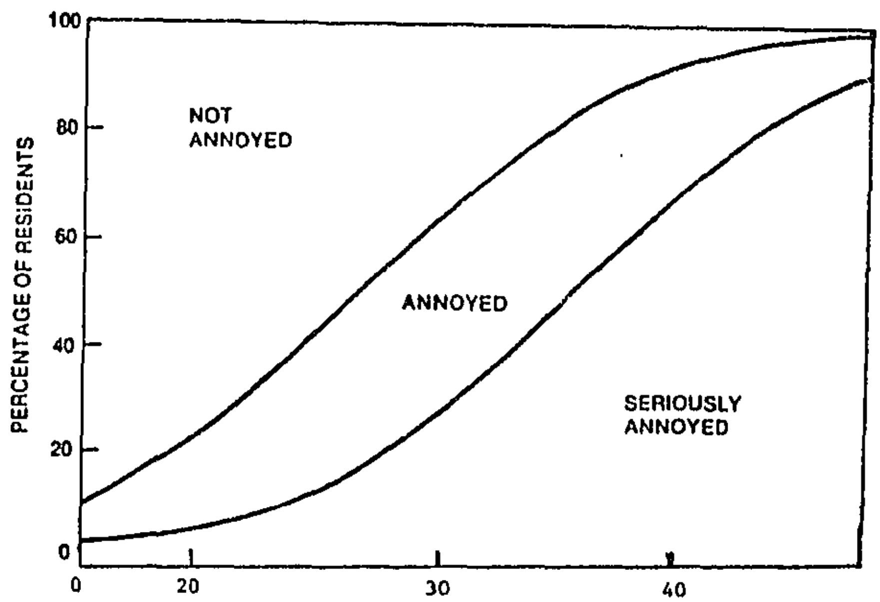
Over 85 dBA, beginning of hearing damage if prolonged

Printing press plant (medium size automatic)	86
Heavy city traffic	92
Heavy diesel-propelled vehicle (about 25 feet away)	92
Air grinder	95
Cut-off saw	97
Home lawn mover	98
Turbine condenser	98
150 cubic foot air compressor	100
Banging of steel plate	104
Air hammer	107
Jet airliner (500 feet overhead)	115

In utilizing data relating any given measure of noise level or exposure to average community annoyance it is important to note that there will exist a given percentage of the population highly annoyed, a given percentage mildly annoyed and others who will not be annoyed at all. The changing percentage of population within a given response category is the best indicator of noise annoyance impact. The population tables contained in the text show the number of people exposed to various levels of cumulative noise exposure. These levels are in turn related to percent of population falling within various response categories.

The ensuing discussion focuses on the results of representative research concerned with the relationship between annoyance and noise exposure. A brief examination of these results follows along with a table summarizing the findings. The references cited are at the end of this appendix.

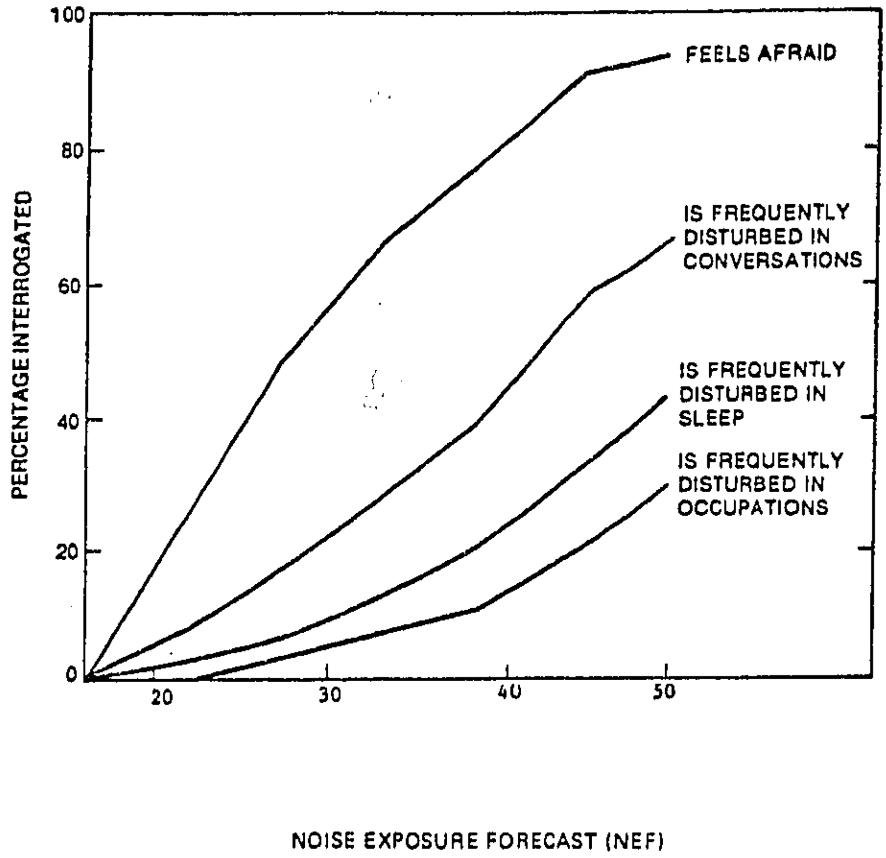
Ollerhead (Ref. 1) in analyzing the results of numerous social surveys conducted at major airports in several countries has derived the curves shown in Figure 1 relating degree of annoyance and percent of population affected with noise exposure expressed in NEF. A survey conducted in the Netherlands (Ref. 4) investigated the relationship between the CNR (an approximate conversion of NEF is shown) and the percentage of those questioned who suffered feelings of fear, disruption of conversation, sleep or work activities (Figure 2).



NOISE EXPOSURE FORECAST (NEF)

ANNOYANCE CAUSED BY AIRCRAFT NOISE IN RESIDENTIAL COMMUNITIES NEAR MAJOR AIRPORTS

Figure 1



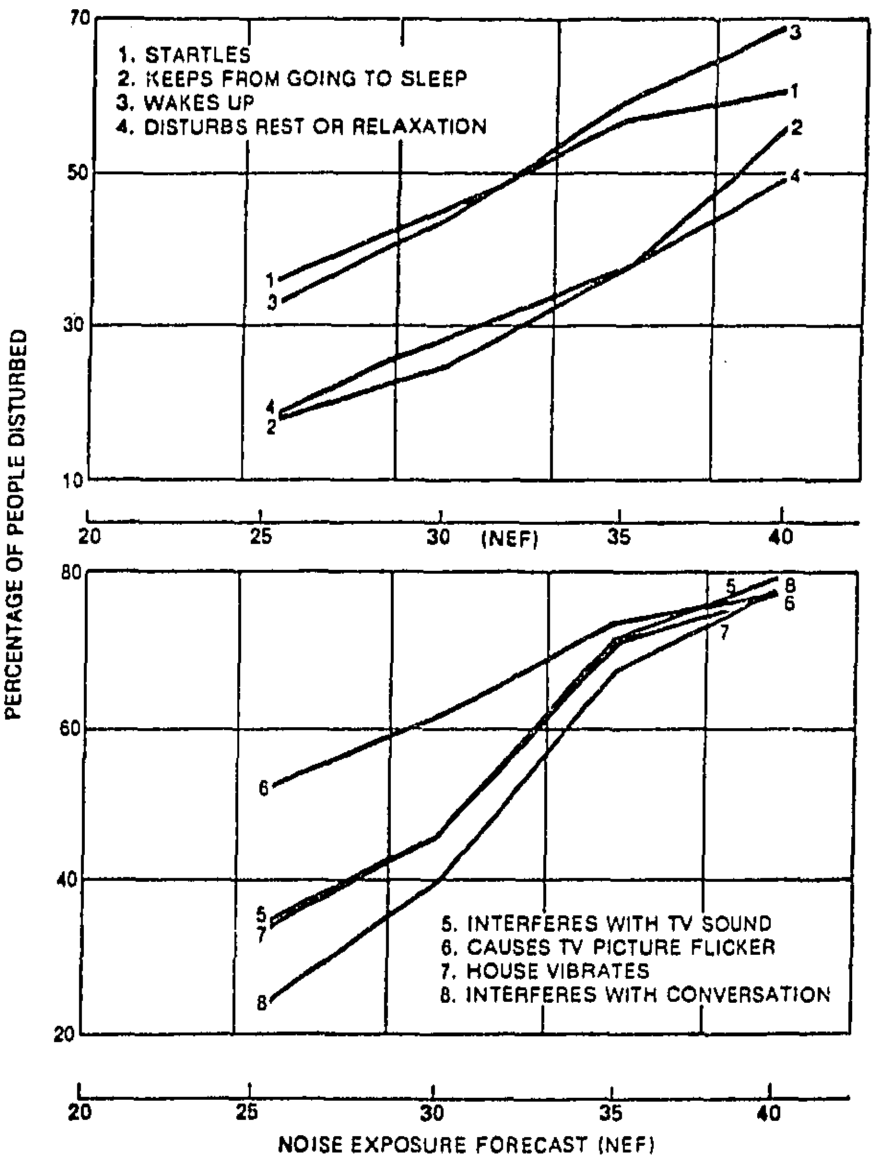
COMMUNITY RESPONSE TO AIRCRAFT NOISE-NETHERLANDS SURVEY

Figure 2

In 1960 the "Wilson Committee" was appointed by the British Government to investigate the nature, sources and effects of the problem of noise. The final report published in 1963 (Ref. 5) included results of extensive examination of community response to aircraft operations at London Heathrow Airport. Figure 3 adapted from that report shows the relationship between noise and NEF (the approximate conversion of NEF to CNR or Ldn was given earlier), and percent of population distrubed in various activities including sleep, relaxation, conversation and viewing television. Disturbance categories for startle and house vibration are also included.

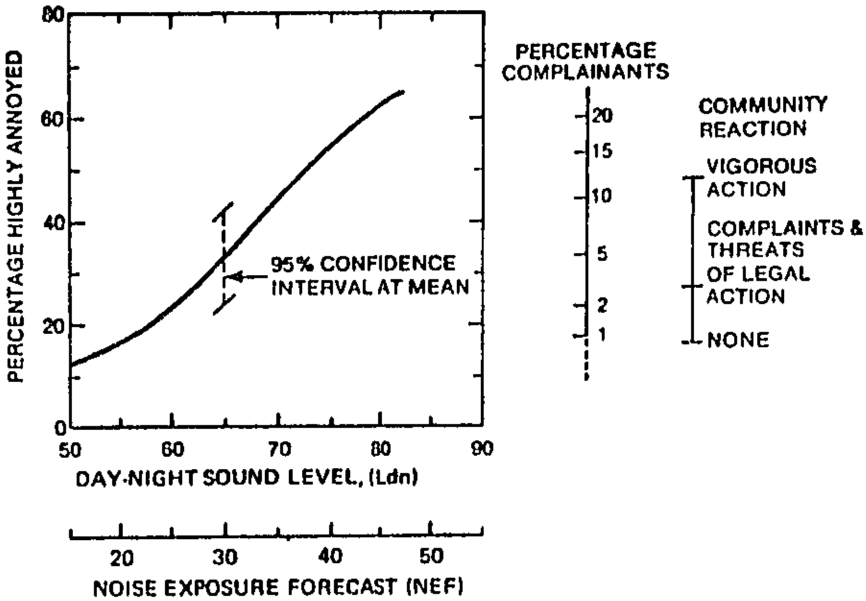
The Environmental Protection Agency publication "Information on Levels of Environmental Noise Requisite to Protect Health and Welfare with an Adequate Margin of Safety" (Levels Document, Ref. 6), provides a relationship between the percent of population highly annoyed and the Day-Night Sound Level (Ldn). These data are shown in Figure 4 along with the relationship between annoyance, complaints and community reaction.

The EPA "Levels Document" describes the relationship between speech interference and Day-Night Sound Levels as shown in Figure 5. In going from NEF 30 to NEF 40 there is an increase in speech interference of nearly 90% outdoors. Indoor interference does not begin to appear until the NEF 35 level is reached.



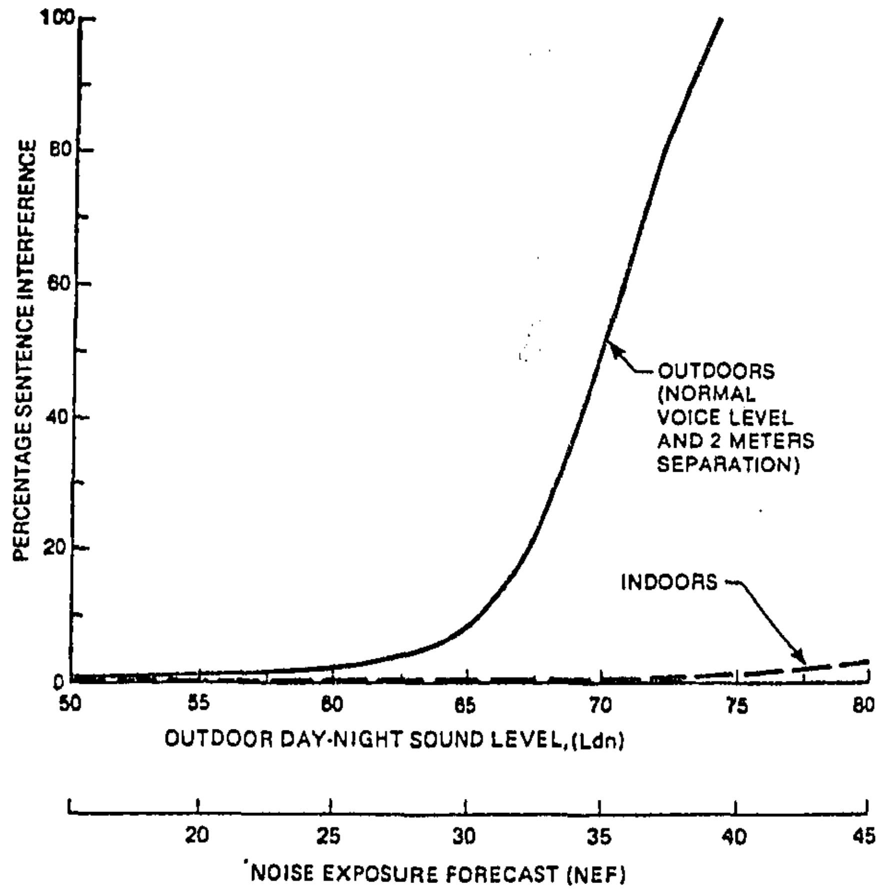
COMMUNITY RESPONSE TO AIRCRAFT OPERATIONS · LONDON HEATHROW AIRPORT

Figure 3



COMPARISON OF VARIOUS MEASURES OF INDIVIDUAL ANNOYANCE AND COMMUNITY REACTION AS A FUNCTION OF THE DAY-NIGHT SOUND LEVEL (Ldn) AND NOISE EXPOSURE FORECAST (NEF)

Figure 4

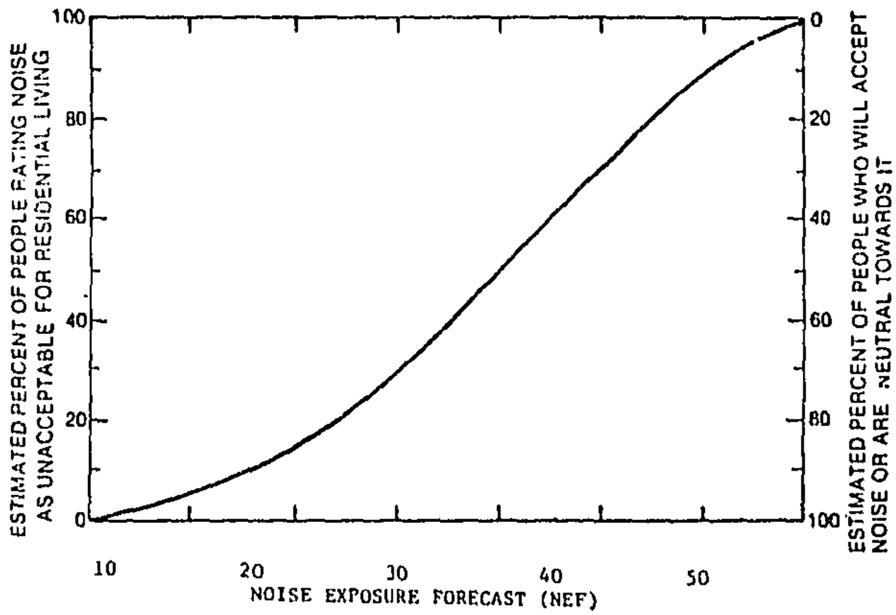


MAXIMUM PERCENTAGE INTERFERENCE WITH SENTENCES AS A FUNCTION OF THE DAY-NIGHT NOISE LEVEL. (PERCENTAGE INTERFERENCE EQUALS 100 MINUS PERCENTAGE INTELLIGIBILITY, AND L_{dn} IS BASED ON Lday + 3)

Figure 5

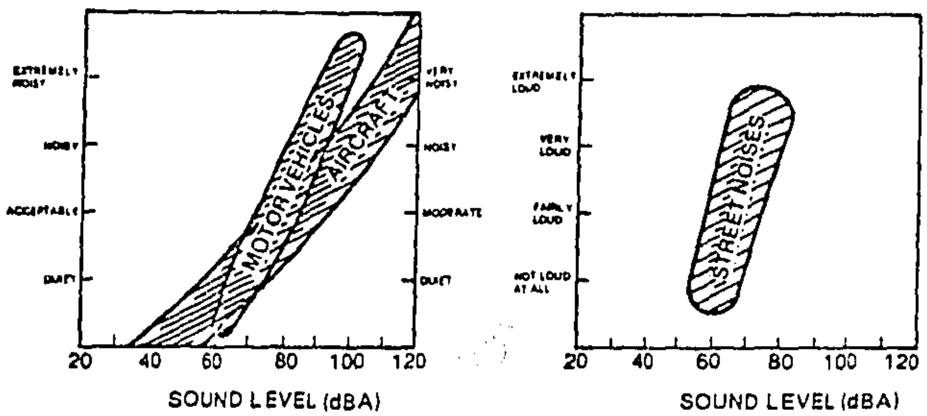
An investigation of attitudes to be expected from non-fear provoking noise in residential areas led Kryter to develop the curve shown in Figure 6. Although he expressed his findings in terms of CNR, the figure is expressed in NEF based on the approximate conversion of CNR to NEF as shown earlier. The figure also shows percent of population rating the noise associated with a given NEF level as acceptable or unacceptable.

The sound level (dBA, EPNdB, PNdB) associated with a single aircraft operation can be put in perspective by referring to the list of comparative sound levels for events encountered in daily life (Table I). In addition, studies have been conducted in which individuals have been exposed to aircraft fly-over noise and asked to make judgments with respect to the noisiness, loudness, annoyance or intrusiveness of the sound. Figure 7 taken from the "Wilson Report" shows comparative judgements between motor vehicles, aircraft and street noise. The variability in opinion associated with any sound level is represented by the vertical extent of the shaded area. Aircraft noise is apparently considered acceptable by some segment of the population at higher levels than those of other noise sources. Other data from the "Wilson Report" shown in Figures 8 and 9 relate dBA sound levels to ratings of intrusiveness and noisiness. A summary of that data is provided in Table II.



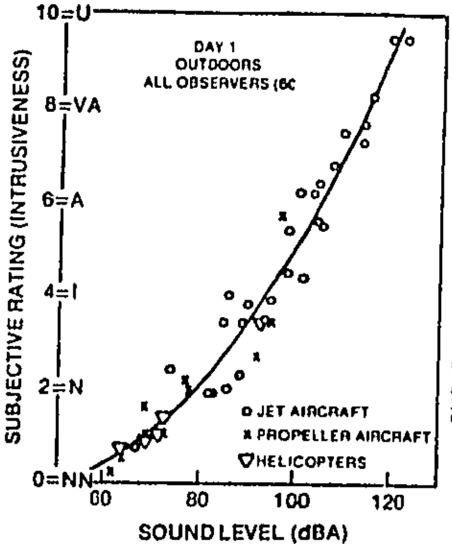
ATTITUDES TOWARD AIRCRAFT NOISE IN THE RESIDENTIAL COMMUNITY

Figure 6



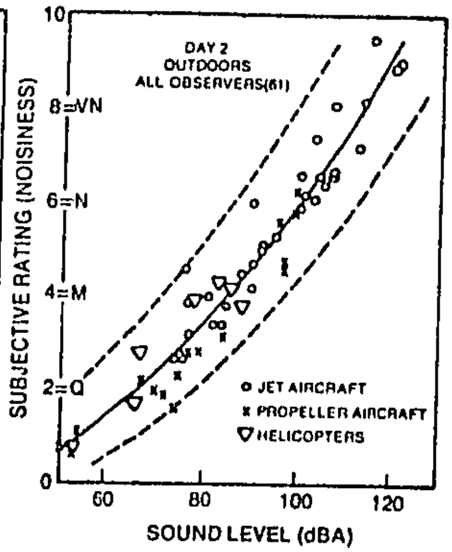
COMPARATIVE JUDGMENTS OF DIFFERENT NOISES

Figure 7



OUTDOOR JUDGMENTS ON THE CATEGORY SCALE OF INTRUSIVENESS PLOTTED AGAINST SOUND LEVEL A

Figure 8



OUTDOOR JUDGMENTS ON THE CATEGORY SCALE OF NOISINESS PLOTTED AGAINST SOUND LEVEL A

Figure 9

TABLE 1

SOUND LEVELS (dBA) AND LOUDNESS OF ILLUSTRATIVE NOISES
IN INDOOR AND OUTDOOR ENVIRONMENTS

dB(A)	OVER-ALL LEVEL	COMMUNITY (Outdoor)	HOME OR INDUSTRY (Indoor)	LOUDNESS (Human Judgment of Different Sound Levels)
130–120	UNCOMFORTABLY	Military Jet Aircraft Take-Off With After-Burner From Aircraft Carrier @ 50 Ft (130)	Oxygen Torch (121)	120 dB(A) 32 Times As Loud
120–110	LOUD	Turbo-Fan Aircraft @ Take-Off Power @ 200 Ft (118)	Riveting Machine (110); Rock-N-Roll Band (108-114)	110 dB(A) 16 Times As Loud
110–100	VERY	Jet Flyover @ [illegible] Ft (103); Boeing 707 [illegible]; [illegible]; Bell J-2A Helicopter @ 100 Ft (100)		100 dB(A) 8 Times As Loud
100–90	LOUD	Power Mower (96); Boeing 737, DC-9 @ 6080 Ft [illegible]; [illegible]; Motorcycle @ 25 Ft (90)	Newspaper Press (97)	90 dB(A) 4 Times As Loud
90–80		Car Wash @ 20 Ft [illegible]; Prop. Plane Flyover @ 1000 Ft (88); Diesel Truck, 40 MPH @ 50 Ft (84); Diesel Train, 45 MPH @ 100 Ft (83)	Food Blender (88); Milling Machine (85); Garbage Disposal (80)	80 dB(A) 2 Times As Loud
80–70	MODERATELY LOUD	High Urban Ambient Sound (80); Passenger Car, 65 MPH @ 25 Ft (77); Freeway @ 50 Ft from Pavement Edge, 10 A.M. [illegible]	Living Room Music (76); TV-Audio, Vacuum Cleaner (70)	70 dB(A)
70–60		Air Conditioning Unit @ 100 Ft [illegible]	Cash Register @ 10 Ft (65-70); Electric Typewriter @ 10 Ft (64); Dishwasher (Rinse) @ 10 Ft (60); Conversation (60)	60 dB(A) ½ As Loud
60–50	QUIET	Large Transformers @ 100 Ft (50)		50 dB(A) ¼ As Loud
50–40		Bird Calls (44); [illegible]; [illegible]		40 dB(A) [illegible] As Loud
40–10	JUST AUDIBLE	(dB(A) Scale Interrupted)		
10–0	THRESHOLD OF HEARING			

Source: Melville C. Branch, et al., Outdoor Noise and the Metropolitan Environment, (Los Angeles: Department of City Planning, 1970), p. 2.

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dBA	EPNdB	PNdB*	FIG. 31	FIG. 32	FIG. 33
120	133	131	EXTREMELY NOISY - VERY NOISY	UNBEARABLE	–
110	123	121	NOISY - VERY NOISY	VERY ANNOYING - ANNOYING	NOISY - VERY NOISY
100	113	111	NOISY	ANNOYING - INTRUSIVE	MODERATE - NOISY
90	103	101	MODERATE/ACCEPTABLE - NOISY	INTRUSIVE - NOTICEABLE	MODERATE
80	93	91	QUIET - MODERATE/ACCEPTABLE	NOTICEABLE	QUIET - MODERATE
70	83	81	QUIET	NOTICEABLE - NOT NOTICEABLE	QUIET
60	73	71		NOT NOTICEABLE	

* ASSUMING PNdB IS APPROXIMATELY
EPNdB MINUS 2

RELATIONSHIP BETWEEN SINGLE EVENT
AIRCRAFT NOISE LEVEL AND SUBJECTIVE RESPONSE

TABLE II

Existing Noise Criteria

Table III summarizes the relationship between various indicators of community annoyance and several cumulative noise indices. It also illustrates the point made earlier that a valid indicator of noise impact is the changing percentage of population associated with a given response category.

The Department of Transportation (DOT) has established Noise Standards and Procedures for use by State highway agencies and the Federal Highway Administration (FHWA) in the planning and design of highways (Ref. 7). Table IV shows the L_{10} values (the DBA levels exceeded 10% of the time for a 24 hour period) considered by FHWA as compatible with various land use categories.

The Department of Housing and Urban Development has published Noise Abatement and Control Standards (Circular 1390.2, August 4, 1971 - Ref.8) to encourage land utilization patterns for housing and other municipal needs. These standards are intended to separate uncontrollable noise sources from residential and other noise sensitive areas, and prohibit HUD

NEF	L_{dn}	ASDS*	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	EPA LEVELS DOCUMENT	ELIGIBILITY FOR HUD SUPPORT
			ANNOYANCE RESPONSE CATEGORIES																				
20	65	APPROX. 1 MINUTE	5%	20%	75%	17%	5%	1%	0%	25%	10%	20%	5%	22%	41%	20%	8%	17%	100%	10%	90%		≤ NEF 30 ACCEPTABLE
30	68	2 MINUTES	27%	38%	35%	55%	21%	8%	4%	45%	25%	44%	28%	45%	61%	45%	39%	33%	90%	30%	70%	OUTDOOR ACTIVITY INTERFERENCE AND ANNOYANCE	NEF 30 - NEF 40 DISCRETIONARY
40	78	APPROX. 40 MINUTES	69%	25%	6%	80%	43%	22%	16%	60%	56%	69%	50%	79%	78%	78%	79%	54%	0%	60%	40%	POTENTIAL HEARING LOSS	≥ NEF 40 UNACCEPTABLE

PERCENT OF POPULATION

A-SERIOUSLY ANNOYED
B ANNOYED
C NOT ANNOYED
(FIG. 25/REF 21)

D EXPRESSING FEAR
E EXPERIENCING SPEECH INTERFERENCE
F EXPERIENCING SLEEP INTERRUPTION
G--DISTURBED AT WORK
(FIG 26/REF 24)

PERCENT OF POPULATION

H STARTLED
I KEPT FROM GOING TO SLEEP
J AWAKENED
K DISTURBED WHILE RESTING OR RELAXING
L INDICATING INTERFERENCE WITH TV SOUND
M INDICATING PICTURE TUBE FLICKER
N INDICATING HOUSE VIBRATION
O EXPERIENCING INTERFERENCE WITH CONVERSATION
(FIG 27/REF 25)

P PERCENTAGE HIGHLY ANNOYED
Q % SPEECH INTELLIGIBILITY
(FIG 28/REF 26)

R-PERCENT RATING NOISE AS UNACCEPTABLE
S PERCENT RATING NOISE AS ACCEPTABLE
(FIG 32/REF. 24)

*USING EQUIVALENCIES
NEF 20 = CNR 85
NEF 30 = CNR 100
NEF 40 = CNR 115

RELATIONSHIP BETWEEN CUMULATIVE NOISE LEVEL AND INDICATORS OF COMMUNITY ANNOYANCE

TABLE III

TABLE IV

FHWA

DESIGN NOISE LEVEL/LAND USE RELATIONSHIPS

Design Noise Level - L_{10}	Description of Land Use Category
60 dBA (Exterior)	Tracts of lands in which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose. Such areas could include amphitheaters, particular parks or portions of parks, or open spaces which are dedicated or recognized by appropriate local officials for activities requiring special qualities of serenity and quiet.
70 dBA (Exterior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, picnic areas, recreation areas, playgrounds, active sports areas, and parks.
75 dBA (Exterior)	Developed lands, properties or activities not included in categories A and B above.
55 dBA (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums.

support for new construction on sites having unacceptable noise exposure. Set out below are the HUD criteria for funding new residential construction.

RATING	DISPOSITION IN HUD
less than 30 NEF	Acceptable
30 to 40 NEF	Discretionary
more than 40 NEF	Unacceptable

The Environmental Protection Agency has also identified noise levels considered requisite to protect health and welfare with an adequate margin of safety. Table V summarizes the EPA findings in terms of Ldn. (As mentioned above, the difference between Ldn and NEF is approximately 35 - e.g., Ldn 65 equals NEF 30).

TABLE V

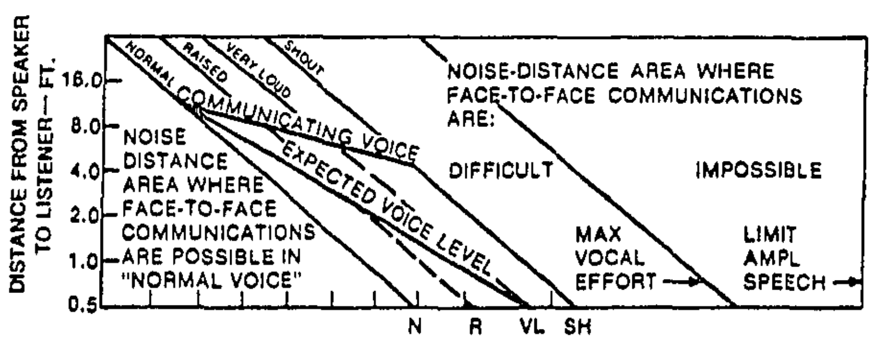
SUMMARY OF NOISE LEVELS IDENTIFIED AS REQUISITE TO PROTECT PUBLIC HEALTH AND WELFARE WITH AN ADEQUATE MARGIN OF SAFETY
(Ref. 6)

Effect	Level	Area
Hearing Loss	Ldn $\leq$ 74 dB	All areas
Outdoor activity interference and annoyance	Ldn $\leq$ 55 dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	Ldn $\leq$ 59 dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	Ldn $\leq$ 45 dB	Indoor residential areas
	Ldn $\leq$ 49 dB	Other indoor areas with human activities such as schools, etc.

NOTE: All Leq values from Reference 6 converted to Ldn for ease of comparison (Ldn equals Leq (24) + 4 dB)

A major complaint raised in conjunction with aircraft noise is interference with talking and listening. This effect has been substantiated in numerous studies of noise complaint data. Figure 10 shows the relationship between speaker-listener separation and ambient sound level necessary for speech communication at various noise levels (Ref. 4). The horizontal axis is calculated in a variety of units, rank-ordered from best to worst in terms of predicting speech interference. The PSIL is the average sound pressure level in the octaves centered at 500, 1000 and 2000 Hertz while the SIL takes the average over three octaves from 600 to 4800 Hertz. In Figure 11, the EPA provides a similar format for gauging speech interference. It is important to note that the dBA and SIL (as well as other indices) are not accurate measures of the masking of speech by noise containing intense low frequency components. It has been shown that if a low frequency noise is sufficiently intense it can mask speech completely. For example, a sound pressure level of 115 dB at 50 Hertz will provide a 10 to 30 dB masking effect through 3000 Hertz.

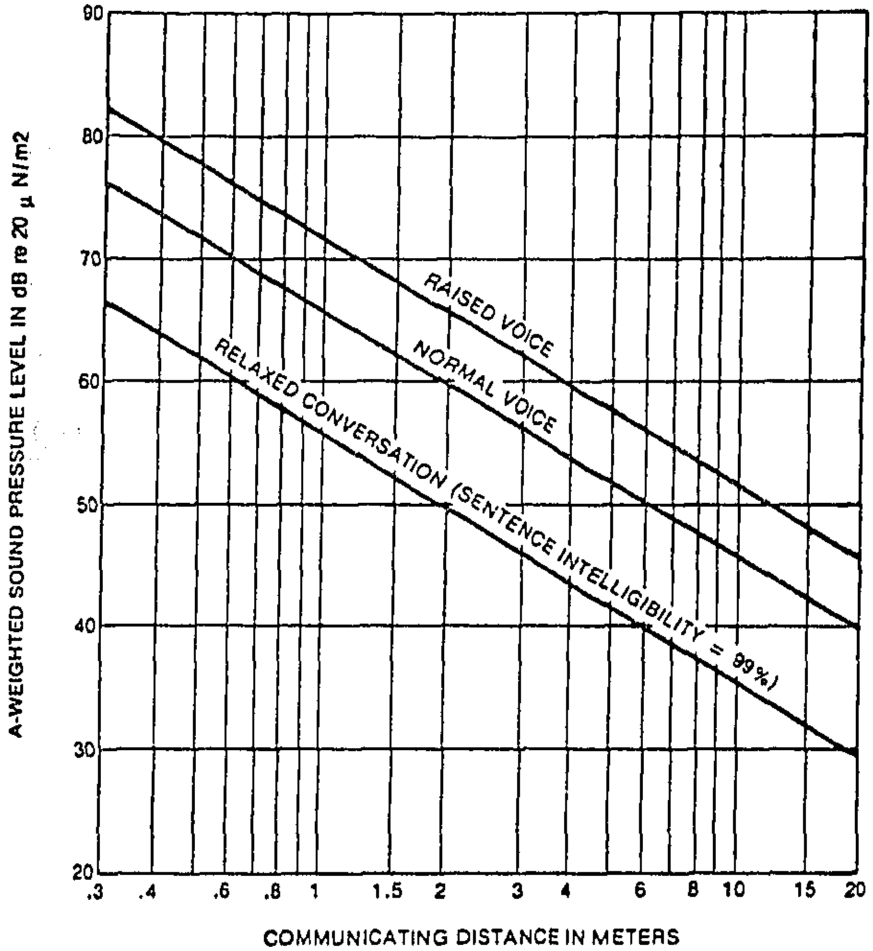
Applying these speech interference criteria (Figures 10 and 11) to aircraft noise, outdoor communication at a distance of



PSIL	40	50	60	70	80	90	100	110	125
SIL	37	47	57	67	77	87	97	107	122
dB(A)	47	57	67	77	87	97	107	117	132
PNdB	60	70	80	90	100	110	120	130	145
dB(C)	54	64	74	84	94	104	114	124	139

RELATIONSHIP BETWEEN SPEAKER-LISTENER SEPARATION, AMBIENT SOUND LEVEL AND ABILITY TO COMMUNICATE

Figure 10



MAXIMUM DISTANCES OVER WHICH CONVERSATION IS CONSIDERED TO BE SATISFACTORILY INTELLIGIBLE (SENTENCE INTELLIGIBILITY = 95% EXCEPT AS NOTED)

Figure 11

two (2) feet would require shouting for those persons within the 100 EPNdB single event footprints. This impact would last for the duration of the noise at this level, up to 30 seconds.

The Occupational Safety and Health Administration of the Department of Labor has established noise standards to protect the health and safety of industrial workers (29 CFR 1910.95). Shown below are the permissible noise exposure times for sound levels of 90 dBA and greater.

DURATION PER DAY, HOURS	SOUND LEVEL dBA SLOW RESPONSE
8	90
6	92
4	95
3	97
2	100
1 -1/2	102
1	105
1/2	110
1/4 or less	115

EPA has recommended that 85 dBA be established as the level not to be exceded when an individual is exposed to noise for an eight-hour work day.

Residential structures generally provide 15 to 20 dBA attenuation. Consequently the indoor noise level shown by the 100 EPNdB (85 dBA) contours would be in the range of 65 to 70 dBA. At this level of noise there would be no interference with normal communication at a distance of three (3) feet. At eight (8) feet communication would require a raised voice.

Hearing Damage

Studies of the temporary auditory threshold shift or temporary hearing loss caused by noise exposure have demonstrated several important facts related to temporary threshold shifts (Ref. 12). Some of those facts are:

1. The temporary elevation of auditory threshold which results from one day of exposure (8 hours) to noise levels of 100 dBA or more may vary from no shift to a temporary 40 dB shift depending on individual susceptibility.

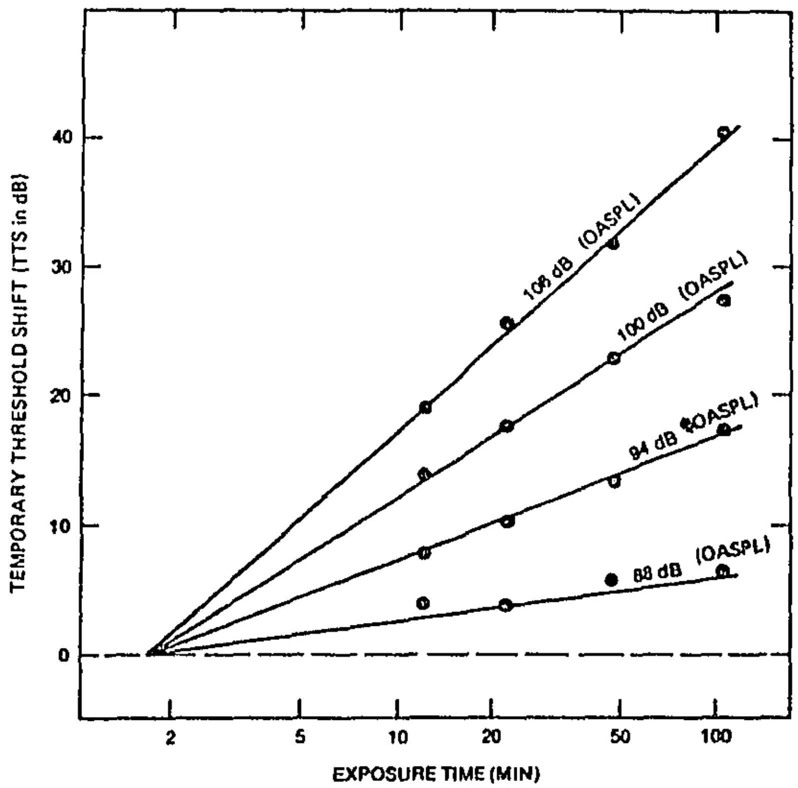
2. Exposure to typical industrial noise produces the largest temporary hearing loss at 4000 to 6000 Hertz.

3. Recovery from temporary or transient hearing loss generally occurs within the first hour or two after the noise exposure has ended.

4. Efforts have been made to predict susceptibility to noise-induced permanent hearing loss on the basis of the amount of temporary threshold shift. A study of the various tests for detecting highly susceptible ears has indicated that there is no test which will predict susceptibility to noise-induced hearing loss.

Figure 12 shows the relationship between a temporary auditory threshold shift (TTS) in terms of level of exposure and exposure time. The "white noise" referred to in Figure 12 is comprised of equal sound pressure levels in each frequency component.

The EPA "Levels Document" discusses a temporary threshold shift hypothesis. This hypothesis states that "a temporary threshold shift measured two minutes after cessation of an eight hour noise exposure closely approximates the Noise Induced Permanent Threshold Shift (NIPTS) incurred after a 10 to 20 year exposure to that same level."



TEMPORARY THRESHOLD SHIFT (TTS) AS A FUNCTION OF EXPOSURE TO WHITE NOISE (OASPL - OVERALL SOUND PRESSURE LEVEL)

Figure 12

The EPA "Levels Document" also discusses the "Equal Energy Hypothesis." This hypothesis states "that equal amounts of sound energy will cause equal amounts of NIPTS regardless of the distribution of the energy across time." While there is some experimental confirmation of this hypothesis, certain types of intermittent sounds limit its application.

Long continued exposure to extensive noise can produce permanent hearing loss but the process is not well understood. It does not appear possible to directly equate the deleterious effects of noise-exposure and the energy content of the noise. That is to say, doubling the energy content in a noise does not produce double the hearing loss. It is assumed that the larger the total energy content of the noise the smaller the time of exposure required to produce the same amount of hearing loss, but the exact relation between time and noise energy is not known.

The total amount of hearing loss produced by noise-exposure depends on many variables. Hearing loss varies with the type of exposure and its degree of intermittency, the susceptibility of the individual exposed, the total duration of the exposure, and possible induced auditory fatigue generated by the totality of exposure in terms of type, degree and duration.

Other Effects of Noise on Humans

It is important to emphasize that many researchers are not convinced that noise exposure can be correlated to any real non-auditory medical problem. The New York City Mayos's Task Force on Noise Control (Ref. 9) reported, "To date, virtually no properly designed formal studies have been published, documenting the palpable indirect effects of noise pollution upon man. Although we may again appeal to personal experience, having been aware of fatigue, distraction, irritation or inefficiency ostensibly precipitated by or aggravated by noise, the tangible nature of these effects vanishes as soon as it is pursued in the laboratory or in formal field studies." However, there is still considerable debate as to whether noise can cause health defects of a non-auditory nature.

Many researchers underscore the need for extensive epidemiological noise surveys concerned with the incidences of acute and chronic ailments in different work groups. Whatever correlation there may arguably be between noise and adverse health effects requires far more definite, controlled tests to demonstrate a cause-effect relationship.

Some studies indicate that it is not necessary to be fully awakened by noise to suffer the consequences in terms of physiological fatigue. Research by H. R. Richter concluded that "noise associated with modern civilization and even natural sounds frequently disturb the rest of sleepers without their awareness" (Ref. 10).

After protracted periods of exposure to intense noise, particulary of high frequency, animals have shown marked depletion of adrenal constituents. This indicates that their physiological tolerance or ability to adapt to stressful situations has been exceeded. Under these conditions, gastroduodenal ulcers and other pathological changes in the liver and kidneys are possible. It is plausible to expect similar findings in man, but neither the levels nor the exposure conditions required to exceed human physiological tolerance to noise are known.

Noise has been reported to cause vasoconstriction, fluctuations in arterial blood pressure, and even alterations of some functional properties of cardiac muscle. Vasoconstriction of the small arterioles of the extremities occurs with noise exposures of moderate level (about 70 dB) and can become progressively stronger with increasing noise intensity.

N. N. Skatalou, a Russian scientist who studied 589 factory workers, found effects of noise on cardiovascular systems varied with the type of exposure. Steady or continuous noise resulted in "arterial tension, downward trend in venous pressure and reduced peripheral resistance." Intermittent noise, on the other hand, caused "hypertension, rising arterial pressure and frequent capillary spasms" (Ref. 10).

The views of several physicians concerned with the adverse physiological impact of noise were summarized by Baron (Ref. 2). Dr. G. Jansen found that blood circulation does not adapt to continuing exposure to noise by a return to its initial level. Instead, peripheral blood flow continues to be reduced as a result of continuing vasoconstriction and increased resistance. This phenomenon begins at 60-70 dB and becomes more pronounced as sound intensity increases. Dr. L. E. Farr summarized his views of the effects of noise in the following way: "In disease states such as anxieties, duodenal ulcers and other so-called tension ills, the additive, deleterious effect of noise is real and immediate" (Ref. 2).

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