



T **E**CHNICAL **I** NFORMATION **P** APER

GLOSSARY OF NOISE COMPATIBILITY TERMS



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GLOSSARY OF NOISE COMPATIBILITY TERMS

A-WEIGHTED SOUND LEVEL - A sound pressure level, often noted as dBA, which has been frequency filtered or weighted to quantitatively reduce the effect of the low frequency noise. It was designed to approximate the response of the human ear to sound.

AMBIENT NOISE - The totality of noise in a given place and time — usually a composite of sounds from varying sources at varying distances.

APPROACH LIGHT SYSTEM (ALS) - An airport lighting facility which provides visual guidance to landing aircraft by radiating light beams in a directional pattern by which the pilot aligns the aircraft with the extended centerline of the runway on the final approach for landing.

ATTENUATION - Acoustical phenomenon whereby a reduction in sound energy is experienced between the noise source and receiver. This energy loss can be attributed to atmospheric conditions, terrain, vegetation, and man-made and natural features.

AZIMUTH - Horizontal direction expressed as the angular distance between true north and the direction of a fixed point (as the observer's heading).

BASE LEG - A flight path at right angles to the landing runway off its approach end. The base leg normally extends from the downwind leg to the intersection of the extended runway centerline. See "traffic pattern."

CNEL - The 24-hour average sound level, in A-weighted decibels, obtained after the addition of 4.77 decibels to sound levels between 7 p.m. and 10 p.m. and 10 decibels to sound levels between 10 p.m. and 7 a.m., as averaged over a span of one year. In California, it is the

required metric for determining the cumulative exposure of individuals to aircraft noise. Also see "Leq" and "DNL".

COMMUNITY NOISE EQUIVALENT LEVEL - See CNEL.

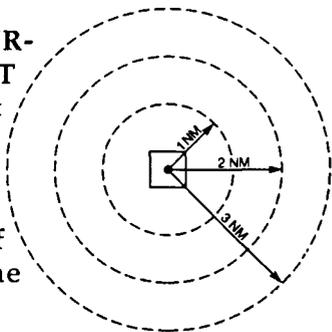
CROSSWIND LEG - A flight path at right angles to the landing runway off its upwind end. See "traffic pattern."

DAY-NIGHT AVERAGE SOUND LEVEL - See DNL.

DECIBEL (dB) - The physical unit commonly used to describe noise levels. The decibel represents a relative measure or ratio to a reference power. This reference value is a sound pressure of 20 micropascals which can be referred to as 1 decibel or the weakest sound that can be heard by a person with very good hearing in an extremely quiet room.

DISPLACED THRESHOLD - A threshold that is located at a point on the runway other than the designated beginning of the runway.

DISTANCE MEASURING EQUIPMENT (DME) - Equipment (airborne and ground) used to measure, in nautical miles, the slant range distance of an aircraft from the DME navigational aid.



DNL - The 24-hour average sound level, in A-weighted decibels, obtained after the addition of ten decibels to sound levels for the periods between 10 p.m. and 7 a.m. as averaged over a span of one year. It is the FAA standard metric for determining the cumulative exposure of individuals to noise. Also see "Leq."



DOWNWIND LEG - A flight path parallel to the landing runway in the direction opposite to landing. The downwind leg normally extends between the crosswind leg and the base leg. Also see "traffic pattern."

DURATION - Length of time, in seconds, a noise event such as an aircraft flyover is experienced. (May refer to the length of time a noise event exceeds a specified dB threshold level.)

EASEMENT - The legal right of one party to use a portion of the total rights in real estate owned by another party. This may include the right of passage over, on, or below the property; certain air rights above the property, including view rights; and the rights to any specified form of development or activity, as well as any other legal rights in the property that may be specified in the easement document.

EQUIVALENT SOUND LEVEL - See Leq.

FINAL APPROACH - A flight path in the direction of landing along the extended runway centerline. The final approach normally extends from the base leg to the runway. See "traffic pattern."

FIXED BASE OPERATOR (FBO) - A provider of services to users of an airport. Such services include, but are not limited to, hangaring, fueling, flight training, repair and maintenance.

GLIDE SLOPE (GS) - Provides vertical guidance for aircraft during approach and landing. The glide slope consists of the following:

1. Electronic components emitting signals which provide vertical guidance by reference to airborne instruments during instrument approaches such as ILS, or
2. Visual ground aids, such as VASI, which provide vertical guidance for VFR approach or for the visual portion of an instrument approach and landing.

GLOBAL POSITIONING SYSTEM - See "GPS."

GPS - GLOBAL POSITIONING SYSTEM - A system of 24 satellites used as reference points to enable navigators equipped with GPS receivers to determine their latitude, longitude, and altitude. The accuracy of the system can be further refined by using a ground receiver at a known location to calculate the error in the satellite range data. This is known as Differential GPS (DGPS).

GROUND EFFECT - The attenuation attributed to absorption or reflection of noise by man-made or natural features on the ground surface.

HOURLY NOISE LEVEL (HNL) - A noise summation metric which considers primarily those single events which exceed a specified threshold or duration during one hour.

INSTRUMENT APPROACH - A series of predetermined maneuvers for the orderly transfer of an aircraft under instrument flight conditions from the beginning of the initial approach to a landing, or to a point from which a landing may be made visually.

INSTRUMENT FLIGHT RULES (IFR) - Rules governing the procedures for conducting instrument flight. Also a term used by pilots and controllers to indicate type of flight plan.

INSTRUMENT LANDING SYSTEM (ILS) - A precision instrument approach system which normally consists of the following electronic components and visual aids:

1. Localizer.
2. Glide Slope.
3. Outer Marker.
4. Middle Marker.
5. Approach Lights.

Ldn - (See DNL). Ldn used in place of DNL in mathematical equations only.

Leq - Equivalent Sound Level. The steady A-weighted sound level over any specified period (not necessarily 24 hours) that has the same acoustic energy as the fluctuating noise during that period (with no consideration of a nighttime weighting.) It is a measure of cumulative acoustical energy. Because the time



interval may vary, it should be specified by a subscript (such as Leq 8) for an 8-hour exposure to workplace noise) or be clearly understood.

LOCALIZER - The component of an ILS which provides course guidance to the runway.

MERGE - Combining or merging of noise events which exceed a given threshold level and occur within a variable selected period of time.

MISSED APPROACH COURSE (MAC) - The flight route to be followed if, after an instrument approach, a landing is not effected, and occurring normally:

1. When the aircraft has descended to the decision height and has not established visual contact, or
2. When directed by air traffic control to pull up or to go around again.

NOISE CONTOUR - A continuous line on a map of the airport vicinity connecting all points of the same noise exposure level.

NONDIRECTIONAL BEACON (NDB) - A beacon transmitting nondirectional signals whereby the pilot of an aircraft equipped with direction finding equipment can determine his bearing to and from the radio beacon and home on or track to or from the station. When the radio beacon is installed in conjunction with the Instrument Landing System marker, it is normally called a Compass Locator.

NONPRECISION APPROACH - A standard instrument approach procedure providing runway alignment but no glide slope or descent information.

PRECISION APPROACH - A standard instrument approach procedure providing runway alignment and glide slope or descent information.

PRECISION APPROACH PATH INDICATOR (PAPI) - A lighting system providing

visual approach slope guidance to aircraft during a landing approach. It is similar to a VASI but provides a sharper transition between the colored indicator lights.

PROFILE - The physical position of the aircraft during landings or takeoffs in terms of altitude in feet above the runway and distance from the runway end.

PROPAGATION - Sound propagation refers to the spreading or radiating of sound energy from the noise source. Propagation characteristics of sound normally involve a reduction in sound energy with an increased distance from source. Sound propagation is affected by atmospheric conditions, terrain, and man-made and natural objects.

RUNWAY END IDENTIFIER LIGHTS (REIL) - Two synchronized flashing lights, one on each side of the runway threshold, which provide rapid and positive identification of the approach end of a particular runway.

RUNWAY USE PROGRAM - A noise abatement runway selection plan designed to enhance noise abatement efforts with regard to airport communities for arriving and departing aircraft. These plans are developed into runway use programs and apply to all turbojet aircraft 12,500 pounds or heavier. Turbojet aircraft less than 12,500 pounds are included only if the airport proprietor determines that the aircraft creates a noise problem. Runway use programs are coordinated with FAA offices as outlined in Order 1050.11. Safety criteria used in these programs are developed by the Office of Flight Operations. Runway use programs are administered by the Air Traffic Service as "Formal" or "Informal" programs.

RUNWAY USE PROGRAM (FORMAL) - An approved noise abatement program which is defined and acknowledged in a Letter of Understanding between FAA - Flight Standards, FAA - Air Traffic Service, the airport proprietor, and the users. Once established, participation in the program is mandatory for aircraft operators and pilots as provided for in F.A.R. Section 91.87.



RUNWAY USE PROGRAM (INFORMAL) -

An approved noise abatement program which does not require a Letter of Understanding and participation in the program is voluntary for aircraft operators/pilots.

SEL - Sound Exposure Level. SEL expressed in dB, is a measure of the effect of duration and magnitude for a single-event measured in A-weighted sound level above a specified threshold which is at least 10 dB below the maximum value. In typical aircraft noise model calculations, SEL is used in computing aircraft acoustical contribution to the Equivalent Sound Level (Leq), the Day-Night Sound Level (DNL), and the Community Noise Equivalent Level (CNEL).

SINGLE EVENT - An occurrence of audible noise usually above a specified minimum noise level caused by an intrusive source such as an aircraft overflight, passing train, or ship's horn.

SLANT-RANGE DISTANCE - The straight line distance between an aircraft and a point on the ground.

SOUND EXPOSURE LEVEL - See SEL.

TACTICAL AIR NAVIGATION (TACAN) -

An ultra-high frequency electronic air navigation system which provides suitably-equipped aircraft a continuous indication of bearing and distance to the TACAN station.

TERMINAL RADAR SERVICE AREA (TRSA) -

Airspace surrounding designated airports wherein ATC provides radar vectoring, sequencing, and separation on a full-time basis for all IFR and participating VFR aircraft. Service provided in a TRSA is called Stage III Service.

THRESHOLD -

Decibel level below which single event information is not printed out on the noise monitoring equipment tapes. The noise levels below the threshold are, however, considered in the accumulation of hourly and daily noise levels.

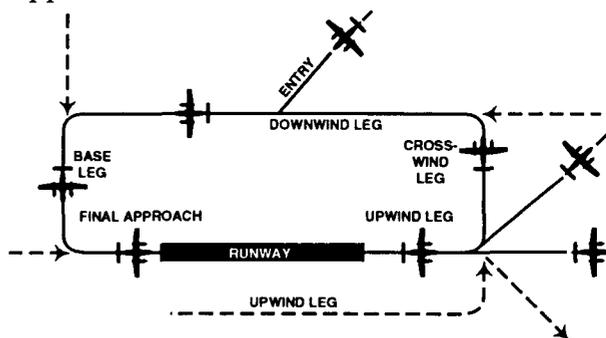
TIME ABOVE (TA) - The 24-hour TA noise metric provides the duration in minutes for which aircraft-related noise exceeds specified A-weighted sound levels. It is expressed in minutes per 24-hour period.

TOUCHDOWN ZONE LIGHTING (TDZ) -

Two rows of transverse light bars located symmetrically about the runway centerline normally at 100 foot intervals. The basic system extends 3,000 feet along the runway.

TRAFFIC PATTERN -

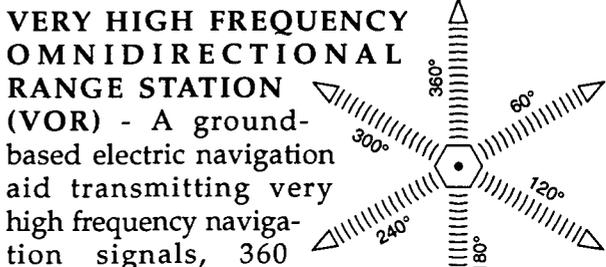
The traffic flow that is prescribed for aircraft landing at or taking off from an airport. The components of a typical traffic pattern are the upwind leg, crosswind leg, downwind leg, base leg, and final approach.



UNICOM - A nongovernment communication facility which may provide airport information at certain airports. Locations and frequencies of UNICOM's are shown on aeronautical charts and publications.

UPWIND LEG - A flight path parallel to the landing runway in the direction of landing. See "traffic pattern."

VECTOR - A heading issued to an aircraft to provide navigational guidance by radar.



VERY HIGH FREQUENCY OMNIDIRECTIONAL RANGE STATION (VOR) - A ground-based electric navigation aid transmitting very high frequency navigation signals, 360



degrees in azimuth, oriented from magnetic north. Used as the basis for navigation in the national airspace system. The VOR periodically identifies itself by Morse Code and may have an additional voice identification feature.

VERY HIGH FREQUENCY OMNIDIRECTIONAL RANGE STATION/TACTICAL AIR NAVIGATION (VORTAC) - A navigation aid providing VOR azimuth, TACAN azimuth, and TACAN distance-measuring equipment (DME) at one site.

VICTOR AIRWAY - A control area or portion thereof established in the form of a corridor, the centerline of which is defined by radio navigational aids.

VISUAL APPROACH - An approach wherein an aircraft on an IFR flight plan, operating in VFR conditions under the control of an air traffic control facility and having an air traffic control authorization, may proceed to the airport of destination in VFR conditions.

VISUAL APPROACH SLOPE INDICATOR (VASI) - An airport lighting facility providing vertical visual approach slope guidance to air-

craft during approach to landing by radiating an directional pattern of high intensity red and white focused light beams which indicate to the pilot that he is on path if he sees red/white, above path if white/white, and below path if red/red. Some airports serving large aircraft have three-bar VASI's which provide two visual guide paths to the same runway.

VISUAL FLIGHT RULES (VFR) - Rules that govern the procedures for conducting flight under visual conditions. The term VFR is also used in the United States to indicate weather conditions that are equal to or greater than minimum VFR requirements. In addition, it is used by pilots and controllers to indicate type of flight plan.

VOR - See "Very High Frequency Omnidirectional Range Station."

VORTAC - See "Very High Frequency Omnidirectional Range Station/Tactical Air Navigation."

YEARLY DAY-NIGHT AVERAGE SOUND LEVEL - See DNL.





T E C H N I C A L I N F O R M A T I O N P A P E R

THE MEASUREMENT AND ANALYSIS OF SOUND



TECHNICAL **I**NFORMATION **P**APER



THE MEASUREMENT AND ANALYSIS OF SOUND

Sound is energy -- energy that conveys information to the listener. Although measuring this energy is a straightforward technical exercise, describing sound energy in ways that are meaningful to people is complex. This TIP explains some of the basic principles of sound measurement and analysis.

NOISE - UNWANTED SOUND

Noise is often defined as unwanted sound. For example, rock-and-roll on the stereo of the resident of apartment 3A is music to her ears, but it is intolerable racket to the next door neighbor in 3B. One might think that the louder the sound, the more likely it is to be considered noise. This is not necessarily true. In our example, the resident of apartment 3A is surely exposed to higher

sound levels than her neighbor in 3B, yet she considers the sound as pleasant while the neighbor considers it "noise". While it is possible to measure the sound level objectively, characterizing it as "noise" is a subjective judgement.

The characterization of a sound as "noise" depends on many factors, including the information content of the sound, the familiarity of the sound, a person's control over the sound, and a person's activity at the time the sound is heard.

MEASUREMENT OF SOUND

A person's ability to hear a sound depends on its character as compared with all other sounds in the environment. Three characteristics of



sound to which people respond are subject to objective measurement: magnitude or loudness; the frequency spectrum; and the time variation of the sound.

LOUDNESS

The unit used to measure the magnitude of sound is the decibel. Decibels are used to measure loudness in the same way that "inches" and "degrees" are used to measure length and temperature. Unlike the linear length and temperature scales, the decibel scale is logarithmic. By definition, a sound which has ten times the mean square sound pressure of the reference sound is 10 decibels (dB) greater than the reference sound. A sound which has 100 times (10×10 or 10^2) the mean square sound pressure of the reference sound is 20 dB greater (10×2).

The logarithmic scale is convenient because the mean square sound pressures of normal interest extend over a range of 11 trillion to one. This huge number (a 1 followed by 14 zeros or 10^{14}) is much more conveniently represented on the logarithmic scale as 140 dB (10×14).

The use of the logarithmic decibel scale requires different arithmetic than we use with linear scales. For example, if two equally loud but independent noise sources operate simultaneously, the measured mean square sound pressure from both sources will be twice as great as either source operating alone. When expressed on the decibel scale, however, the sound pressure level from the com-

bined sources is only 3 dB higher than the level produced by either source alone. Furthermore, if we have two sounds of different magnitude from independent sources, then the level of the sum will never be more than 3 dB above the level produced by the greater source alone.

The equation below describes the mathematics of sound level summation:

$$S_t = 10 \log \sum_i 10^{S_i/10}$$

where S_t is the total sound level, in decibels, and S_i is the sound level of the individual sources.

A simpler process of summation is also available and often used where a level of accuracy of less than one decibel is not required. Table 1 lists additive factors

TABLE 1
Additive Factors for Summation
of Two Sound Levels

Difference in Sound Level (dB)	Add to Larger Level (dB)
0	3.0
1	2.5
2	2.1
3	1.8
4	1.5
5	1.2
6	1.0
7	0.8
8	0.6
9	0.5
10	0.4
12	0.3
14	0.2
16	0.1
Greater than 16	0

Source: HUD 1985, p.51.



The noise values to be added should be arrayed from lowest to highest. The additive factor derived from the difference between the lowest and next highest noise level should be added to the higher level. An example is shown below.

Example of Sound Level Summation

Sound Levels to be Added	Summation Process
59 dB	} Add 2.5 to 60 = 62.5
60 dB	
66.5 dB	} Add 1.5 to 66.5 = 68
<hr/> $59 \text{ dB} + 60 \text{ dB} + 66.5 \text{ dB} = 68 \text{ dB}$ <hr/>	

Logarithmic math also produces interesting results when averaging sound levels. As the example below shows, the loudest sound levels are the dominant influence in the averaging process. In the example, two sound levels of equal duration are averaged. One is 100 dB the other 50 dB. The result is not 75 as it would be with linear math but 97 dB. This is because 100 dB contains 100,000 times the sound energy as 50 dB.

Example Of Sound Level Averaging

Assume two sound levels of equal duration: 100 dB and 50 dB. What is the average sound level?

$$\frac{100\text{dB} + 50\text{dB}}{2} = 97\text{dB}$$

100 dB is 100,000 times more energy than 50 dB!

Another interesting attribute of sound is the human perception of loudness. Scientists researching human hearing have determined that most people perceive a 10 dB increase in sound energy over a given frequency range as roughly a doubling of the loudness. Recalling the logarithmic nature of the decibel scale, this means that most people perceive a ten-fold increase in sound energy as a two-fold increase in loudness (Kryter 1984, p. 188). Furthermore, when comparing sounds over the same frequency range, most people cannot distinguish between sounds varying by less than two or three decibels.



Exhibit A presents examples of various noise sources at different noise levels, comparing the decibel scale with the relative sound energy and the human perception of loudness. In the exhibit, 60 dB is taken as the reference or "normal" sound level. A sound of 70 dB, involving ten times the sound energy, is perceived as twice as loud. A sound of 80 dB contains 100 times the sound energy and is perceived as four times as loud as 60 dB. Similarly, a sound of 50 dB contains ten times less sound energy than 60 dB and is perceived as half as loud.

FREQUENCY WEIGHTING

Two sounds with the same sound pressure level may "sound" quite different (e.g. a rumble versus a hiss) because of differing distributions of sound energy in the audible frequency range. The distribution of sound energy as a function of frequency is known as the "frequency spectrum". The spectrum is important to the measurement of sound because the human ear is more sensitive to sounds at some frequencies than others. People hear best in the frequency range of 1,000 to 5,000 cycles per second (Hertz) than at very much lower or higher frequencies. If the magnitude of a sound is to be measured so that it is proportional to its perception by a human, it is necessary to weight more heavily that part of the sound energy spectrum humans hear most easily.

Over the years, many different sound measurement scales have been developed, including the A-weighted scale (and also the B, C, D, and E-

weighted scales). A-weighting, developed in the 1930s, is the most commonly used scale for approximating the frequency spectrum to which humans are sensitive. Because of its universality, it was adopted by the U.S. Environmental Protection Agency and other government agencies for the description of sound in the environment.

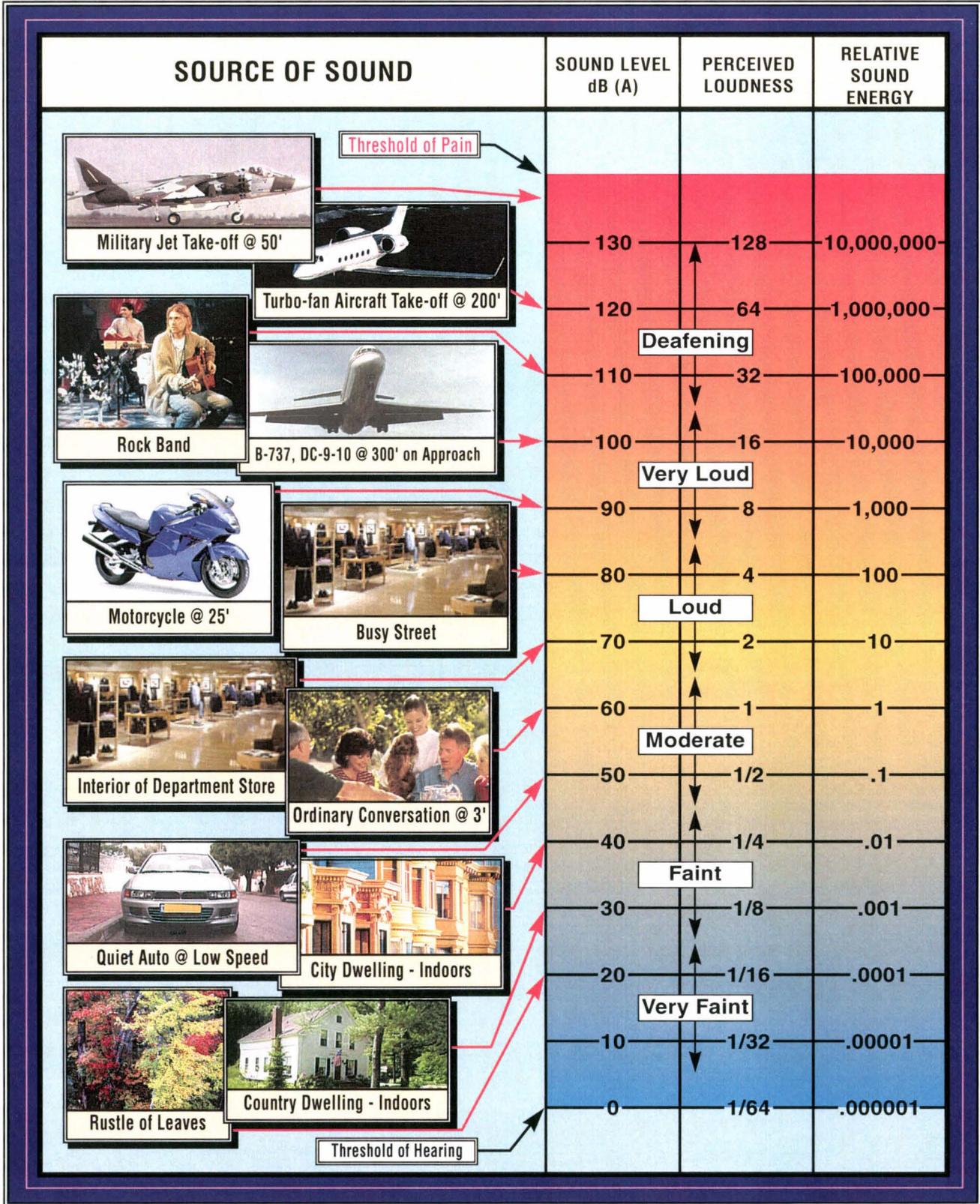
The zero value on the A-weighted scale is the reference pressure of 20 micro-newtons per square meter (or micropascals). This value approximates the smallest sound pressure that can be detected by a human. The average sound level of a whisper at a distance of 1 meter is 40 dB; the sound level of a normal voice at 1 meter is 57 dB; a shout at 1 meter is 85 dB; the threshold of pain is 130 dB.

TIME VARIATION OF SOUND LEVEL

Generally, the magnitude of sound in the environment varies randomly over time. Of course, there are many exceptions. For example, the sound of a waterfall is steady with time, as is the sound of a room air conditioner or the sound inside a car or airplane cruising at a constant speed. But in most places, the loudness of outdoor sound is constantly changing because it is influenced by sounds from many sources.

While the continuous variation of sound levels can be measured, recorded, and presented, comparisons of sounds at different times or at different places is very difficult without some way of reducing the time variation.





Source: Coffman Associates 1990



Sound Exhibit A
TYPICAL SOUND LEVELS

One way of doing this is to calculate the value of a steady-state sound which contains the same amount of sound energy as the time-varying sound under consideration. This value is known as the Equivalent Sound Level (Leq). An important advantage of the Leq metric is that it correlates well with the effects of noise on humans. On the basis of research, scientists have formulated the "equal energy rule". It is the total sound energy perceived by a human that accounts for the effects of the sound on the person. In other words, a very loud noise lasting a short time will have the same effect as a quieter noise lasting a longer time if the total energy of both sound events (the Leq value) is the same.

KEY DESCRIPTORS OF SOUND

Four descriptors or metrics are useful for quantifying sound (Newman and Beattie 1985, pp. 9-15). All are based on the logarithmic decibel (dB) scale and incorporate A-weighting to account for the frequency response of the ear.

Sound Level

The sound level (L) in decibels is the quantity read on an ordinary sound level meter. It fluctuates with time following the fluctuations in magnitude of the sound. Its maximum value (Lmax) is one of the descriptors often used to characterize the sound of an airplane overflight. However, Lmax only gives the maximum magnitude of a sound – it does not convey any information about

the duration of the sound. Clearly, if two sounds have the same maximum sound level, the sound which lasts longer will cause more interference with human activity.

Sound Exposure Level

Both loudness and duration are included in the sound exposure level (SEL), which adds up all sound occurring in a stated time period or during a specific event, integrating the total sound over a one-second duration. The SEL is the quantity that best describes the total noise from an aircraft overflight. Based on numerous sound measurements, the SEL from a typical aircraft overflight is usually four to seven decibels higher than the Lmax for the event.

Exhibit B shows graphs of two different sound events. In the top half of the graph, we see that the two events have the same Lmax, but the second event lasts longer than the first. It is clear from the graph that the area under the noise curve is greater for the second event than the first. This means that the second event contains more total sound energy than the first, even though the peak levels for each event are the same. In the bottom half of the graph, the sound exposure levels (SELs) for each event are compared. The SELs are computed by mathematically compressing the total sound energy into a one-second period. The SEL for the second event is greater than the SEL for the first. Again, this simply means that the total sound energy for the second event is greater than for the first.

Equivalent Sound Level

The equivalent sound level (Leq) is simply the logarithm of the average value of the sound exposure during a stated time period. It is typically used for durations of one hour, eight hours, or 24 hours. In airport noise compatibility studies, use of the Leq term applies to 24-hour periods unless otherwise noted. It is often used to describe sounds with respect to their potential for interfering with human activity.

Day-Night Sound Level

A special form of Leq is the day-night sound level (abbreviated as DNL and referred to as Ldn in equations). DNL is calculated by adding up all the sound exposure during daytime (0700 - 2200 hours) plus 10 times the sound exposure occurring during nighttime (2200 - 0700 hours) and averaging this sum by the number of seconds during a 24-hour day. The multiplication factor of 10 applied to nighttime sound is often referred to as a 10 dB penalty. It is intended to account for the increased annoyance attributable to noise during the night when ambient levels are lower and people are trying to sleep.

Exhibit C shows how the sound occurring during a 24-hour period is weighted and averaged by the DNL descriptor (or metric). In that example, the sound occurring during the period, including aircraft noise and background sound, yields a DNL value of 71. As a practical matter, this is a reasonably close estimate of the aircraft noise alone because, in this example, the background

noise is low enough to contribute only a little to the overall DNL value during the period of observation.

Where the basic element of sound measurement is Leq , DNL is calculated from:

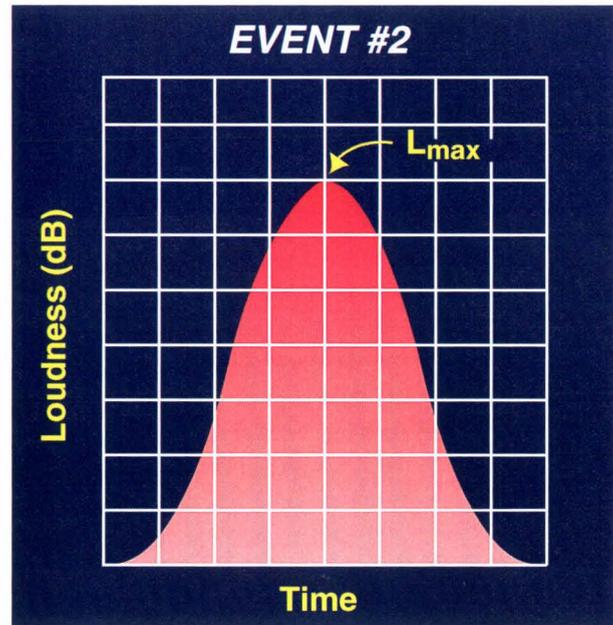
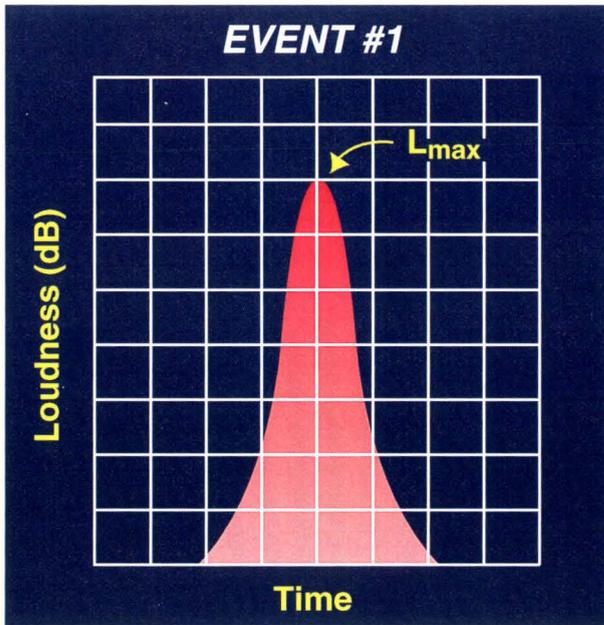
$$Ldn = 10 \log \frac{1}{24} \left(\sum_{d=1}^{15} 10^{[Leq(d)]/10} + \sum_{n=1}^9 10^{[Leq(n)+10]/10} \right)$$

where DNL is represented mathematically as Ldn , and $Leq(d)$ and $Leq(n)$ are the daytime and nighttime hour values combined. This expression is convenient where Leq values for only a few hours are available and the values for the remainder of the day can be predicted from a knowledge of day/night variation in levels. The hourly Leq values are summed for the 15 hours from 0700 to 2200 and added to the sum of hourly Leq figures for the 9 nighttime hours with a 10 dB penalty added to the nighttime $Leqs$.

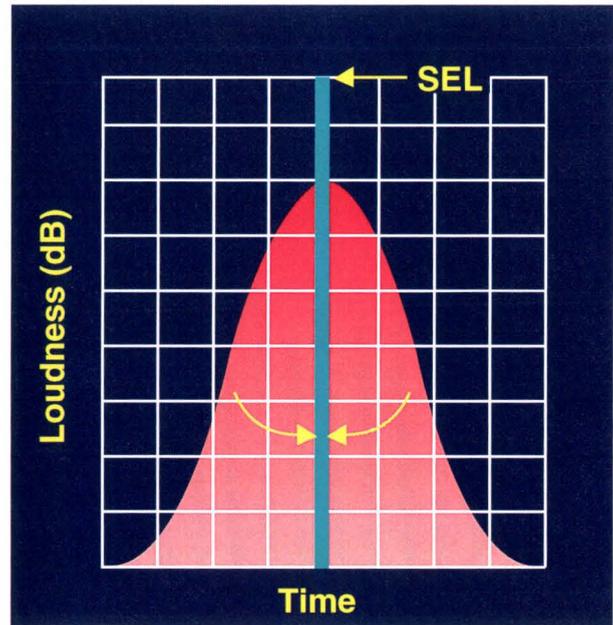
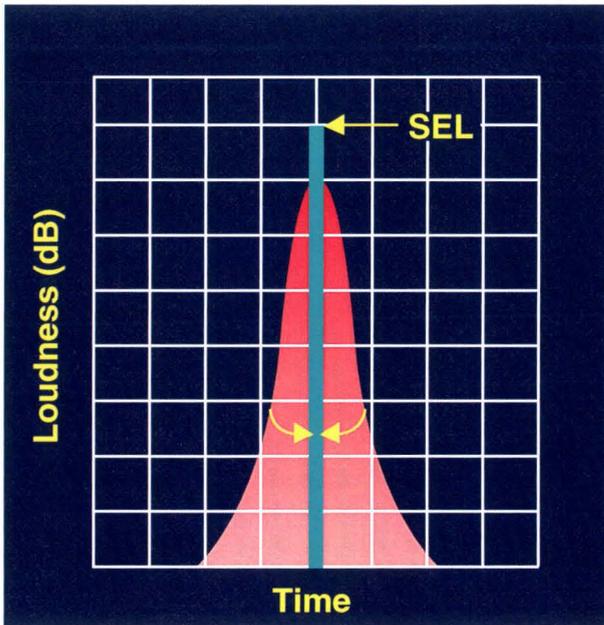
Another way of computing DNL is described in this equation:

$$Ldn = 10 \log \frac{1}{86400} \left(\int_{\text{day}} 10^{LA/10} dt + \int_{\text{night}} 10^{(LA+10)/10} dt \right)$$

where LA is the time-varying, A-weighted sound level, measured with equipment meeting the requirements for sound level meters (as specified in a standard such as ANSI S1.4-1971), and

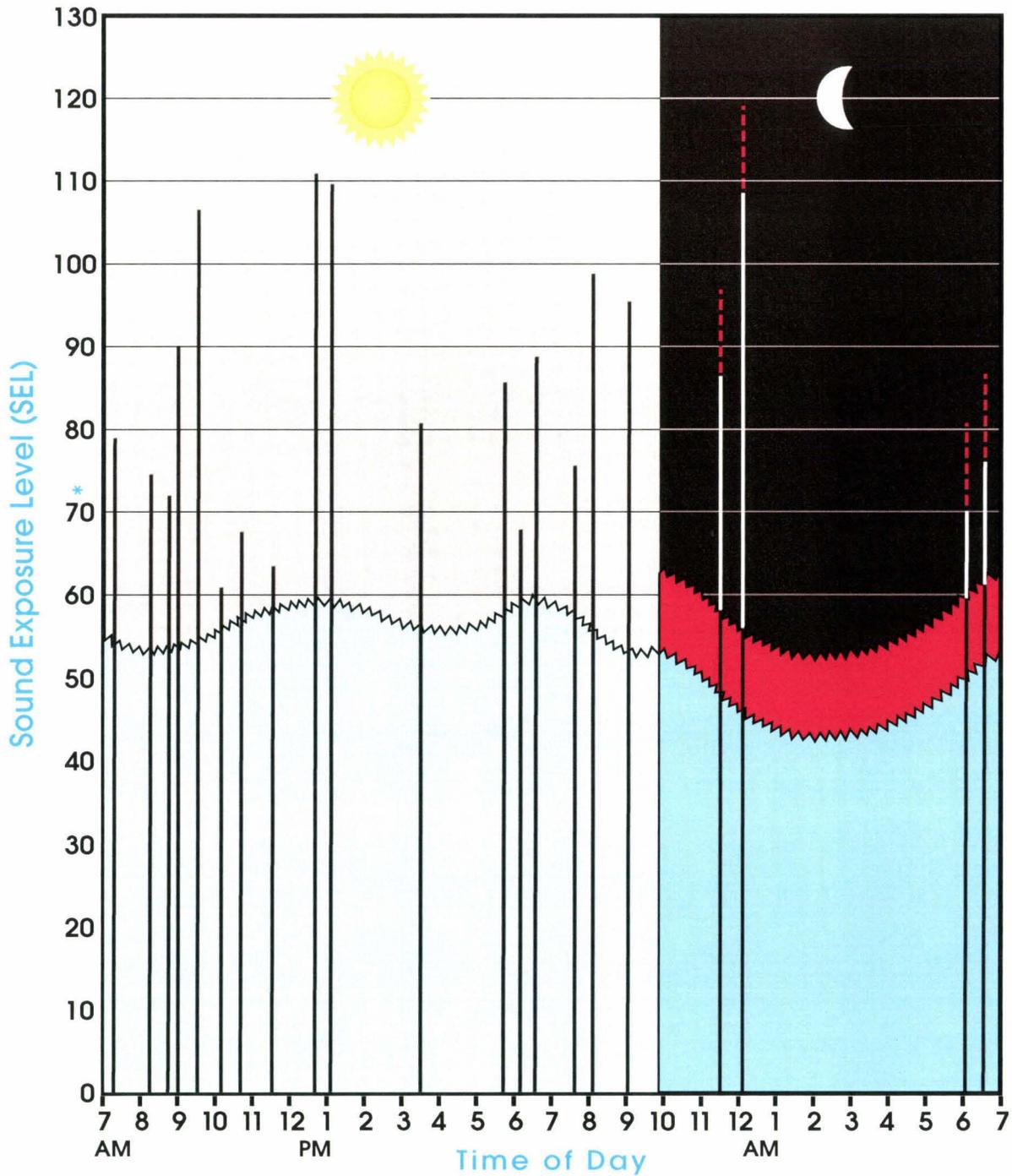


Two sound events with the same maximum sound level (L_{max}).



Different sound exposure levels (SEL) for two sound events with the same L_{max} .





LEGEND

- ~~~~~ Average ambient sound level
- █ 10 dB penalty for nighttime sound level
- Aircraft noise event (SEL)
- - - 10 dB penalty for nighttime noise
- * 24-hour average DNL 71 dBA

Source: Coffman Associates 1990



dt is the duration of time in seconds. The averaging constant of 86,400 is the number of seconds in a day. The integrals are taken over the daytime (0700 - 2200) and the nighttime (2200 - 0700) periods, respectively. If the sound level is sampled at a rate of once per second rather than measured continuously, the equation still applies if the samples replace LA and the integrals are changed to summations.

Use of the DNL metric to describe aircraft noise is required for all airport noise studies developed under the regulations of F.A.R. Part 150. In addition, DNL is preferred by all federal agencies as the appropriate single measure of cumulative sound exposure. These agencies include the FAA, the Federal Highway Administration, Environmental Protection Agency, Department of Defense, and Department of Housing and Urban Development.

One might think of the DNL metric as a summary description of the total "noise climate" of an area. DNL accumulates the noise energy from passing aircraft in the same way that a precipitation gauge accumulates rain from passing storms. This analogy is presented in Exhibit D. Rain usually starts as a light sprinkle, building in intensity as the squall line passes over, then diminishing as the squall moves on. At the end of a 24-hour period, a rain gauge indicates the total rainfall received for that day, although the rain fell only during brief, sometimes intense, showers. Over a year, total precipitation is summarized in inches. When snow falls, it is converted to its equivalent measure as water. Although the total volume of precipitation occurring during the year

may be billions or trillions of gallons of water, its volume is expressed in inches because it provides for easier summation and description. We have learned how to use total annual precipitation to describe the climate of an area and make predictions about the environment.

Aircraft noise is similar to precipitation. The noise level from a single overflight begins quietly and builds in intensity as the aircraft draws closer. The sound of the aircraft is loudest as it passes over the receiver, diminishing as it passes. The total noise occurring during the event is accumulated and described as a Sound Exposure Level (SEL). Over a 24-hour period, the SELs can be summed, adding a special 10-decibel factor for nighttime noise, yielding a DNL value. The DNL developed over a long period of time, say a year, defines the noise environment of the area, allowing us to make predictions about the average response of people living in areas exposed to various DNL levels.

HELPFUL RULES-OF-THUMB

Despite the complex mathematics involved in noise analysis, several simple rules-of-thumb can help in understanding the noise evaluation process.

- *When sound events are averaged, the loud events dominate the calculation.*
- *A 10 decibel change in noise is equal to a tenfold change in sound energy. For example, the noise from ten aircraft is ten decibels louder than the noise from one*



aircraft of the same type, operated in the same way.

- *Most people perceive an increase of 10 decibels as a relative doubling of the sound level.*
- *The DNL metric assumes one nighttime operation (between 10:00 p.m. and 7:00*

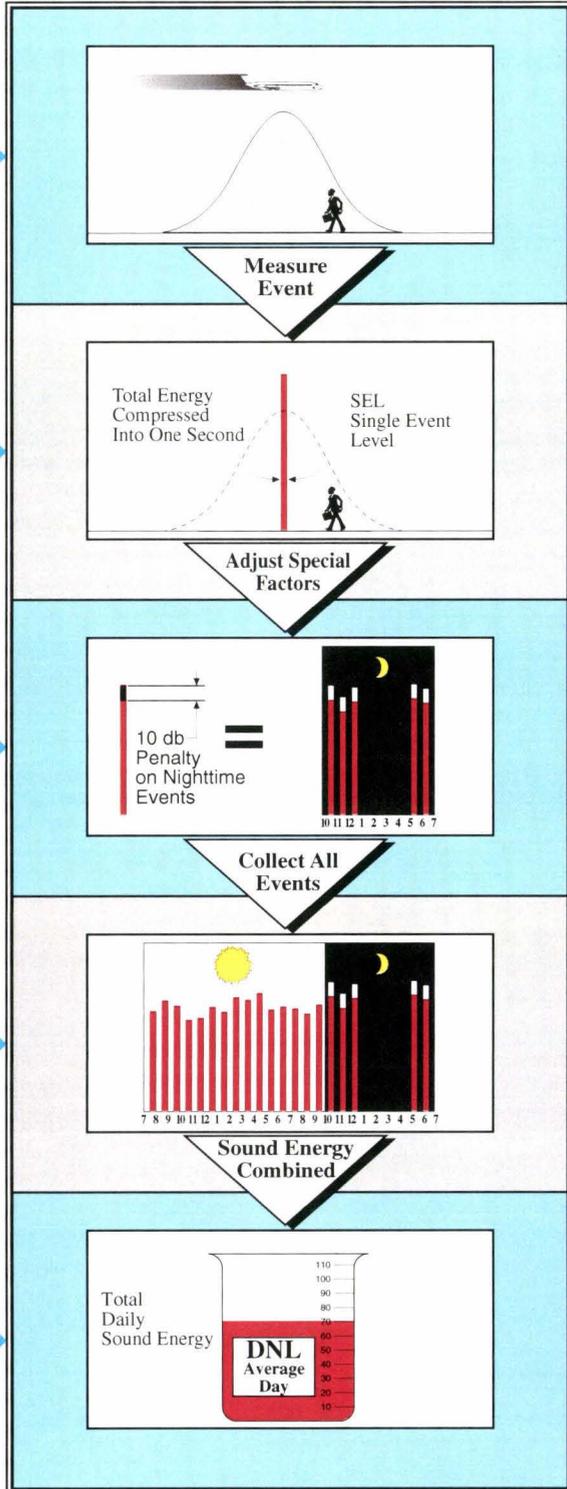
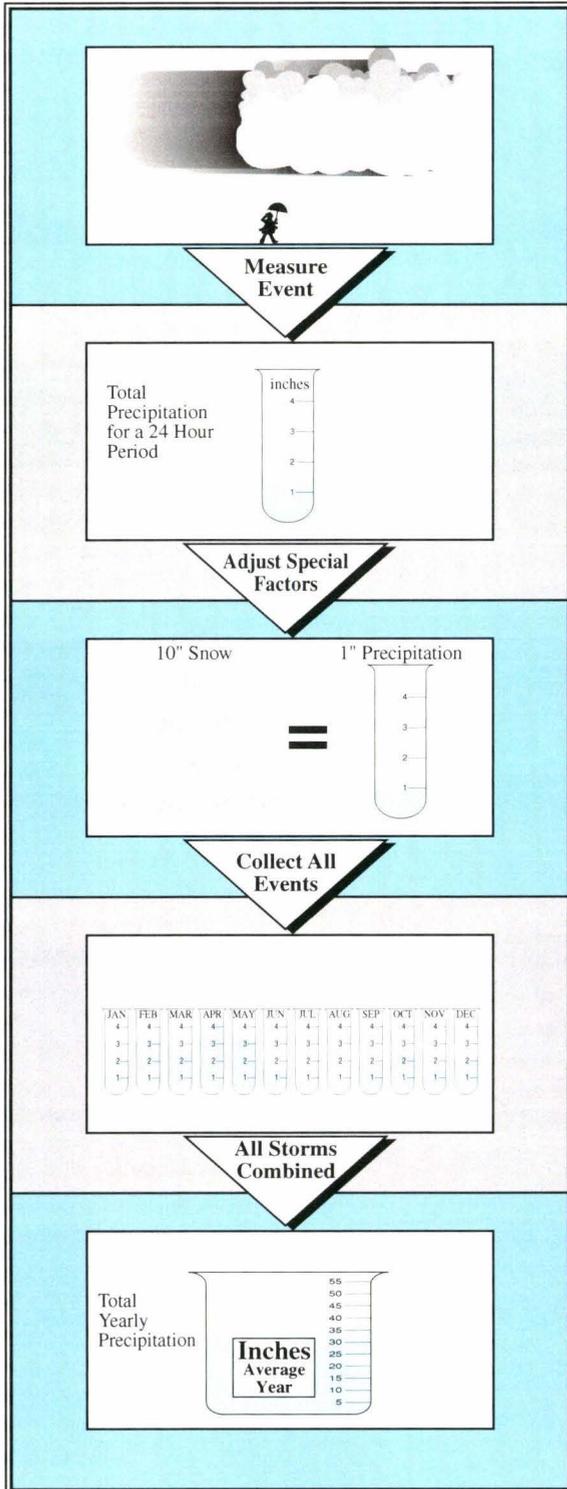
a.m.) is equal in impact to ten daytime operations by the same aircraft.

- *A doubling of operations results in a three decibel noise increase if accomplished by the same aircraft operated in the same way.*



Precipitation Measurement

Noise Measurement



Source: Coffman Associates 1990



References

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TECHNICAL **I**NFORMATION **P**APER

E F F E C T S O F N O I S E E X P O S U R E



T ECHNICAL I NFORMATION P APER



EFFECTS OF NOISE EXPOSURE

Aircraft noise can affect people both physically and psychologically. It is difficult, however, to make sweeping generalizations about the impacts of noise on people because of the wide variations in individual reactions. While much has been learned in recent years, some physical and psychological responses to noise are not yet fully understood and continue to be debated by researchers.

EFFECTS ON HEARING

Hearing loss is the major health danger posed by noise. A study published by the U.S. Environmental Protection Agency (1974) found that exposure to noise of 70 Leq or higher on a continuous basis, over a very long time, at the human ear's most damage-sensitive frequency, may result in a very small but permanent loss of hearing. (Leq is a pure noise dosage metric,

measuring cumulative noise energy over a given time.)

In *Aviation Noise Effects* (Newman and Beattie, 1985, pp. 33-42), three studies are cited which examined hearing loss among people living near airports. They found that, under normal circumstances, people in the community near an airport are at no risk of suffering hearing damage from aircraft noise.

The Occupational Safety and Health Administration (OSHA) has established standards for permissible noise exposure in the work place to guard against the risk of hearing loss. Hearing protection is required when noise levels exceed the legal limits. The standards, shown in **Table 1**, establish a sliding scale of permissible noise levels by duration of exposure. The standards permit noise levels of up to 90 dBA for eight hours per day without requiring hearing



protection. The regulations also require employers to establish hearing conservation programs where noise levels exceed 85 Leq during the 8-hour workday. This involves the monitoring of work place noise, the testing of employees' hearing, the provision of hearing protectors to employees at risk of hearing loss, and the establishment of a training program to inform employees about the effects of work place noise on hearing and the effectiveness of hearing protection devices.

TABLE 1 Permissible Noise Exposures, OSHA Standards	
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

Source: 29 CFR Ch. XVII, Section 1910.95 (b)

Experience at other airports has shown that even at sites with cumulative noise exposure near 75 DNL, the total time noise levels exceed 80 dBA typically ranges from 10 to 20 minutes, far below the critical hearing

damage thresholds (Coffman Associates 1993, pp. 2-11). This supports the conclusion that airport noise in areas off airport property is far too low to be considered potentially damaging to hearing.

With respect to the risk of hearing loss, the authors of an authoritative summary of the research conclude: "Those most at risk [of hearing loss] are personnel in the transportation industry, especially airport ground staff. Beyond this group, it is unlikely that the general public will be exposed to sustained high levels of transportation noise sufficient to result in hearing loss. Transportation noise control in the community can therefore not be justified on the grounds of hearing protection." (See Taylor and Wilkins 1987.)

NON-AUDITORY HEALTH EFFECTS

It is sometimes claimed that aviation noise can harm the general physical and mental health of airport neighbors. Effects on the cardiovascular system, mortality rates, birth weights, achievement scores, and psychiatric admissions have been examined in the research literature. The question of pathological effects remains unsettled because of conflicting findings based on differing methodologies and uneven study quality. It is quite possible that the contribution of noise to pathological effects is so low that it has not been clearly isolated. While research is continuing, there is insufficient scientific evidence to support these concerns (Newman and Beattie 1985, pp. 59-62).

