Supporting Information for the Adopted Noise Regulations For California Airports

Final Report to the
California Department of Aeronautics

Report No. WCR 70-3(R)

Prepared by
Wyle Laboratories Research Staff
El Segundo, California

January 29, 1971

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TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

By passage of Assembly Bill 645 (1969), the Legislature mandated the California Department of Aeronautics to adopt noise standards to govern the operation of aircraft and aircraft engines at airports operating under a permit from the Department. This covers all but military airports and some small private airports which do not invite the general public.

A seven-member Advisory Committee on Noise Standards, whose members were appointed by the Governor in accordance with AB 645, assisted the Department in selecting an acoustical consultant and in reviewing and recommending modifications as the consultant's work progressed. In a series of meetings of the Committee, the Department, the consultant and legal counsel from the Office of the Attorney General, a proposed noise standard was developed and agreed upon by vote of the Advisory Committee for purposes of the public hearings. On April 1, the Department of Aeronautics provided copies of the proposed noise standard to all members of the Legislature, and thereafter to all persons requesting copies, in a document entitled "Report to the Legislature on Proposed Noise Standards for California Airports Pursuant to Public Utilities Code Section 21669."

Public hearings on the proposed standard were held in Los Angeles and San Francisco on May 19 and 20, under the auspices of the California Aeronautics Board. Subsequent to these hearings, additional working sessions were held with the Department, their consultants, the Advisory Committee and the Aeronautics Board to revise and improve the noise standard on the basis of testimony received in the public hearings. On November 10, 1970, the California Aeronautics Board formally adopted the revised noise standard. The adopted noise regulations are included in this report as Appendix B.

The purpose of this report is to present the findings of the acoustical consultant and to provide the background and explanatory information related to the adopted noise regulations, insofar as the realm of technical acoustics is concerned. A draft version of this report was presented to the Department on May 12, 1970, in order to make the information available under a single cover in advance of the public hearings. It is not the intent of this background report to delve into the legalities involved in the noise regulations, since those matters lie outside the responsibility and expertise of the acoustical consultant.

In the report which follows, Chapter 2 provides an introduction to the basic concepts involved in solving or preventing a community noise problem and describes the basic physical and human factors concepts required for quantitative description of a noise environment. Chapter 3 presents the underlying rationale for the structure of the noise regulations -- a structure which includes both (a) limitation of the "noise footprint" generated by total activity at the airport and (b) limitation of the noise of individual aircraft.

In the regulation, the scale utilized to limit the "noise footprint" of an airport is called "community noise equivalent level," and that utilized to limit the noise of individual aircraft is called "single event noise exposure level." Background material and data underlying the selection of the numerical limits for community noise equivalent level (CNEL) in residential areas are presented in Chapter 4, and the basis for selection of the limits on single event noise exposure level (SENEL) is presented in Chapter 6.

Potential methods of controlling and reducing the extent of an airport's "noise footprint," as quantified by the location of the footprint perimeter (or "noise impact boundary"), are discussed in Chapter 5. Chapter 7 discusses the general implementation of the single event noise exposure level limits and is supplemented by noise prediction curves for various jet aircraft categories (Appendix D).

Chapter 8 presents the rationale behind the noise monitoring system requirements specified in the regulation, and provides suggestions on the use of monitoring systems and estimates of the costs and staffing requirements involved in the noise monitoring which will be required of some airports.

In addition to the adopted noise regulations (Appendix B), appendices to the report include a glossary of acoustical terms, the authorizing statute, the amendment modifying the reporting date and effective date of the noise regulations, and noise prediction curves.

2.0 THE NATURE OF COMMUNITY NOISE

Community noise is the total outdoor noise environment that comes from many sources, such as motor vehicles, rapid transit systems, industrial plants, aircraft and the general activities of the residents themselves. In recent times, communities adjacent to airports have been subjected to increasing noise exposures because of the advent of jet aircraft and the increase in air transportation. As a consequence, aircraft noise has become the dominant component of community noise in many areas adjacent to airports.

In order to assist the reader in understanding the adopted airport noise regulation, and the subsequent portions of this background information report, we must first introduce the basic concepts utilized to quantify noise. These concepts include the characteristics which typify the physical properties of the sound itself, and those additional concepts needed to include the characteristics of human hearing.

2.1 Basic Concepts Regarding the Physical Properties of a Sound

2.1.1 Magnitude of the Sound

If we examine the noise produced by an aircraft flyby, we find that as the aircraft approaches the sound increases in magnitude until it reaches a maximum and then gradually decreases and dies away. If we were to place a measuring instrument on the ground and record the sound as a pen trace on paper, we would see the sound of the flyby represented as a hill-shaped curve. Such a trace records the time history of the noise magnitude, as illustrated in Figure 1. The absolute magnitude or level of the sound at any instant is expressed in terms of a logarithmic scale in which the unit is the decibel (dB). The maximum sound level observed as the aircraft passes by will depend on the sound output characteristics of the aircraft itself, and on the distance between the point of observation and the aircraft flight path.

2.1.2 Duration of the Sound

We also say that the sound of the flyby has a duration. This duration has in the past been defined in various ways, such as the time the sound level stays within some given value (such as 10 decibels) from the maximum value. In the noise regulation we have utilized a more meaningful quantity called the "effective duration," which allows us to include all the acoustic energy received, at the observation point, from the flyby. This "effective duration" will be more precisely described in the more technical sections of this report. However one chooses to define duration, we find that if we are located a

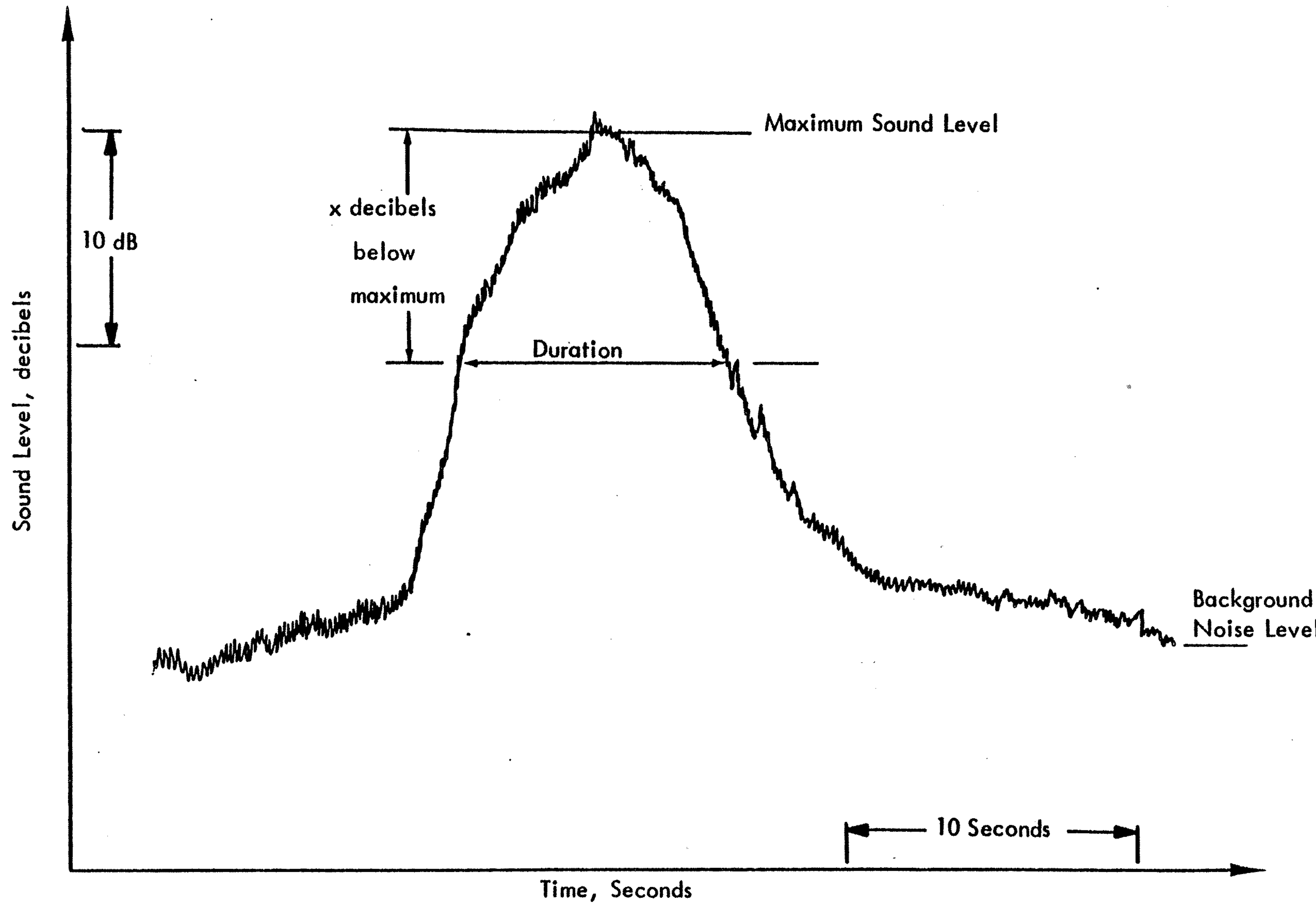


Figure 1. TYPICAL TIME HISTORY TRACE OF AN AIRCRAFT FLYBY

great distance from the aircraft flight path, the duration will be longer (and the maximum sound level lower) than if we were nearer the aircraft flight path. A comparison of recorder traces corresponding to these two situations is given in Figure 2.

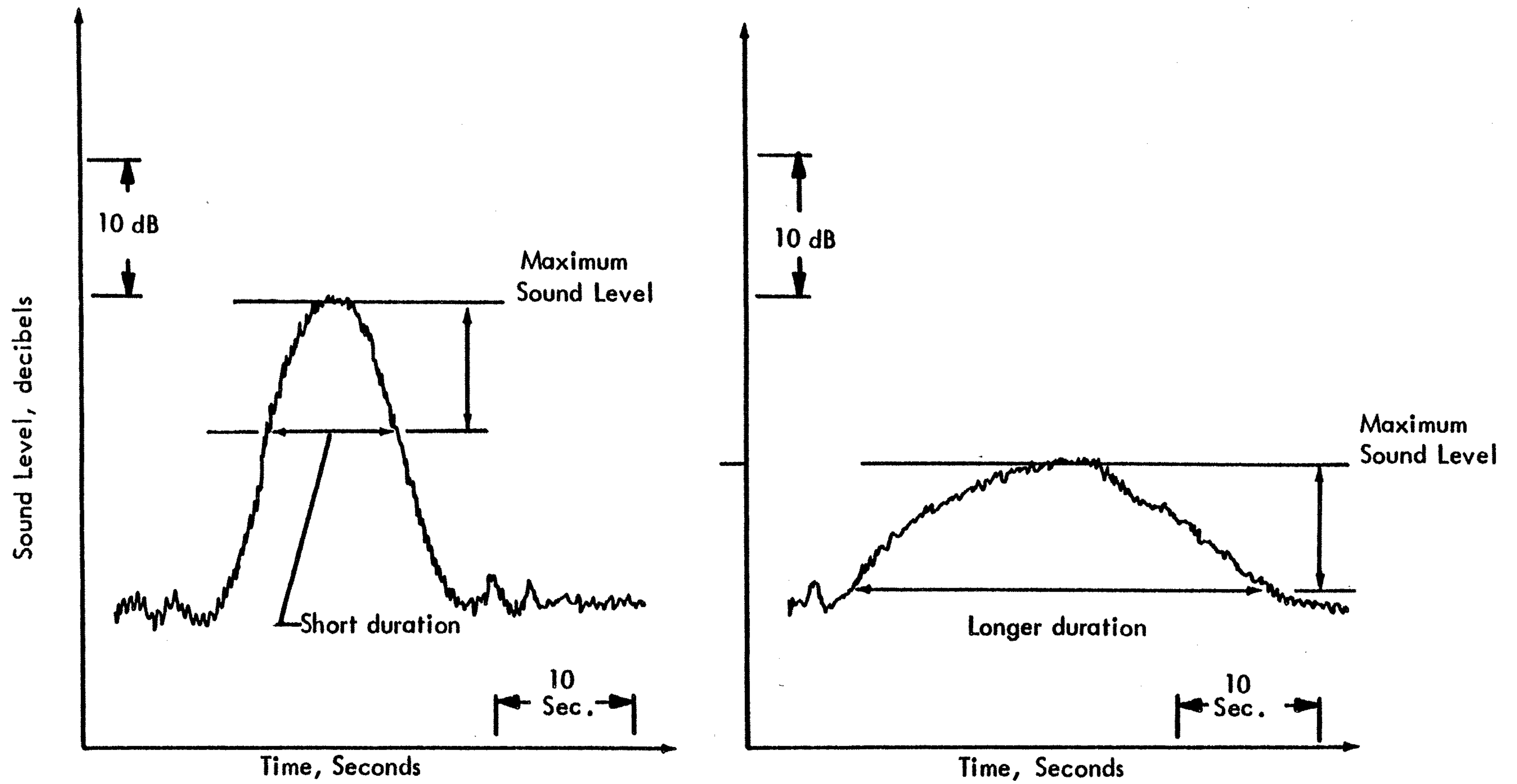
2.1.3 Background Noise Level in the Community

The noise of aircraft flybys is typified by high sound levels occurring for short periods of time. Residents of a community will be more aware of aircraft noise (or any other noise) if it stands out clearly above the general ambient or "background noise" which exists in the community. This background noise is a low-level, slowly-varying result of all the distant noise sources, such as distant freeways, traffic arterials and general urban activity. We are generally unaware of this background noise unless we try to listen for it.

Because background noise levels depend so much upon activities of people, and especially on ground traffic, the level varies from one community to another, and is lower at night than in the daytime -- sometimes as much as ten decibels lower. Since a given noise will be more intrusive if heard against a lower background noise level, the same noise will be more noticeable at night than in the daytime, and more noticeable in a quiet rural community than in a busy urban area. Figure 3 shows a comparison of the same aircraft flyby in a community with a high background noise as compared with a community with a lower background noise. The same comparison could be made with respect to the change in background levels from day to night which occurs in most communities.

2.1.4 Tonal Characteristics of the Sound

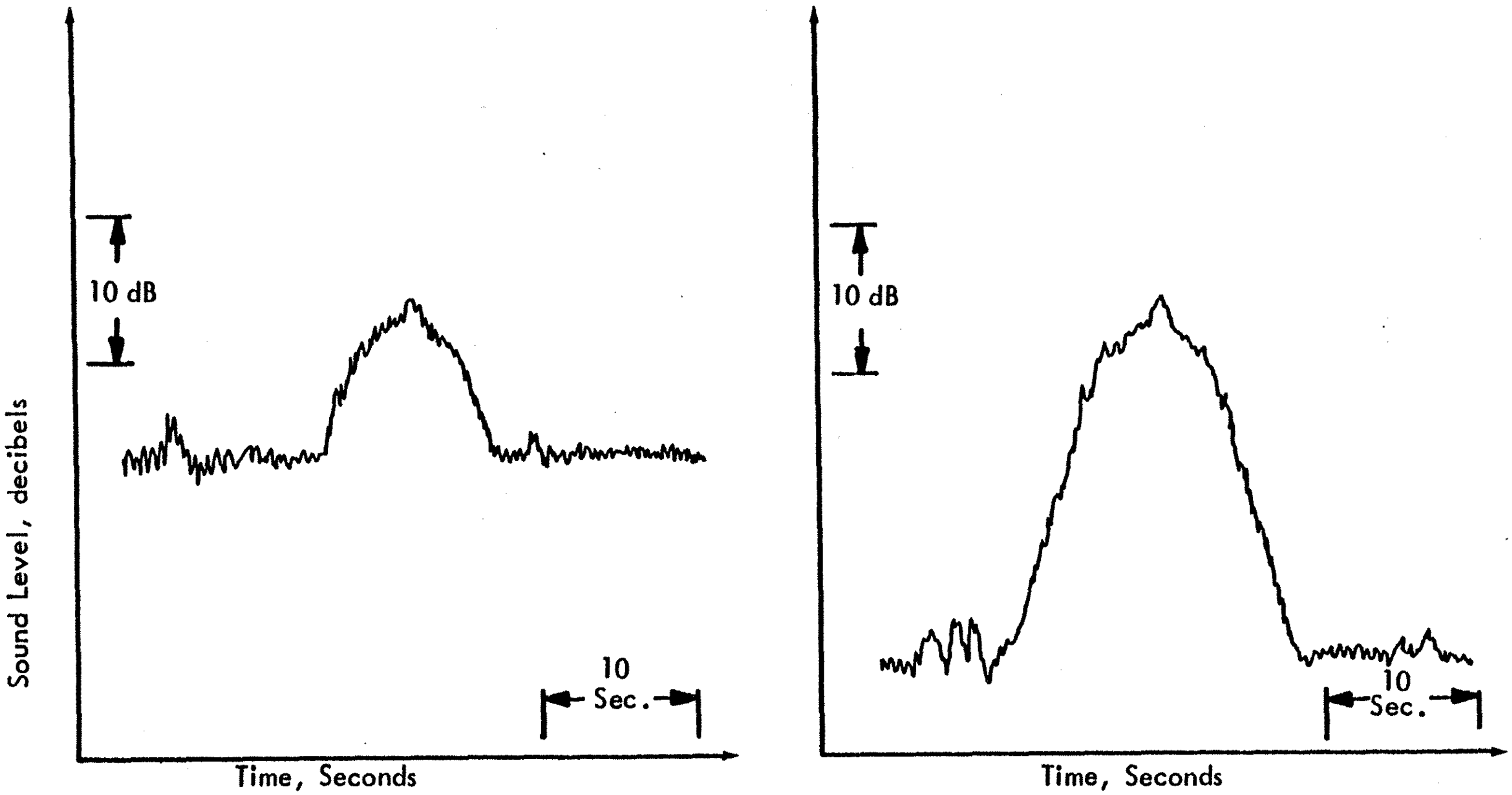
If we station ourselves at various points in the vicinity of an airport and listen to the sounds of aircraft, we hear sounds having different tonal qualities, depending on the particular aircraft to which we are listening and whether it is in the process of a take-off or a landing approach. For example, when a jet aircraft is operating at a high power setting (as for take-off and climb), the sound is a low-pitched roar, dominated by the noise of the jet exhaust. When a jet aircraft is under reduced power, on a landing approach, the sound is a high-pitched whine, dominated by the sound of the compressor and fan. These differing tonal qualities can be expressed graphically, in terms of the way in which the acoustic energy is distributed across the frequency spectrum.



(a) Near the aircraft

(b) Farther from the aircraft

Figure 2. COMPARISON OF TIME HISTORY FOR AN OBSERVER NEAR THE AIRCRAFT AND AN OBSERVER FARTHER FROM THE AIRCRAFT



(a) High background noise level

(b) Same sound, but lower background noise level

Figure 3. INTRUSIVENESS OF A TRANSIENT SOUND HEARD AGAINST DIFFERENT BACKGROUND NOISE LEVELS

We could stop our pen recorder trace of an aircraft flyby at a given instant and examine it in terms of the way in which the acoustic energy is distributed across the frequency spectrum. This can be done by breaking up the signal into the sound levels in each octave band. An octave is an interval of the frequency spectrum whose upper limit is just twice as high a frequency as its lower limit; for example, high C is two octaves above middle C on the piano. Examples of spectrum shapes (with the frequency spectrum broken down into octave bands) for take-off noise and for landing noise are shown in Figures 4(a) and 4(b). The sharp points in the curve of Figure 4(a) are generated by the engine compressor and fan; they correspond to the "whine" that is heard on landing approach.

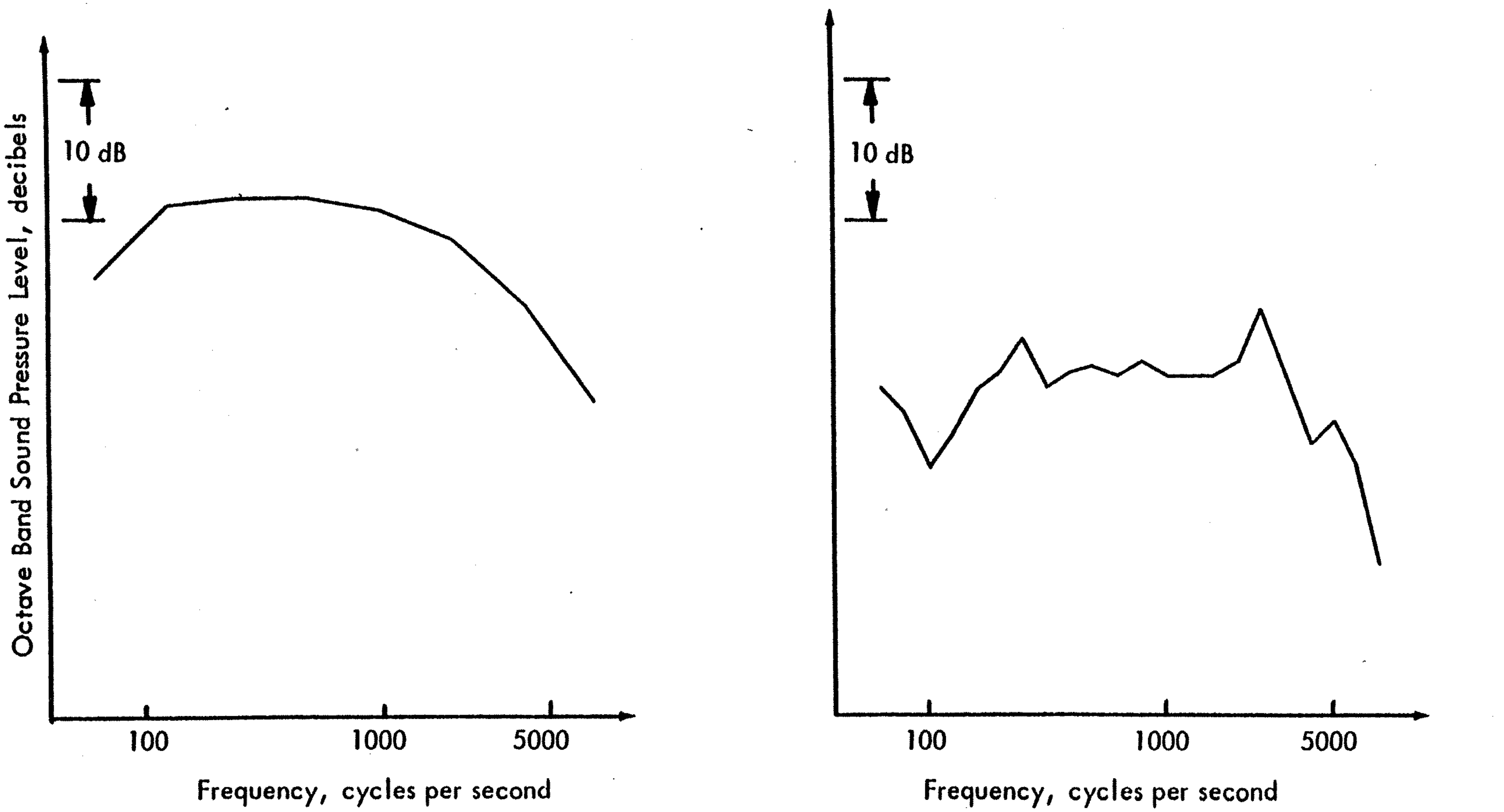
This completes the basic physical concepts which must be included in a quantitative description of a sound as measured at a given point. However, since we are dealing with people, we must also include in our quantification methods those concepts arising from the way the way the ear performs as a receptor, and the other concepts which are important in how people relate to noise.

2.2 Human Factors Concepts

The most important property of an audible sound is its apparent magnitude. Our hearing is most acute at frequencies around 3000 cycles per second (or Hertz), and the acuity of our hearing decreases gradually at lower and higher frequencies, Figure 5. Thus, the way a given noise will sound to us depends on how its energy is distributed along the frequency spectrum. Methods have been devised to make measuring instruments that will approximate the frequency response of the human ear, and one of the simplest and most reliable of these is the A-weighting circuit in an ordinary sound level meter. Thus, both the magnitude of a sound and its frequency spectrum will have a bearing on how loud or how noisy a given sound will seem to us.

Other things which affect the degree of annoyance we will experience from a recurring noise are:

- The length of time the noise lasts each time we hear it (its duration),
- How often it is repeated throughout the 24-hour time period (number of occurrences); and
- Whether it occurs during the day (when most of us are awake and active), during the evening (when we are usually engaged in quiet activities and the family is generally at home together) or at night (when most people want to sleep).



(a) Takeoff noise

(b) Landing noise

Figure 4. SPECTRUM SHAPES CHARACTERISTIC OF JET AIRCRAFT TAKEOFF AND LANDING SOUNDS

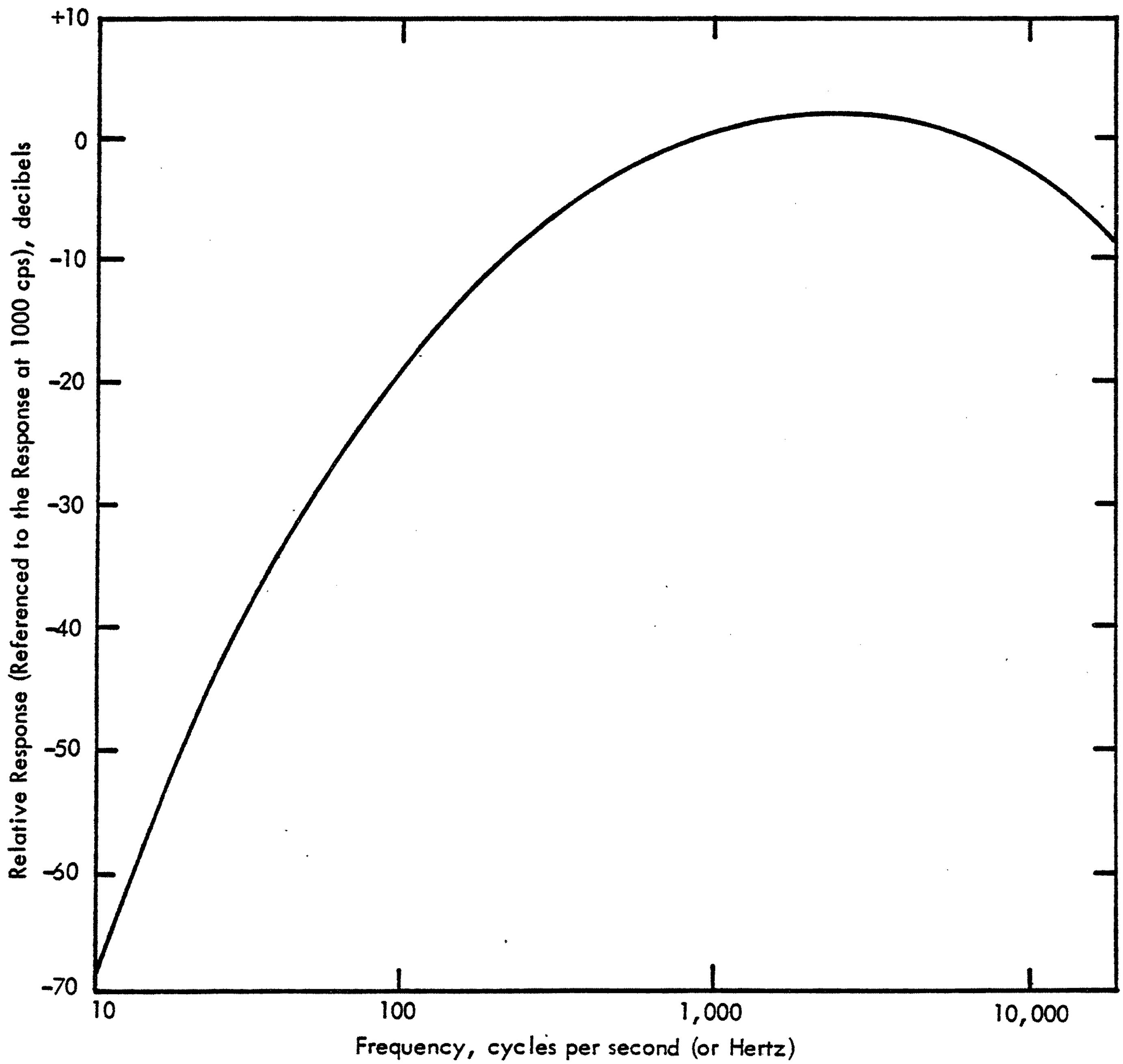


Figure 5. AN APPROXIMATION TO THE FREQUENCY RESPONSE OF THE HUMAN EAR

There is much more of a noise problem, for example, from ten or twenty noisy flights per hour than there would be from one per hour. Also, three noisy flights between 10:00 and 11:00 p.m. would be more annoying than the same three flights between 10:00 and 11:00 a.m., since many people are engaged in quiet activities or sleeping during that part of the night. Finally, a person farther from the airport may be annoyed by a given flight, even though it produces a relatively low sound level at his house, simply because the sound has a longer duration and thus attracts his attention or interferes with his concentration for a longer time.

All of the foregoing factors should be taken into account in any kind of noise scale which will be used to describe the noise environment around an airport in a way that is related to people. In selecting such a scale to use for purposes of a noise standard for airports, these factors were taken into account in the following ways:

- To quantify the combination of noise magnitude, frequency distribution of the acoustic energy and frequency response of the human ear, we have chosen to use the A-weighted sound level. This is a quantity which is easy to utilize in noise monitoring systems, and is generally utilized in measuring the noise of other types of vehicles.

- To incorporate the effects of duration and number of flights, we have chosen to utilize the time integral of the A-weighted sound level. In effect, this means we are summing all the acoustic energy that the ear will perceive (for an outdoor observer). This total energy will be greater if there are more flights and will generally be dominated by the noisiest flights.

- To take account of the importance of when the noise occurs, weighting factors have been incorporated into the accounting procedure. A larger weighting factor is used as a multiplier against flights that occur in the evening (7:00 to 10:00 p.m.) as compared to those which occur in the daytime (7:00 a.m. to 7:00 p.m.), and a still larger weighting factor is used for flight operations at night (10:00 p.m. to 7:00 a.m.). In effect, these weighting factors result in one flight at night being the equivalent of ten equally noisy flights in the daytime or three in the evening. This is to account for the increased need for quiet in residential areas at night.

The combination of all these choices has resulted in a composite rating scale for describing the noise environment, which is called the community noise equivalent level (CNEL) scale. It is a logarithmic scale with the units expressed in decibels. Any specific value of CNEL represents simply the average A-weighted sound level which would exist as a constant value if all the acoustic energy from all the flights were first weighted according to the time period (day, evening or night) and then distributed evenly over the 24-hour day. It is important to understand that this averaging on an energy basis is not the same as arithmetic averaging. Since we are working in a logarithmic scale, the resulting average level will be dominated by the noisier flights, since they produce much greater amounts of acoustic energy.

The noise standard establishes a limit value on the CNEL scale which should not be exceeded in residential areas around airports. In the section that follows, some further concepts necessary to the description of the total noise environment around an airport are introduced.

2.3 The Concept of Noise Impact

Each airport (or freeway or industrial plant which generates noise) produces a noise environment around it which can be quantitatively described in terms of a composite rating scale which includes the factors mentioned above. The customary way to show this noise environment is by showing noise contours on a map or aerial photograph, Figure 6. These noise contours are lines of equal noise (in the composite scale) just as the contour lines on a topographic map are lines of equal elevation. The region enclosed by some selected contour of the contour family is sometimes popularly referred to as the "noise footprint" of the airport. In terms of the rating scale utilized in the noise regulation, the contours are lines of equal CNEL.

The CNEL contours can be approximately predicted, based on the type and number of aircraft which will be using the airport per day, their approximate flight paths in connection with each runway, and the distribution of flights by the three time periods. Thus, one can estimate the noise environment of a proposed new airport in advance of its construction, based upon its eventual intended use. For an operating airport, it is best to verify the current contours by measurement; and this is required in the regulation, for airports deemed (by the enforcing authority) to have an existing noise problem.

In the regulation, a given limit value of CNEL is established as a criterion value which should not be exceeded in residential areas. One contour in the family of noise contours around an airport will correspond to this criterion value of CNEL. This particular CNEL contour is called the noise impact boundary. This selection of a criterion CNEL value for the noise impact boundary does not imply that there will be no noise problems whatever outside this boundary; we are dealing in shades of gray rather than in

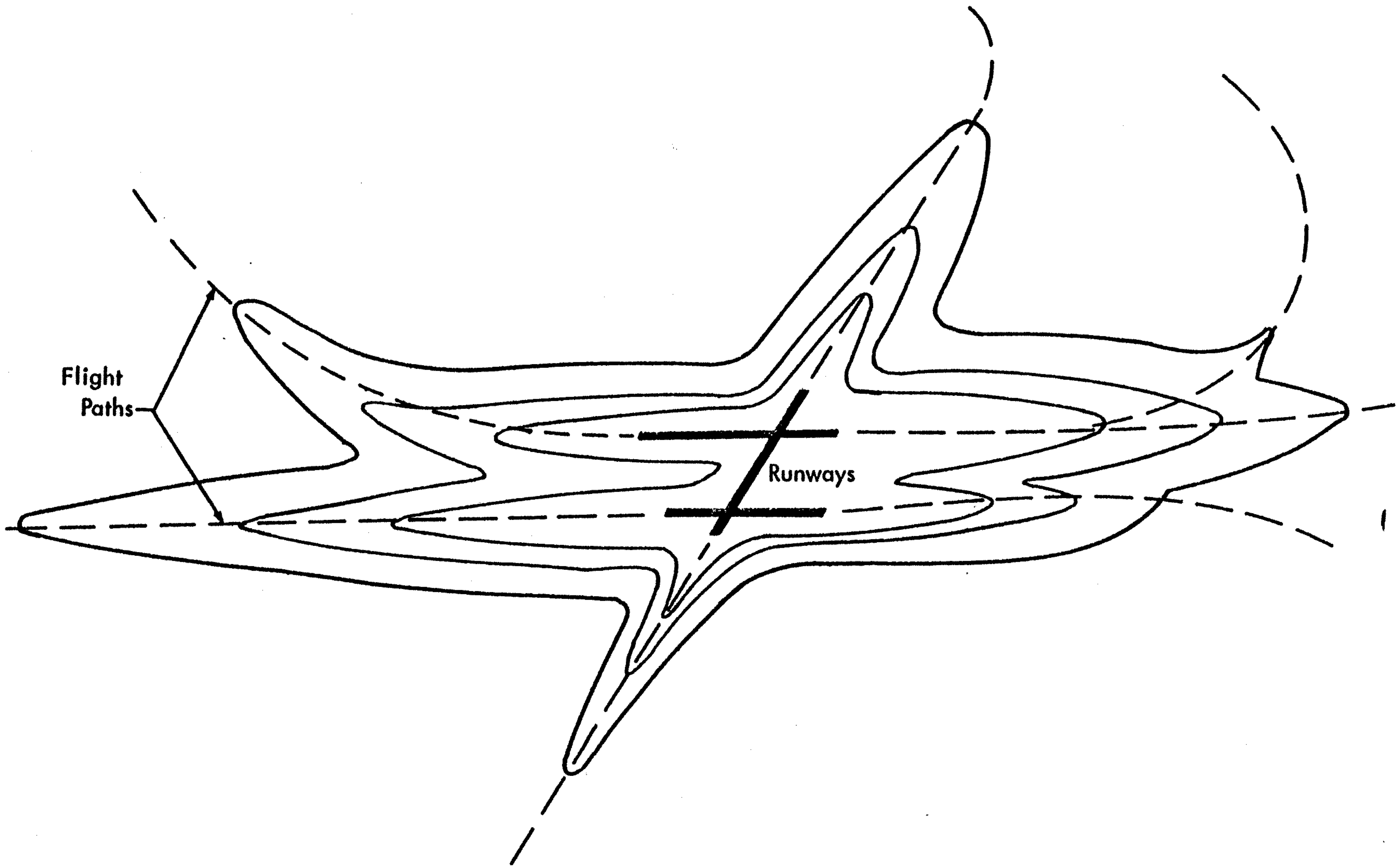


Figure 6. IDEALIZED EXAMPLE OF NOISE CONTOURS AROUND AN AIRPORT

a sudden change from black to white. However, if this noise impact boundary reaches far enough from the airport to enclose residential areas, it is expected that a significant percentage of the residents within the noise impact boundary will experience noise problems.

A busy airport with many commercial jet flights will generate noise contours that spread out over many square miles of land; a smaller (or general aviation) field will generate contours which do not spread as far. (This will be shown by some specific examples later in this report.) In either case, the particular noise contour which represents the noise impact boundary must not encompass residences. The quantitative measure of the degree of incompatibility between an airport and its adjacent communities chosen for use in the standard is the noise impact area; e.g., the number of square miles of residential land lying inside the noise impact boundary. Under the regulation, proposed new airports must have a predicted zero noise impact area throughout their future service lifetime; and existing airports with a nonzero noise impact area must gradually reduce their noise impact area to zero. Land uses other than residential, as set forth in the standard, are deemed to be compatible (although some of them may require attention to noise control in design of the buildings), and land given to those uses is not counted in the calculation of noise impact area. The concept of noise impact area is shown in Figure 7, for a hypothetical airport.

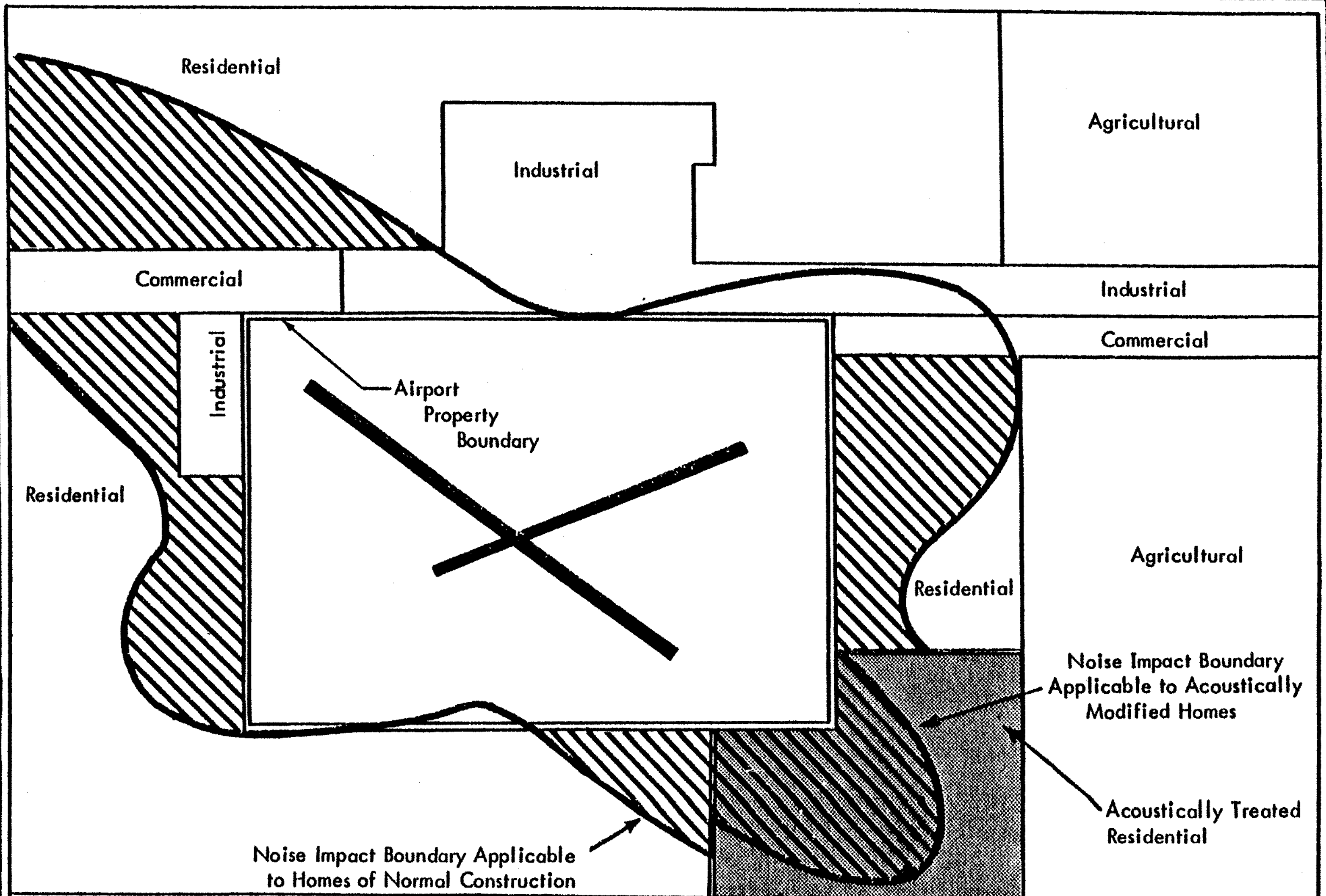


Figure 7. CONCEPTUAL SKETCH OF NOISE IMPACT BOUNDARIES AND NOISE IMPACT AREA

The noise impact area is the sum of all the cross-hatched areas, in square statute miles.

3.0 RATIONALE FOR THE NOISE STANDARD

A good noise standard for airports should be effective in fostering a condition of environmental compatibility between airports and their neighbors. The standard must provide for both limitation of the noise in residential communities and operation of a viable air transportation system sufficient to meet the genuine air travel needs of the area. To achieve this, a noise standard (in conjunction with the remaining body of law) must provide the incentive structure to bring about the following results:

- That new airports be located only at sites where their future uses will be compatible with land use from the time of the siting decision onward. This requires a commitment on the part of the airport authority to a design ceiling on the noise associated with the ultimate level of use of the airport, a valid prediction of the noise contours associated with the planned level of use, and a commitment by the community for effective control of the future land use surrounding the airport to prevent future encroachment by residential tracts.

- For existing airports which presently are compatible with their surrounding communities, a similar dual commitment (combining controlled use of the airport and controlled use of the surrounding land) must be made to prevent the development of a future noise incompatibility.

- For existing airports which presently have a noise problem with respect to their residential neighbors, the processes of planned change must be set in motion so as to control and reduce the extent of the noise environment wherever it encompasses residential areas. When such land lies in extreme noise regions very near the airport boundaries, the earliest and most equitable means should be applied to provide relief for the residents. When all available methods have been utilized by the airport to reduce the noise in residential communities, processes should be set in motion to convert the remaining land to a compatible use.

It should be realized at the outset that for existing airports with major noise problems, the size of the "noise footprint" may be so large as to preclude land use conversion as a viable solution. Solution of the noise problem at such airports is dependent on reduction of the size of the "noise footprint" itself, through (a) the attainment of quieter aircraft and (b) use of operational techniques to reduce the noise impact upon residential communities. Progress towards quieter aircraft can be expected as a result of (1) the federal noise certification test, (2) possible modification of certain existing aircraft engines (retrofit) currently being considered by the federal government, and

(3) the results of the "quiet engine" program. It is believed the existence of the California airport noise regulation will encourage the process of achieving quieter aircraft, and that advantage should be taken of these technological improvements as they occur to solve the noise problem at California airports.

The federal requirement that new subsonic jet aircraft pass a noise test before they receive a type certificate is an important step in the overall solution of the noise problem, in that it places an upper limit on how far the noise contour of an individual flight operation of that aircraft type can extend. Without a limit of this type, planning has little value. However, aircraft noise certification gives no guarantee that the aircraft can operate into a given airport and be compatible with the residential communities near that particular airport. Neither can certification of individual aircraft treat such problems as flight frequency, flight paths with respect to communities, and normal changes in the surrounding land use. Effects of these factors must be evaluated for each airport in an appropriate framework of state and local guidelines and regulations. The purpose of the noise impact boundary and the noise impact area concepts in the adopted noise regulation is to define the problem in specific terms for each airport and to provide the basic framework for local evaluation and ultimate solution.

The purpose of imposing a single event noise limit, for which the aircraft operator is responsible, is to provide the airport operator with one of the necessary tools for limiting the noise environment emanating from his airport. Although airport operators already had the power to exclude aircraft from their airports for noise reasons, there was no uniform agreement on measuring scales nor on maximum limits which would provide them guidance in doing so. Hence, there was no framework by which the development of uniformly applicable monitoring instruments could proceed in an economical fashion. Under the adopted noise regulation, the power of the state is added to that of the airport proprietor to assist him in holding the line on noise, while retaining for the proprietor the flexibility of going to lower noise limits if desired for his airport.

In practice, single event noise limits will have several functional effects. First, the way in which an aircraft is operated can, to some degree, affect the amount of noise it makes at various points on the ground. The aircraft operator has some options, such as loading of the aircraft (which affects its ability to gain altitude sooner after takeoff), throttle handling, accuracy of keeping to a prescribed flight path, and approach and climbout procedures (within safety limits). Performance of individual aircraft in complying with published noise abatement procedures in effect at the airport can be monitored in terms of single event noise limits.

Second, one of the major sources of noise problems has been the entry of noisier aircraft into existing airports without a technique which assists the airport proprietor in holding the line on noise. Single event noise limits at airports will require some study on the part of the aircraft operator, before entering an airport, on whether that airport is noise-rated for his aircraft or not, just as he presently has to plan his flights with regard to whether the destination airport is suited to his aircraft in terms of runway length and navigational aids.

The adopted regulation makes noise monitoring mandatory only by those airports which have a noise problem as determined by the enforcing agency according to criteria given in the regulation. The single event limits are intended primarily as a tool for the use of the airport proprietor to control and decrease the noise environment associated with his airport. Hence, the regulation requires the airport proprietor to propose single event noise limits for his airport which, once approved by the Department of Aeronautics, would be enforced under the regulation. The maximum limits the airport proprietor may select are set forth in the regulation, and depend upon the categories of aircraft which routinely utilized his airport during the six month period before it was determined to have a noise problem. This basis for the maximum single event limits prevents entry of new, noisier aircraft types into an airport which already has a noise problem, while the option of selecting lower limits adds the strength of the $1,000 fine (for violation of single event limits) to the means available to the airport proprietor for controlling the extent of his airport's "noise footprint."

In establishing which sectors of the population should be protected from noise by the regulation, the primary guideline was the wording of the authorizing statute (AB 645) which referred to "a reasonable person residing in the vicinity of an airport." This guideline points out the fact that our concern must be primarily residential areas. In addition, because noise can be such a destructive element in schools, and because some schools lie outside residential areas, we have given specific attention to protection of schools in the standard.

There are many land uses which the standard deems compatible within the noise impact boundary. This does not mean, and should not be construed to mean, that the land uses deemed compatible can be developed without taking a responsible attitude toward the noise aspects of planning for use of specific building sites and for adequate noise insulation in the design and construction of buildings. The activities of a large metropolitan airport generate a demand for industrial land and land for hotel and office space. The standard does not specify maximum interior noise levels for such uses, but takes the view that the commercial and industrial development interests have sufficient resources at their disposal to have their buildings properly located and designed.

The phrase, "the vicinity of the airport," as construed in the standard means the airport interface and does not include the very real and growing noise problem from aircraft operating in the transition air space. Acoustically, the "vicinity of the airport" is the region enclosed by the airport's noise impact boundary. For a large busy airport, this boundary may enclose many square miles of land and extend several miles outward from the airport along the flight paths emanating from it. For a small airport without jet aircraft, the noise impact boundary will enclose a much smaller land area, and in most cases will actually lie within the airport's own property boundary.

While the approximate location of a noise impact boundary can be predicted by calculation, this is no substitute for actual measurement in the case of an existing airport. Prediction methods cannot take sufficiently accurate account of such effects as terrain features, attenuation of sideline noise by passage through blocks of buildings, and local variations in weather conditions. Such meteorological variations may, in some areas, include temperature inversions and resulting downward reflection of sound to points far away from the airport, unique humidity conditions affecting sound propagation or even altitude and temperature conditions which affect aircraft climb performance, and hence noise contours. The use of data from an entire year's measurements to verify the position of the noise impact boundary will assure inclusion of meteorological variations as well as seasonal variations in air traffic volume and runway utilization.

The definition of monitoring systems in the noise standard has been purposely written in the form of a performance specification without constraining the method by which the required accuracy and other performance requirements are to be met. There has been a general advance in the state-of-the-art of components (solid state components, integrated circuits, et cetera) which has not yet been utilized in noise measurement systems of a kind applicable here. Given the performance requirements set in legal form, plus a market demand for noise monitoring systems, we believe the acoustical instrumentation manufacturers will embark upon a development program to meet the demand for monitoring systems which are designed to be operable by technical personnel with a minimum amount of specialized training and sold at a price which is lower than that of existing specialized monitoring systems.

The selection of the A-weighting network for monitoring purposes (rather than more complex scales such as perceived noise level in PNdB or effective perceived noise level in EPNdB) has been based on the need to keep the monitoring systems as inexpensive as possible, coupled with evidence that the noise level measured in dBA is a reasonable predictor of community judgment of aircraft noise and approaches the accuracy of the more complex scale being used for aircraft noise certification (References 1 and 2). This determination is supported by statistical analysis of judgments of the same aircraft sounds as those on which the more complicated scales were based (for example, see Reference 3).

When the standard becomes effective, a number of existing airports will find they do not comply with the requirement that their noise impact boundary not enclose residential areas. Any meaningful noise standard must have this result, since there are several major airports with serious noise problems and a number of smaller ones with less extensive noise problems. Rather than take the unrealistic step of closing down airports, the standard provides a variance procedure which, if properly administered, will bring each airport gradually into compliance by a series of steps agreed upon with the Department and according to a definite time schedule.

For all airports (existing and proposed new airports) the end goal is the same: that the CNEL = 65 dB contour not enclose homes. For all existing airports, the time limit for achieving the end goal is set forth in the noise regulation: the end of 1985. Within this time range, those airports which are likely to have the most extensive noise footprint are given a specific stepwise set of goals, beginning at CNEL = 80 dB and reducing in 5 dB steps every 5 years, ending in the CNEL = 65 dB value by the end of 1985. This schedule applies to the major airports in the state which currently have 4-engine jet aircraft operations and at least 25,000 annual air carrier operations.

For all other existing noise problem airports, the initial requirement is that the CNEL = 70 dB contour not enclose homes. Here, no specific stepwise reduction is stated, but the goal to be met is CNEL = 65 dB by the end of 1985.

The foregoing schedules also dictate the value of CNEL where noise impact boundary monitors are to be located. Placement of the monitors according to this noise-reduction schedule focuses attention first on that region nearest the airport where the noise is most severe. Then, as progress is made in reducing the noise environment, and as the criterion value of CNEL for monitor location becomes progressively more stringent, the land region within the boundary tends to remain stable (facilitating land use planning), rather than contracting from a very large area to a smaller area. This use of a stated schedule informs in advance all those concerned with the solution of airport noise problems and the development of quieter airplanes as to the state's intentions, in a manner quite analogous to scheduled goals for exhaust emission standards for motor vehicles.

Within the framework of the scheduled goals and the guidelines stated at the beginning of the section on variances, the standard leaves the airport proprietor free to select those strategies he believes will be most effective in reducing noise from his airport. Several strategies for the reduction of the extent of the noise impact boundary (together with estimates of their effectiveness in reducing the enclosed total area) are described in Section 5.2 of this report.

In summary, the standard is based on the following basic concepts:

- That there is a noise environment around each airport which depends on the nature and use of the airport and is therefore subject to control through changes in that use.

- That above a certain numerical value the noise is exceissve for residential areas.

- That whenever this excessive noise intrudes upon residential areas, the noise environment should be measured and the airport proprietor directed to take steps to bring the noise environment into compliance with specific performance standards.

- That the airport proprietor himself is best qualified to select specific operational changes at his airport (with approval of the enforcing agency) to meet the performance standards.

- That new airports should be sited and operated in such a manner as to comply with the performance standards at all times.

We believe the basic structure of the adopted noise regulation (in conjunction with other existing laws) provides for the first time the basis for genuine solution of existing community noise problems around airports and prevention of such problems in the future.

4.0 BASIS FOR THE RECOMMENDED LIMIT ON COMMUNITY NOISE EQUIVALENT LEVEL

It must be realized that there is a wide range of variability among people concerning susceptibility to noise, in terms of both its physical and psychological effects upon them and their individual subjective reactions to it. That fact is evident in the statistical distribution of results from any kind of experiment such as on sleep disturbance, and is evident from our everyday observations of people. The setting of noise limits for a large population, therefore, is far from being an exact science, and data must be obtained from a variety of sources and considered as a body to provide a basis for the judicious setting of limits.

Much of the available data on the effects of noise on people was reviewed as a basis for establishing the limit value for community noise equivalent level (CNEL) within which the noise environment would be too high for residences. These effects include disturbance of sleep, interference with speech communication, physiological stress reactions and the possibility of hearing loss. It was found that the most restrictive of these are sleep and speech communication criteria, and these criteria have been considered in arriving at the proposed limit value of CNEL applicable to residential land uses.

However, these kinds of factors only tell us something about limiting the magnitude of the noise, but not about limiting the number of flights. Certainly, our subjective experience tells us that it would be worse to have ten noisy flights at night than to have one, or to have a transient sound of sufficient magnitude to interfere with conversation occur ten times per hour as compared with once per hour. Also, one would expect that if levels sufficient to cause physiological stress reactions are experienced frequently, then such long term health effects as they might induce would be more probable or more pronounced as flight frequency is increased. However, the research data on the above human factors do not give us any quantitative basis for determining how much relative importance to place on the number of events as compared to the magnitude of noise per event, for those criteria most relevant to residential noise limits: speech communication and sleep disturbance. Only in the case of permanent hearing loss due to noise exposure is the effect of cumulative exposure time well known. For information on the quantitative importance of frequency of occurrence, it was necessary to refer to two other kinds of data:

- Results of community-wide questionnaire surveys about noise.

- Collections of case histories of people's complaints and other actions in response to aircraft and other kinds of noise in their environment.

From cautious analysis of this kind of data against the background of data from experiments on directly measurable effects as described above, one can determine approximately how much relative importance to place on number of events and magnitude per event, and can be guided in the setting of a composite noise limit.

The following sections present the background information and data which have formed a basis for the proposed limit value of CNEL at the noise impact boundary. There is a vast amount of literature on the subject. The portion referenced here is typical, relevant to the problem at hand, and comprehensive in scope, but by no means does it include every available reference on the subject.

4.1 Human Factors Basis

The human factors basis for limitation of noise in residential areas includes sleep disturbance, speech communication, physiological stress reactions induced by noise and the possibility of permanent hearing loss due to noise exposure. The evidence comes from laboratory research and field studies. Individual annoyance appears to be related to the sleep, speech interference and stress factors (since it appears to be from such factors that the annoyance arises), and thus individual annoyance is not treated here as an additional factor. It will, however, play a role in the responses of individuals to noise in their environments, to be discussed in Section 4.2, below.

4.1.1 Sleep Disturbance

Sleep disturbance caused by noise often occurs without the sleeping person's knowledge. Noise which is not sufficient to arouse the subject may impair the quality of sleep by shifting him from a deeper stage of sleep to a shallower stage, or by depriving him of a sufficient amount of the portion of the sleep period which is connected with dreaming and which is thought to be most important for rest.

The effects of noise on sleep have been observed by studying the subject's brain wave patterns with an electroencephalogram (EEG). A number of laboratory experiments have been done using this technique, some using artificial and steady sounds as the disturbing noise, and others using transient sounds (such as aircraft flyby noise and truck noise) more related to the present subject. Other laboratory experiments have been performed in which actual awakening of the subjects was the only means of observing sleep disturbance effects of the noise. Further information on sleep disturbance by noise (particularly aircraft noise) comes from community annoyance surveys in which each person is asked to complete a detailed questionnaire (including questions on how frequently he is kept from going to sleep or is awakened by noise) and the noise characteristics of the environment are also measured. Results of several of the better documented studies are described below.

Grandjean (Reference 4) studied the disruption of sleep by noise among 343 persons sleeping in their bedrooms, observing only actual awakening, without benefit of EEG traces. He used noise without any sudden changes in volume and in which equal energy existed across the whole frequency spectrum. The sounds he used (converted to A-weighted sound level) produced the following results:

Table 1

RESULTS OF GRANDJEAN'S SLEEP EXPERIMENTS

Level of the Disturbing Sound, dBA	Percent of Subjects Awakened
36	10
41	23
46	40
51	50

Jansen (Reference 5) used EEG traces and noise of a quality similar to that used by Grandjean to study the sensitivity of seven subjects for a total of more than 120 nights. Jansen found that noise of modest intensities influenced even the deepest stages of sleep when his sleeping subjects were exposed to noise stimuli lasting for periods ranging from 300 milliseconds to 90 minutes. The levels of noise he used were rather high in comparison with those used in most other sleep experiments, and were in the vicinity of 60 to 65 dBA.

Another study of sleep through recording of brain wave patterns was made by Thiessen (Reference 6), using the recorded noise of passing trucks, at levels ranging upward from 40 dBA. He found that at levels between 40 and 45 dBA, 10 percent of the subjects either shifted to a shallower stage of sleep or awakened; at a level of 50 dBA, 50 percent of the subjects either shifted to a shallower stage or awakened.

Lukas and Kryter (Reference 7) experimented with recorded noise of aircraft flybys and used EEG traces. They found that at noise levels corresponding to about 87 dBA outdoors (which would probably correspond to about 67 dBA indoors, although we do not have sufficient information on the level to which the sleeping subjects were exposed), 50 percent of their subjects were fully awakened. The effect of going to lower levels was not explored, but a limited experiment was used to find the trend with age of the subjects. As one might expect from experience with children and their grandparents, the older people were found to be more susceptible to being awakened by aircraft noise than middle-aged people, and children were found to be by far the least susceptible to noise as a source of sleep disturbance.

There are some inconsistencies among the results of the foregoing experiments, and these are likely a result of differences in age of subjects, background noise level during the experiment or such other parameters as may have a strong effect upon the results but were not always reported. More definitive research will be needed before these discrepancies can be resolved.

In the meantime, some additional light is shed on the matter by the responses of people in questionnaire surveys (in conjunction with measurement surveys of the noise environment) insofar as complete awakening is concerned. A number of such survey results are available:

(1) From studies around military air bases, some of which are reported in References 8 through 13 and which led to the development of annoyance prediction guides and land use planning guides in the late 1950's, References 14 and 15.

(2) From studies in Europe on aircraft noise and traffic noise (e.g., References 16 through 20).

(3) From a small sample obtained in the course of a project in the soundproofing of homes around an airport (Reference 21).

Most of the references from the work around air bases are more related to community annoyance (Section 4.2), but Clark (Reference 8) made one of the early attempts to determine a relationship between sound level from aircraft flybys and the number of persons reporting sleep disturbance.

A more comprehensive study in London (References 16 and 18) related the noise exposure to the various activities disturbed as reported by 1730 persons in the survey. The responses were related to a noise rating scale which includes both noise magnitude and number of events. From these results, if one makes a reasonable assumption about the noise reduction performance of the homes with some windows open, it is possible to relate the percentage of persons reporting sleep disturbance to the approximate interior noise levels they would be experiencing for any typical number of flights. Figure 8 shows their responses, for about 30 flights per day, and compares them with the data from sleep experiments in which sleep disturbance was reported in terms of percentage of persons affected. It is important to note that the noise levels in Figure 8 are the indoor noise levels and that the outdoor levels would be significantly higher (See Section 4.1.4).

From Figure 8, it is apparent that as noise level is increased, a gradually increasing fraction of the population can be expected to experience sleep disturbance, and that (from any basis) 20 percent or more of the population may suffer some form of sleep disturbance if the indoor noise exceeds 45 dBA. Results from a project in soundproofing of homes (Reference 21) tend also to support the foregoing conclusion. In that project, 20 owner-inhabited homes around a major airport were acoustically modified, extensive interior and exterior acoustical measurements were made during aircraft flybys (both before and after the modifications) and the owners were interviewed at length (both before and after the soundproofing) about specific activities with which the noise interfered including sleep. While there was a wide scatter in the data, the results tend to support the conclusions one would draw from Figure 8. Namely, there appears to be a significant increase in sleep disturbance problems above interior noise levels of 45 dBA.

The tenuous nature of this conclusion is apparent from the spread of the data. Nevertheless, some authorities have acted to establish indoor noise limits for health resorts and residential areas (see Figure 8) as reported in Reference 22. While it is not yet possible to scientifically demonstrate a direct connection between sleep disturbance and long term health, it is logical to believe that repeated exposures to sleep-disturbing levels of noise may well result in some form of health deterioration.

4.1.2 Interference with Speech Communication

Noise can interfere with speech communication by preventing one's hearing some of the words or sentences being communicated. Speech communication includes direct communication between speaker and listener (such as conversation and classroom lectures) and includes listening to television or radio and telephone communication.

The speech interference effects of noise have been thoroughly studied and well documented and criteria for designing environments for good speech communication have been a standard tool of acousticians and architects for

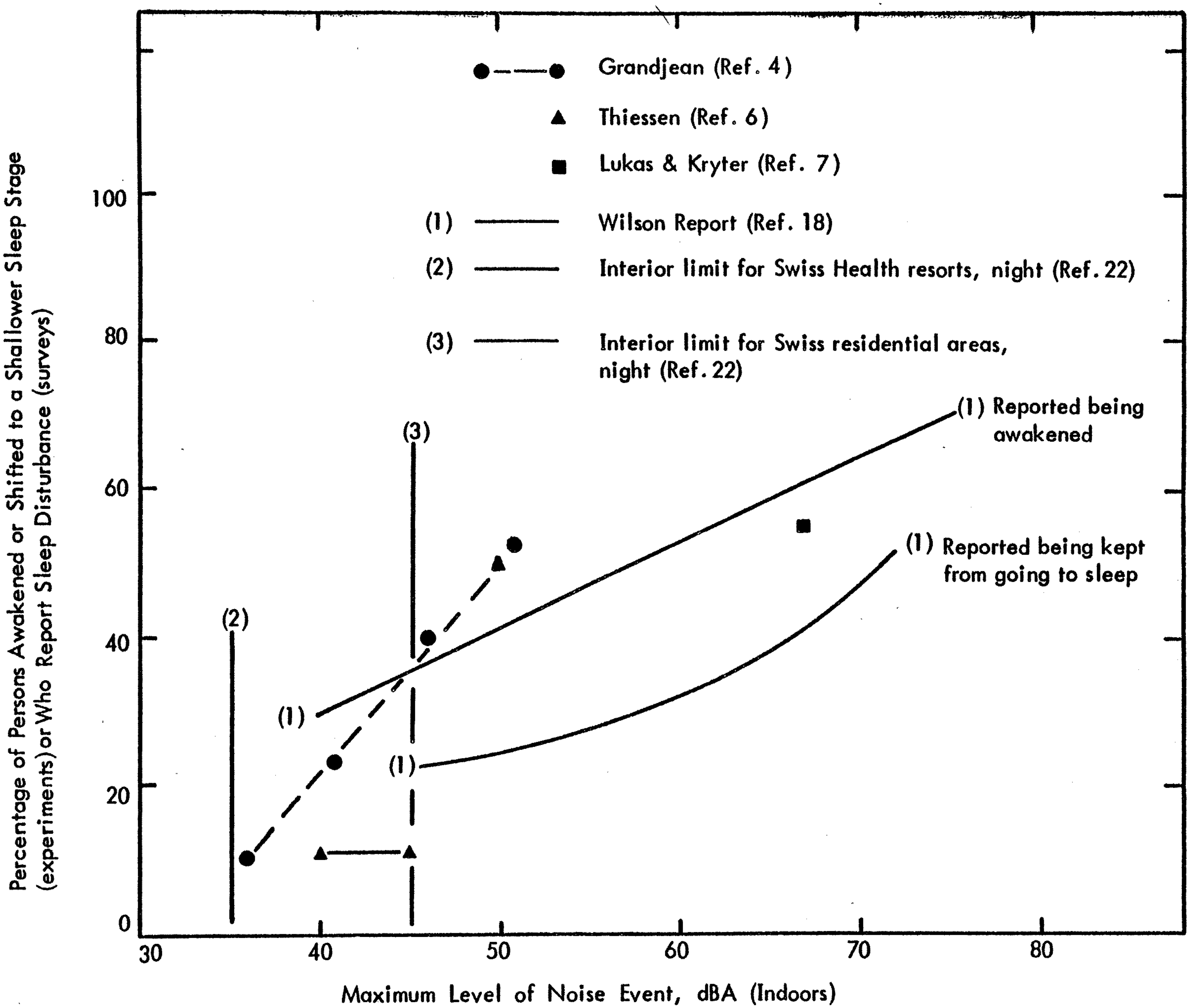


Figure 8. SOME DATA ON SLEEP DISTURBANCE BY NOISE

many years in the design of offices, classrooms, auditoria, et cetera. The criteria which have been developed are expressed in terms of the "speech interference level" (SIL) of the interfering noise. The range of frequencies most important to speech communication is comprised of the three octave bands centered at 500, 1000 and 2000 cycles per second (or Hertz), and the magnitude of a noise can be expressed in terms of the noise level (in decibels) in the SIL scale, by the average of the octave band sound pressure levels in the three octave bands.

The ability of a speaker and listener to continue good communication in spite of an interfering noise depends not only on the magnitude and tonal characteristics of the noise but also on the volume of the speaking voice and on the distance between the listener and the speaker. Standard curves have been published, based on the accumulation of much experimental research, which show the noise limits to be set for various speaker-listener distances. The limits corresponding to the case where the speaker is using a normal voice level (as opposed to a raised voice) have been extracted from Reference 23 and shown in Table 2. For such sounds, the level in the SIL scale is typically 7 dB lower than the A-weighted sound level. The precise conversion from values in the SIL scale to the A scale depends on the spectrum of the sound in question. The numbers in Table 2 are typical for aircraft and many other transportation noise sources.

Table 2

NOISE LEVELS THAT BARELY PERMIT RELIABLE CONVERSATION AT VARIOUS DISTANCES AND A NORMAL VOICE LEVEL

Distance Between Speaker and Listener, Feet	Level of the Interfering Noise, dBA
1	75
2	70
3	66
4	64
5	62
6	60
10	56
20	50

The values in this table represent the limiting case, and more reliable and complete understanding of communication in a conversational tone could be achieved at slightly lower levels of the interfering noise.

From information on typical speaker-listener distances in the rooms involved (such as living rooms, family rooms or classrooms), a noise limit can be set which provides for good, uninterrupted speech communication. This basis for setting of limits is extremely important in the residential application, since (as will be seen later) it constitutes the most restrictive criterion for daytime activities typical of residential areas. In general, a typical listener-speaker distance in homes does not exceed 10 feet for a normal conversation, and one would therefore tend to limit the level of any frequently occurring interfering noise to 56 dBA or less in living rooms, family rooms, et cetera.

4.1.3 Physiological Stress Reactions to Noise and Potential Health Effects

There have been a number of experiments reported on the ability of noise to produce measurable physiological stress reactions. These stress reactions derive from a widespread activation of the autonomic nervous system, resulting in changes in salivation, gastric activity, heart rate, respiration rate, blood vessel diameter, pupil size and sweat gland activity. Experiments to establish some of the kinds of stress reactions which can be induced in animals and humans by exposure to noise are typified by References 24 through 30.

Many of the experiments have used stimulus sounds at levels well above the region of interest here. However, the indications of the experiments at noise levels more ordinary to everyday experience do reinforce the (lower) levels required for a good speech communication environment. Jansen (Reference 5) has tentatively concluded from his own experiments that the threshold of stress response is at about 65 dBA and that reactions become pronounced at 80 to 85 dBA. The region of 80 to 85 dBA, incidentally, corresponds approximately to the threshold level at which temporary hearing loss can occur.

There is a growing body of evidence that recurrent exposure to noise levels capable of inducing measurable stress reactions may produce physical health effects in a substantial portion of the exposed population. Attempts to gain insight into this question have produced results which would encourage conservatism in the setting of noise limits. For example, a Swedish study of traffic noise (Reference 19) has shown that symptoms such as headache, insomnia, and nervousness are so well correlated with the noise exposure that one can use the intensity of annoyance as an index of the severity of the exposure. There is reason to suspect that periods of exposure to stress (including noise as a stressor) may temporarily alter the subject's resistance to infectious disease, Reference 31. The question of psychological effects has been raised by a British study (Reference 32) which implicated noise as a possible factor in increased rates of admission to mental hospitals. In this study, such factors as age, sex, marital status, population density, and socioeconomic status were reasonably well controlled, and the study (covering two years of admissions to a psychiatric hospital) showed significantly higher rates of admission from inside an area of maximum noise near London's Heathrow Airport than outside that area.

In a position paper for the American Association of Public Health on the effects of noise on health in the residential environment, Dr. John Goldsmith (California Department of Public Health) and Erland Jonsson (sociologist with the Swedish National Institute of Public Health) (Reference 22) recommended epidemiological studies of exposed populations in order to determine the health effects of noise-induced stress.

Thus far we know of only one study where the effects of aircraft noise on populations have been studied in terms of physical health effects. This was a study in the USSR, Reference 33, which contained the following elements:

(1) Measurements were made of the noise at ground level around nine (unidentified) airports utilized by all the main types of Soviet civil aircraft, including turbojet, turboprop and piston-engine powered transport aircraft.

(2) Health statistics concerning the same populations were collected and analyzed, and it was found that those residents within 6 kilometers (approximately 3.7 statute miles) of an airport had higher incidence (by a factor 2 to 4 times) of otorhinolaryngological diseases (otitis and auricular neuritis), cardio-vascular diseases (hypertension and hypotension), nervous diseases (neuritis, asthenic states), and gastrointestinal diseases (gastric and duodenal ulcers, gastritis), especially the young and middle-aged people. The brief summary report in the published literature, unfortunately, does not give the trend or distribution of these results as a function of the noise environment itself. We infer from their table of sound levels and distances, however, that the quoted distances are measured along the primary climb paths, from a point at the beginning of take-off roll. These studies were carried out for the adult population (over 15 years of age) by analyzing 145,000 diagnostic cards, and for the school children

(9 to 13 years of age) by clinical examination in residential areas adjacent to airports and in a control area remote from airports.

(3) The research team carried out physiological tests of 15 healthy subjects in the age range 21 to 30 years, by exposing them in a soundproofed chamber to tape-recorded noise of the TU-104 turbojet transport aircraft at 60, 70, 80, and 90 dBA for 10 and 20 flights per hour. The physiological effects of the noise were studied by direct measurement of brain waves, pulse rate and pulse wave amplitude. Aircraft noise at 60 and 70 dBA was found to have no effect, while 80 dBA produced slight effects and 90 dBA produced pronounced effects. Most of the effects which occurred at 90 dBA for 10 flights per hour became more pronounced at 20 flights per hour. The kinds of effects found were decreases in pulse wave amplitude (due to constriction of the blood vessels) and depression of the electric activity of the cerebral cortex which caused increases in the latent period of response to both light and sound.

(4) The subjective reactions of the populations surrounding the airports were studied by sociological survey (individual interviews using a questionnaire) including over 2000 persons in 22 urban and rural areas located within 40 kilometers (approximately 25 statute miles) of the airports.

From the combined results of all the foregoing studies, the Russian research team concluded that aircraft noise of 90 dBA is not permissible in populated areas and recommended that maximum permissible levels be set at 85 dBA in the daytime and 75 dBA at night for populated areas.

Again, it seems apparent that health effects of the kind reported in the Russian study must be a function not only of the magnitude of sound but of the number of times (per 24-hour period) the populace is exposed to it. Certainly a sound intense enough to cause a stress reaction will have more effect on health if it occurs many times a day than if it occurs only once or twice a day. Until a more definitive answer is obtained regarding the importance of flight frequency, we would do well to check any limits established in a composite scale such as CNEL, by comparing the sound levels of individual flybys at the noise impact boundary against the limits recommended by the Russian researchers.

Considering the growing evidence of long term health from repeated exposure to noise levels capable of inducing stress responses, it is fortunate that the health-related criteria which may emerge in the future are not as restrictive as the criteria related to sleep and speech communication, for which we already have a firmer data base.

4.1.4 Noise-Induced Hearing Loss

It is the purpose of this section to show that the noise limits required for hearing conservation are so much higher than those required by other considerations (such as sleep- and speech-related criteria) that in a properly protected community, hearing loss criteria cannot play a role in the setting of noise limits.

Exposure to high-intensity sound can cause a temporary loss of hearing, with normal hearing acuity returning gradually after the noise ceases. If the conditions leading to temporary loss are repeated frequently enough over a period of years, some degree of permanent hearing loss will result. Some permanent loss of hearing can result from a single exposure to very extreme noise, of magnitudes never experienced by most people, such as from being too near a dynamite blast or explosion.

The basis for predicting hearing loss from noise exposure is relatively well established and given in Reference 34. A convenient expression of limits in the A-scale, though slightly less protective than implied in Reference 34, exists in both the California labor code and the federal Walsh-Healey Act as amended, Reference 35. The federal regulation states that personal ear protectors must be worn whenever noise levels exceed those shown in Table 3, when measured on the A-scale of a sound level meter at slow response.

Table 3

WALSH-HEALEY ACT AMENDMENT VALUES

Noise Exposure Limits

Duration per Day, Hours	Sound Level, dBA
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
1/2	110
1/4 or less	115

The limit values are based on the assumption of a ten-year exposure of the worker to the noise environment, day in and day out. On the other hand, these limits are based on the most damaging case; namely a steady noise which lasts for the entire time period given in the table and thus leaves the ear no opportunity to recover between sounds. Intermittent noise, as typified by aircraft flybys, is much less able to produce a temporary shift in hearing threshold and hence is much less able to produce permanent hearing loss than steady noise. In fact, the temporary threshold shift, according to Ward (Réference 36), is proportional to the fraction of the time the noise is present. A noise that is present only half the time (in durations of a few minutes or less, comparable to aircraft flyby noise) can be tolerated for more than twice the total exposure time that could be spent in the noise if it were continuous, before a given temporary threshold shift would be produced, and hence a given potential for permanent loss. These two facts (the intermittence of aircraft flyby noise and the ten-year basis of the limits themselves) provide a margin of safety when the limits are applied to the problem at hand.

Based on the foregoing information, we believe a limit of 110 dBA (per event) should be established in any populated area, whether used for residential purposes or not. However, noise limits in residential communities will be set at lower values than these for other reasons; e.g., sleep and speech communication criteria. If the limits imposed by these criteria are met, the hearing of the residents will definitely be conserved as well.

4.1.5 Outdoor Noise Levels

Noise limits for airports need to be stated in terms of the outdoor noise level the airport generates. For those activities which occur indoors (sleep and much of the speech communication), the outdoor limit will be the sum of the indoor limit and the noise insulation properties of residences.

There remains the question of the relative importance of the indoor and outdoor noise environments, which requires a value judgment, and this judgment would best be made by the residents themselves. In most residential areas of California, the outdoor environment is prized as a major facet of the life style. This is particularly true in areas of single family dwellings, but appears to be less true in the case of multifamily dwellings or apartments. There is reason for uncertainty regarding this apparent lesser importance of the outdoors to apartment dwellers, since the design of apartment complexes in the past has not given sufficient emphasis to the provision of outdoor recreation space, thus limiting the alternatives open to the apartment dweller. A strong indication was obtained from homeowners around a major airport (Reference 21) that they definitely judge the area to be unfit for residential use whenever the outdoor noise levels from aircraft flybys (on average) exceed approximately 85 dBA, regardless of how quiet the interior of their home had become as a result of acoustical modifications. It must be noted that these people were probably experiencing approximately 250 flight operations per day and that the same level would be judged less annoying if there were only a few flights per day.

Caution in interpreting this response is in order, since the people may have been somewhat inured by a long history (more than two years) of exposure to these noise levels, particularly in light of the rising complaints (at approximately 10 dB or more lower levels and much lower flight frequencies) from people with a shorter exposure history. It should be noted that uninterrupted speech communication outdoors is impossible at these noise levels (85 dBA), which are comparable to levels produced by a large diesel truck passing by. From the opinions of the people in Reference 21, however, one can establish a noise region around very busy airports where the land is definitely judged unsuited for single-family residences, no matter how much acoustical protection they afford.

It is also certain that the interior environment in homes must be maintained below acceptable noise levels. For normal California residential construction, with some windows open about 6 inches, the noise insulation of the average house (on the noisy side) is 20 dBA, Reference 21. Self-shielding can account for additional protection of as much as 10 dBA on the "shadow side," for homes situated well to the side of the flight path. With all doors and windows closed, the average noise reduction (on the noisy side) is 28 dBA. This data is based on an average of measurements in more than 100 rooms in 20 houses scattered around the airport, using actual aircraft flybys as the noise source. These values, if added to the interior noise limits will give the exterior noise limits for normal residential areas. The value of 20 dBA for the noise reduction performance of homes has been utilized in development of the noise regulation.

If it is felt desirable to retain existing residential areas nearer to airports than the resulting exterior noise limit allows, a noise insulation of 35 dBA can be achieved by modifications to existing homes, at considerable cost (on the order of $4,000 to $6,000 per home when achieved by modification rather than original design). It could also be achieved in new construction (at much less cost) by special attention to acoustical requirements during the design. However, one questions whether new construction of single-family residences should be permitted in a noise region better suited to uses which place less value on use of the outdoors. For high-rise residential constructions (e.g., with substantial walls, air conditioning and fixed plate glass windows) the same noise insulation (35 dBA) is easily achieved in normal construction.

4.1.6 Summary of Implications for Noise Limits Based on Human Factors Data for Single Noise Events

From the foregoing sections, one may conclude that

- Interior noise levels much above 45 dBA are likely to cause sleep disturbance effects in a significant percentage of the population. This corresponds to exterior levels of 65 dBA with some windows slightly open, or 73 dBA with all doors and windows closed.

- Interior noise levels to allow uninterrupted speech communication at normal voice levels (at distances typical of rooms in houses) should be restricted to levels below 56 dBA. This corresponds to exterior levels of 76 dBA with some open windows, or 84 dBA with doors and windows closed.

- The necessity to restrict interior noise to levels below 65 dBA is reinforced by tentative indications from the limited research on physiological stress reactions. This is equivalent to outdoor levels of 85 dBA with some windows slightly open.

- Outdoor levels above 85 dBA, for areas with very frequent flight operations (approximately 250 per day or more), are judged by the residents to make the area unsuited to residential use, irrespective of the indoor levels. This outdoor limit for residential areas is further reinforced by studies correlating physical health effects with aircraft noise environments.

- At no time should individual noise events (outdoors or indoors) be allowed to exceed 110 dBA in populated areas, even for very short time durations.

4.2 Community Annoyance Reaction Bases

The foregoing human factors bases do not provide any quantitative information on the relative importance of noise magnitude and frequency of events. Evidence which brings in the factor of exposure time (and thus allows determination of noise limits that include the effect of flight frequency and duration per event) must come from situations in which the residents' opinions have been collected and can be related to known properties of the noise environment they were experiencing at the time, including both noise magnitude and exposure times. Such evidence comes from (1) community annoyance surveys, and (2) spontaneous reactions of individuals and groups to specific community noise situations.

4.2.1 Community Annoyance Surveys

The first category of data source is the results of community questionnaire surveys as represented by References 16 through 20. This survey technique was tested and formalized by sociologists working with the Organization for Economic Cooperation and Development (OECD), Reference 37. When accompanied by noise measurement surveys of the same area in which the social survey is conducted, and compared against the distribution of complaints in the area, such community questionnaire surveys can be quite illuminating. The major results from one such survey will be reviewed next.

In the survey around Heathrow Airport (London), References 16 and 18, some 1730 persons were interviewed and their responses correlated against the specific aircraft noise environment where they lived. This environment was described in terms of a composite rating scale called Noise and Number Index (NNI), which incorporates the magnitude of the noise of each flyby and the number of flybys heard. The questionnaire technique involves a series of nondirective questions which will allow the respondent to initiate the subject of aircraft noise, followed by more specific questions leading into the subject of noise. Questions are asked about specific activities interfered with by the noise, how frequently this occurs and how annoying it is, and a number of other questions which taken as a group allow a total picture of how the subject judges the noise environment.

The nature of many of the questions will be evident from Figures 9 through 12. Figures 9 and 10 summarize the responses to questions dealing with interference with speech and TV listening and with disturbance of sleep or rest. From these two figures, there does not seem to be any specific value of NNI at which one could draw a limit without almost arbitrarily drawing the limit at some given percentage disturbance. Figures 11 and 12, however, show that the specifically noise-related responses begin to increase at a rapid rate around NNI 35. The subjective overall rating given the aircraft noise environment by the people is shown in Figure 13, from which the boundary between "little annoyance" and "moderate annoyance" appears to be in the region 35 to 40 NNI.

Another interesting result of the same survey was a finding which is illuminating regarding complaint data: when 1 percent of the people were registering complaints, 10 percent actually felt like doing so; and when 10 percent were complaining, 40 percent actually felt like doing so. For this reason, and because there are other factors which can cloud the meaning of complaint data, it is dangerous to base decisions on complaint data alone without specific knowledge of the situation and without cross-checking against all other available bases.

Based partly on community questionnaire survey results and partly on studies of spontaneous community reaction to aircraft noise, many countries have developed their own rating scales analogous to NNI. Some of these scales will be further described in Section 4.2.3.

4.2.2 Community Reaction Data

The second type of data source for prediction of community annoyance is collected information on spontaneous reactions of individuals and groups to specific community noise situations.

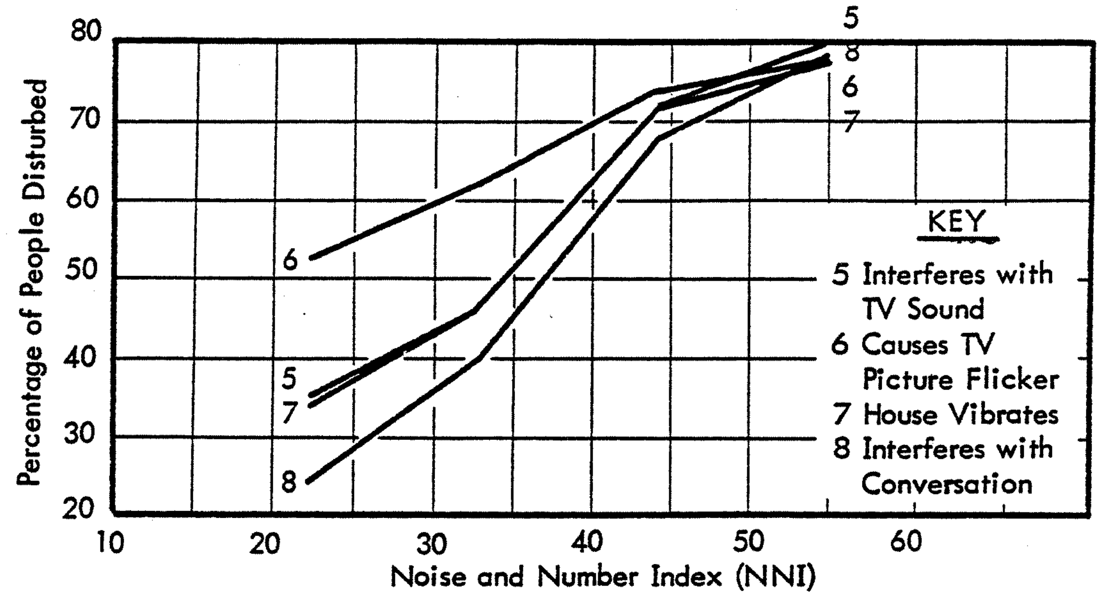


Figure 9. PERCENTAGE OF PEOPLE DISTURBED BY AIRCRAFT NOISE FOR VARIOUS TYPES OF REASONS CONCERNED WITH DOMESTIC FACTORS

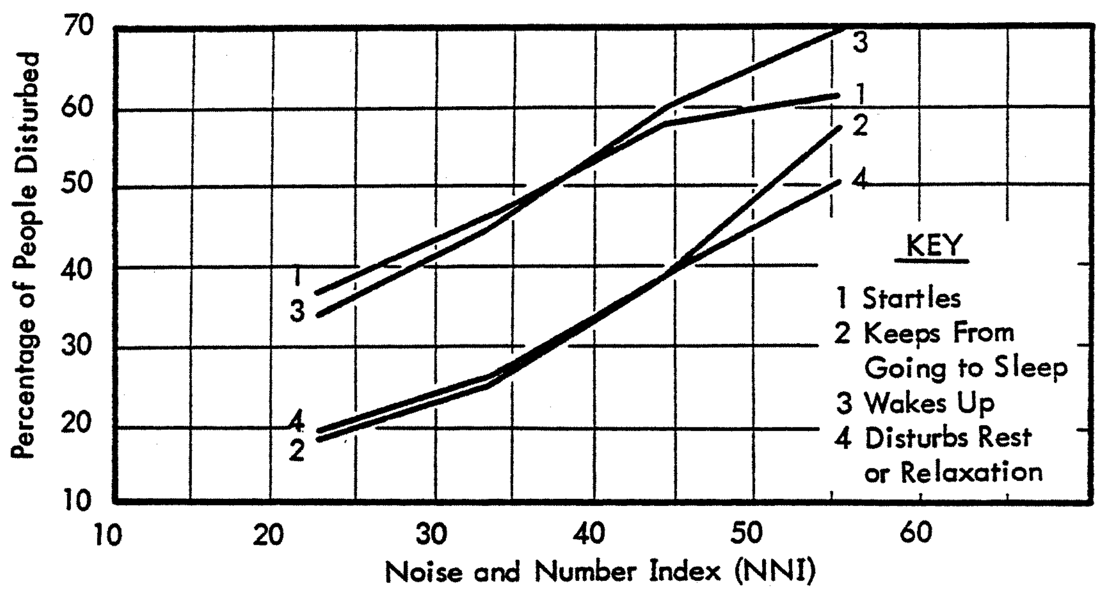


Figure 10. PERCENTAGE OF PEOPLE DISTURBED BY AIRCRAFT NOISE FOR VARIOUS TYPES OF REASONS CONCERNED WITH REST AND SLEEP

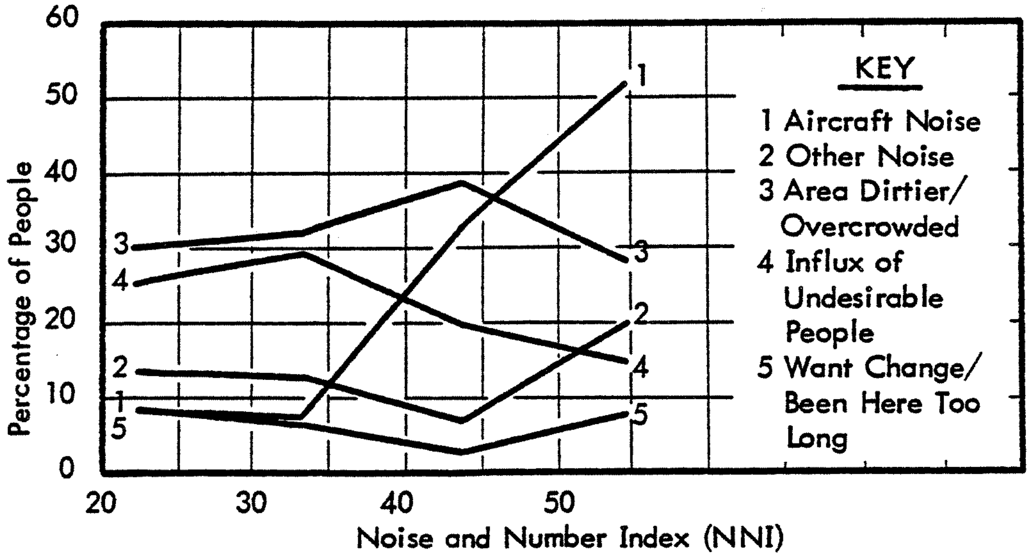


Figure 11. PERCENTAGE OF PEOPLE LIKING THEIR AREA LESS NOW THAN IN THE PAST FOR VARIOUS REASONS

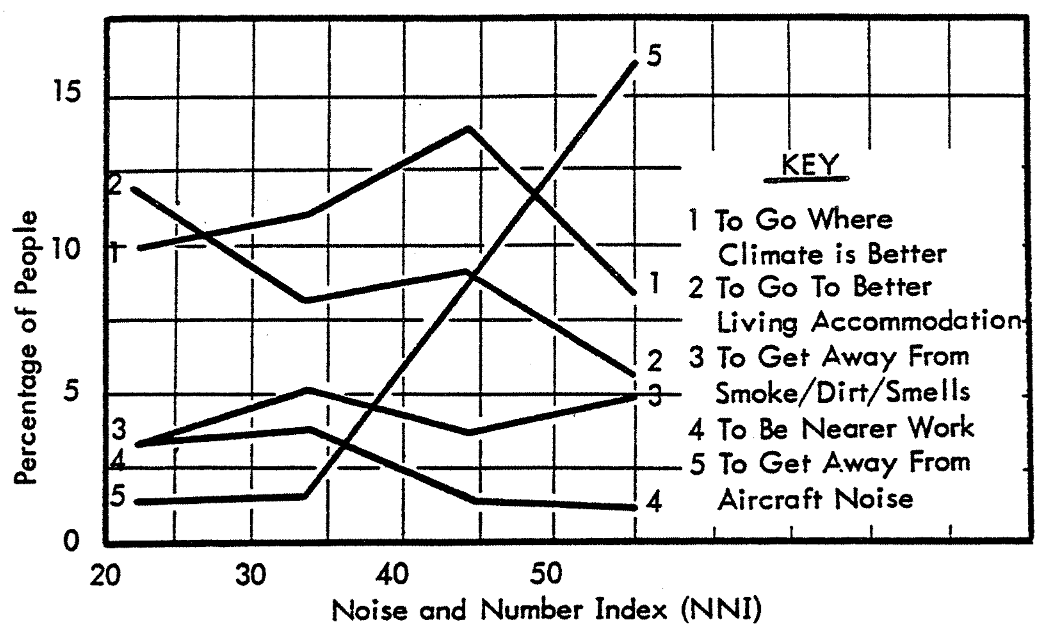


Figure 12. PERCENTAGE OF PEOPLE GIVING PARTICULAR REASONS FOR WANTING TO MOVE

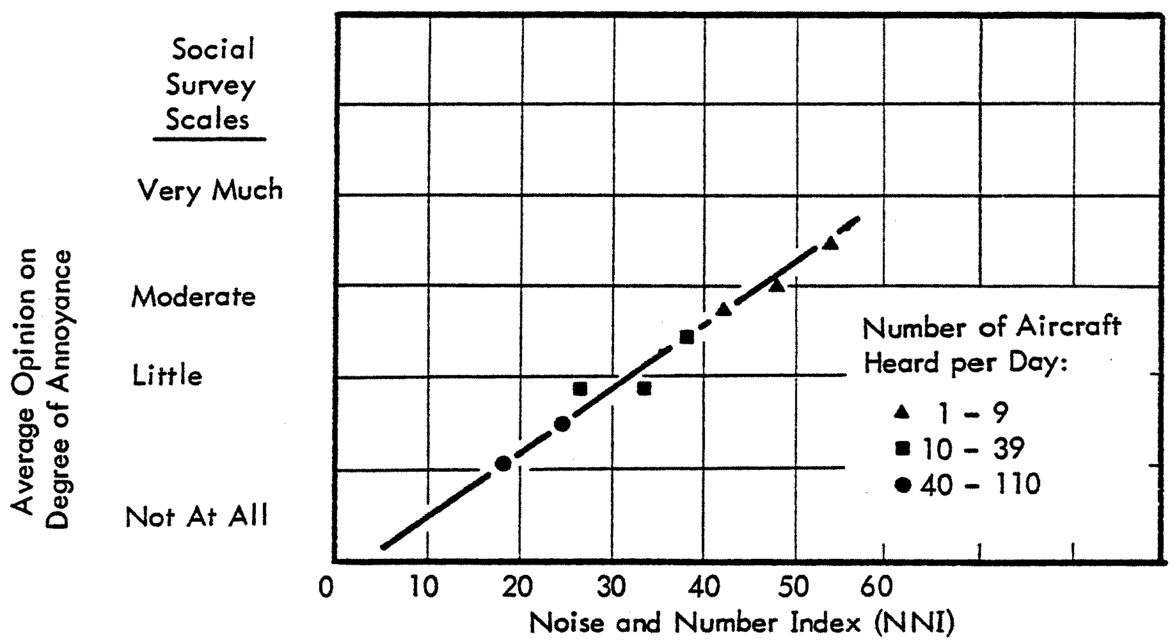


Figure 13. RELATION BETWEEN DEGREE OF ANNOYANCE AND NOISE ENVIRONMENT (NNI)

As early as 1957, studies of the jet aircraft noise problems around air bases had led to a method of predicting the degree of annoyance in residential communities, Reference 14. In addition, a methodology had been developed for making noise abatement design decisions, based on the need to minimize the annoyance in communities arising from all kinds of noise sources (industrial plants, refineries, drilling rigs, et cetera), Reference 38. These methods were the result of accumulated years of experience with community noise problems.

Individual data cases differ in terms of such things as time of day or night, exposure time related to the duration and repetition pattern of the disturbing noise, background noise level in the particular community, previous exposure history, presence or absence of discrete tones in the noise, and impulsiveness of the noise. Corrections can be applied to account for the effects of such circumstances, so that the meaning of the particular case in terms of the noise magnitude itself can be clarified. Corrections of this kind were given, for example, in References 14 and 38, and are shown in Tables 4 and 5. The result of applying these corrections to a group of specific case histories in community noise will be that all the cases are reduced to an equivalent steady noise, occurring under similar conditions of background noise level, time of day, et cetera. This treatment allows them to be compared on a normalized basis which displays the effect of noise magnitude alone.

Table 4

CORRECTION FACTORS FOR NORMALIZING COMMUNITY NOISE CASES TO A SINGLE MAGNITUDE SCALE

Type of Correction	Description	Amount of Correction to the Measured Noise Levels, dBA
Seasonal Correction	Summer (Year-around operations)	0
	Winter only	-5
Time of Day	Daytime	0
	Evening	+5
	Nighttime	+10
Correction for Background Noise	Very quiet suburban or rural community (remote from large cities and from industrial activity and trucking)	+10
	Normal suburban community (not located near industrial activity)	+5
	Residential urban community (not immediately adjacent to heavily traveled roads and industrial areas)	0
	Noisy urban community (near relatively busy roads or industrial areas)	-5
Correction for Previous Exposure and Community Attitudes	Community has had some previous exposure to aircraft noise but little effort is being made to control the noise. This correction may also be applied in a situation where the community has not been exposed to aircraft noise previously, but the people are aware that bona fide efforts are being made to control the noise.	0
	Community has had considerable previous exposure to aircraft noise, and airport relations with the community are good.	-5
	This correction can be applied for an operation of limited duration and under emergency circumstances; it cannot be applied for an indefinite period.	-10

Table 5

APPROXIMATE DURATION CORRECTIONS* FOR INTERMITTENT NOISE, FOR NORMALIZING COMMUNITY NOISE CASES TO A SINGLE MAGNITUDE SCALE

Effective Duration of Noise Each Hour		Approximate Time Duration Correction,** in Decibels
0.5-2.0	seconds	-35
2-6	seconds	-30
6-20	seconds	-25
20-60	seconds	-20
1-3	minutes	-15
3-10	minutes	-10
10-30	minutes	- 5
30-60	minutes	0

* Only one of the corrections is to be applied in a given case.

** Exact expression is $10 \log_{10} (\Delta t/3600)$, where Δt is the total on-time of the sound (in seconds) within each hour.

It should be noted (by the locations of the zero correction points in Tables 4 and 5) that this set of corrections is normalized to the following set of conditions:

- Year-around operations
- Daytime operations
- Background noise characteristic of a residential urban community
- Minimum correction for previous noise exposure history
- Noise occurs over an "on-time fraction" of zero to 50 percent; that is, up to 30 minutes per hour.

When the actual responses of a number of individuals or communities are plotted as a function of the resulting normalized average noise level, a correlation curve is obtained which represents the probable opinion (or action) in response to a steady noise having various levels. This is done by applying to each data case the set of corrections (from Tables 4 and 5) which correspond to the particular noise event or case history. The result is that differences between cases (such as different background noise levels, different percentages of on-time, et cetera) drop out, leaving a set of normalized data cases which differ only in their "normalized average noise level" and in the actual community response engendered by that noise situation. Figure 14 shows such a plot of nineteen (19) data cases, including both aircraft noise and noise from other sources and including several recent cases from areas not previously disturbed by noise. The kinds of community noise cases included on Figure 14 are as follows:

- Aircraft noise complaints from residential communities under the approach path of a major metropolitan airport in the early days of jet transports.
- Recent case of community action against aircraft noise from over-flights in the transition air space.
- Aircraft noise around an Air Force base with jet aircraft.
- Ground runup noise from aircraft engines.
- Aircraft noise complaints from hotel residents.
- Noise from ground testing of rocket engines for research aircraft.
- Noise from air system exhaust pumps at a factory, from electrical power substations, from vibration testing machines, from a cement plant, from a chemical plant, and from a large wind tunnel.

The usefulness of such a curve lies in its ability to (1) confirm the relative importance of noise magnitude and total exposure time, and (2) provide a prediction of community annoyance in response to a given noise situation, based on past value judgments made by the members of residential communities.

The horizontal scale in the figure is the time-averaged noise level (in dBA), which is approximately equivalent to the time-averaged values represented by the CNEL scale in the proposed noise standard. The two outer curves

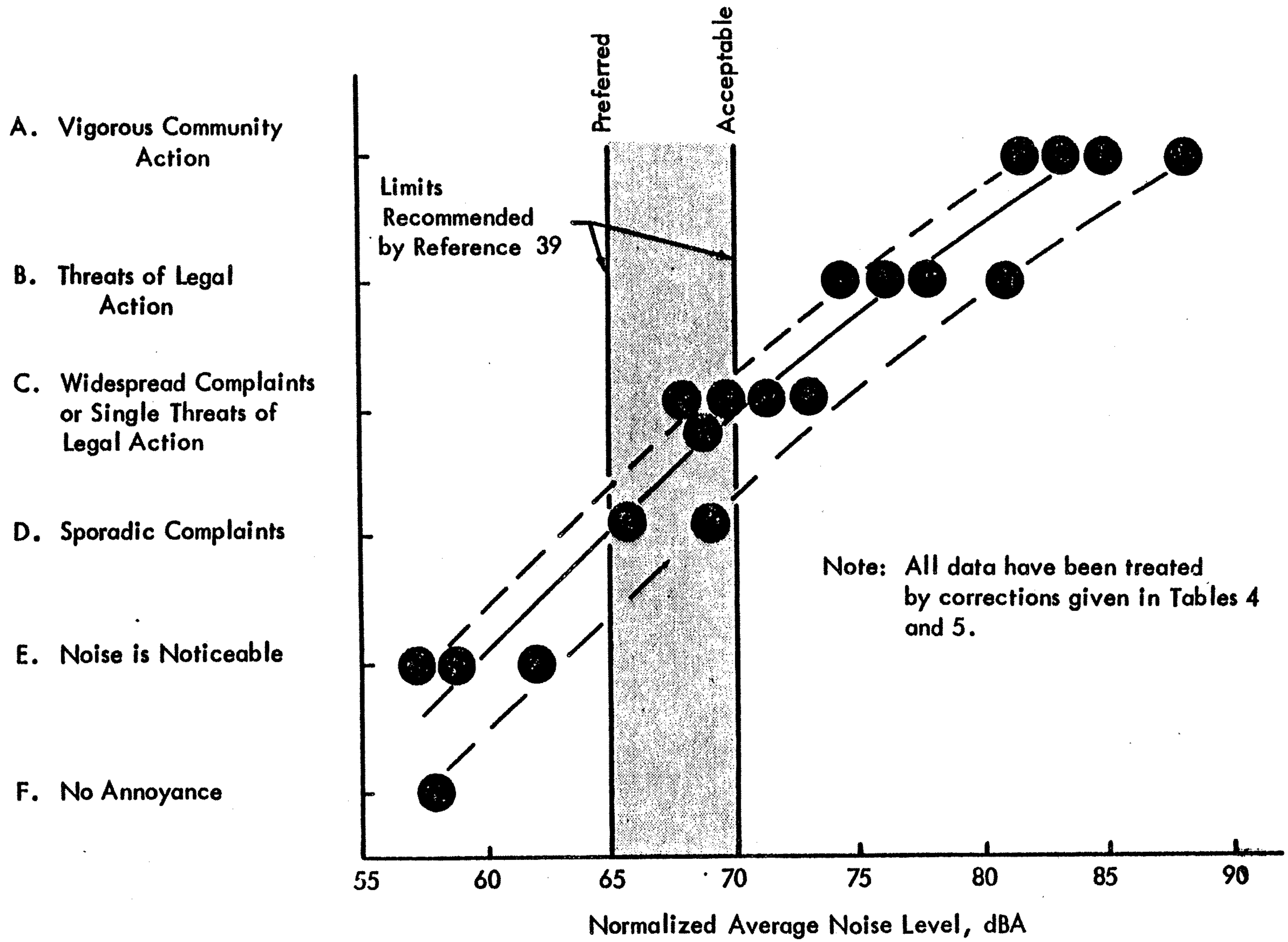


Figure 14. CORRELATION OF THE NORMALIZED AVERAGE NOISE LEVEL WITH COMMUNITY RESPONSE

show the range of the data scatter (about 10 dB) and the central curve is a median result. Using the median result for guidance, the threshold of complaints appears to be at an average noise level of 65 dBA (sporadic complaints), and the degree of discomfort expressed by the residents increases by one step about every 6 or 7 dBA thereafter. On the basis of this data, the recommended limit value of CNEL, applicable to residential areas and for purposes of the regulations only, is 65 dB.

The selection of a noise limit obviously involves a value judgment, and it is next desirable to compare this recommended limit with value judgments previously made here and in other countries. One such cross-check is available (Reference 39) from the work of Dr. Jonsson (Swedish National Institute of Public Health) who has recommended the setting of aircraft noise limits in terms of a scale which:

(1) Accounts for the effect of number of flights and for weighting in the three time periods of the day (day, evening, night) in the same way as in the proposed standard, and

(2) Recommends a "preferred" numerical limit for daytime operation which, after application of the same correction factors as have been applied to the data cases in Figure 14, is approximated by the line shown in Figure 14.

It will be noted that the "preferred" and "acceptable" limits correspond to CNEL = 65 dB and 70 dB respectively. In the words of Dr. Jonsson, the lower of these two limits is based on "20 percent of the population much bothered" in the Swedish study of reactions to aircraft noise (1959).

The recommended CNEL limit of 65 dBA should not be misconstrued or indiscriminantly used for purposes other than the noise regulation. Obviously, planning agencies and airport authorities may wish to utilize a lower figure in their own planning, particularly where the background noise levels may be lower than those in typical urban residential areas. On the other hand, in areas where outdoor living is not a primary element in the life style and the homes have air systems so that windows are normally closed, a limit 5 dB higher may be acceptable. In selecting other limits, one should note that existing knowledge of noise effects in residential communities is not precise enough to warrant changes in steps smaller than 5 dB.

In response to the requirement (in the authorizing statute) for consideration of economic and technological feasibility, a temporary criterion value of CNEL = 70 dB is recommended for existing airports. This value is to be applied in the determination of whether an existing airport has a noise problem. By 1985, the preferred criterion value of CNEL = 65 dB should be applied to all existing as well as all proposed new airports. For those major airports with 4-engine jet aircraft and at least 25,000 annual air carrier operations, consideration of economic and technological feasibility has included allowance of an initial noise impact boundary located at CNEL = 80 dB (for the purpose of determining noise impact area and locating boundary monitors). This initial value of CNEL = 80 dB is to be gradually reduced, in 5 dB steps, to arrive at the preferred value of 65 dB by the end of 1985.

Other rating scales analogous to the CNEL scale will be introduced next, and the recommended CNEL limits for the residential areas evaluated against them.

4.2.3 Comparison with Other Rating Scales

The community noise equivalent level scale in the noise standard includes those elements which are of importance in describing the noise environment around an airport:

- The magnitude of the noise from each noise event, and the way its energy is distributed across the frequency spectrum.
- The duration of individual noise events.
- The frequency of occurrence of the noise events.
- The distribution of the noise events among the time periods (day, evening, night).

We are using the generic term "composite rating scale" to include scales which account for these kinds of factors, and there are several such scales in use in various parts of the world. These composite rating scales were reviewed in Reference 40 and 41 and are briefly described here. They are generally used for purposes of decision making on suitable locations for new airports, on areas suitable for new residential construction around existing airports and for guidance in the amount of noise reduction needed for existing residential areas near airports. Also, a few European airports have noise monitoring systems installed to detect illegal flyover noise and for use as a tool in controlling and diminishing aircraft noise, e.g., Reference 42.

It is useful to compare the CNEL scale with other composite rating scales, in terms of the way in which they treat the various factors and in terms of how the recommended numerical limit (in CNEL) for residential areas compares with their limits. The major composite rating scales are listed below (Table 6) together with their country of origin. Basically, they all start from some measure of the magnitude of the individual noise event and add a weighting factor for the number of flights. This weighting factor is some multiplier to be used against the logarithm (to base 10) of the number of flights; this multiplier ranges from 10 (based on summation of total acoustic energy reaching the observer) to 15. Some of the scales include the effect of duration, but many do not. In the CNEL scale, accounting for duration and number of flights is easy to accomplish in a relatively simple monitoring system, since the monitoring device is to continuously sum all the A-weighted acoustic energy arriving at the monitor, whether from many flights producing relatively short duration sounds or from fewer flights producing relatively long duration sounds.

The more familiar of these scales (the first five in Table 6) are compared in Figure 15. In the figure, the relative vertical alignment of the scales shows their relationships to each other. The Q and NNI scales handle the effect of flight frequency in a way that differs from CNEL, CNR, and NEF, and so the comparison is approximate for numbers of flights other than the 200 per day on which the figure was based. The change in relationship among the scales, as the number of flights changes, is indicated by Figure 16. However, Figure 15 provides a visual means of approximate comparison and, more importantly, a comparison between the various zones and our selected CNEL limit of 65 dB.

The meanings of the various zones and notes are given in Table 7, insofar as those recommendations of the various countries which deal with residences. Lines corresponding to the values CNEL = 65 and 70 dB have been carried across the page for ease of comparison. While there is no official limit designated in England (on the NNI scale) for residential areas, a limit of NNI 40 is generally recommended, and some workers (Reference 43) have recommended a limit at NNI 38. The recommended limit CNEL = 65 dB is confirmed by this comparison to be a reasonable limit for noise in residential areas.

4.2.4 Summary of Implications for Noise Limits in the Residential Environment

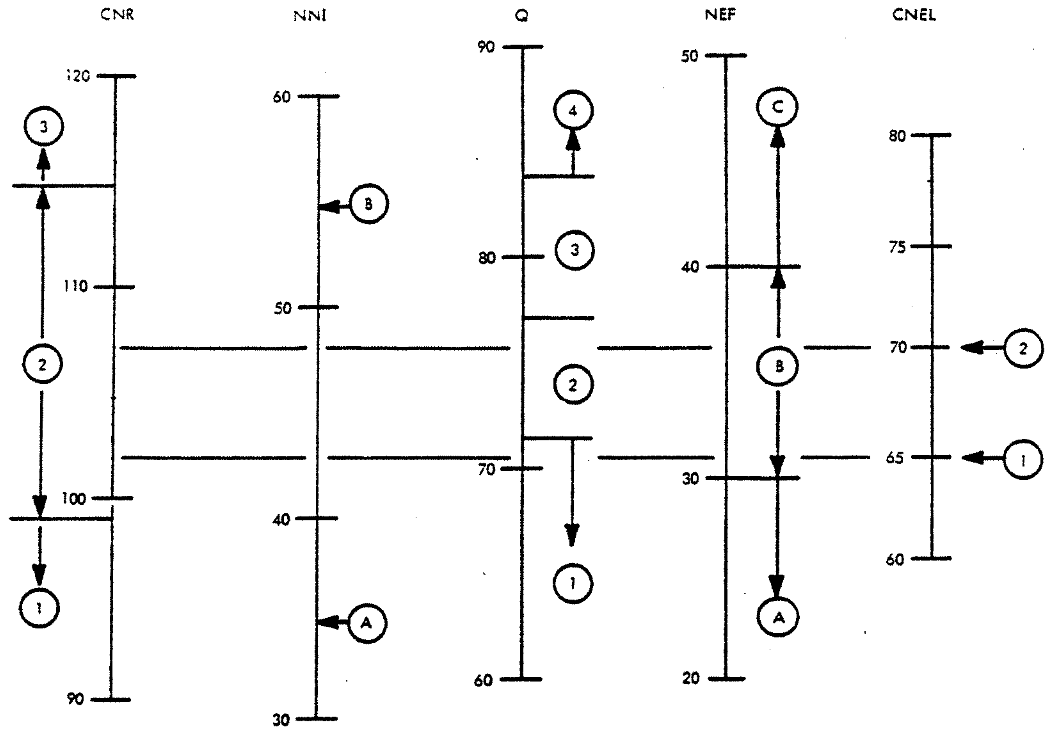
It is now of interest to assess the implications of the recommended limit value of community noise equivalent level (CNEL) in terms of the single-event noise levels implied at the noise impact boundary for various numbers of flights and in the light of the human factors data from Section 4.1.

Table 6

COMPOSITE RATING SCALES*

Title	Abbreviation	Country of Origin	Single-Event Magnitude Basis	Multiplier in Term for Effect of Flight Frequency
Community Noise Equivalent Level	CNEL	California (monitoring)	Noise Level, in dBA	10
Composite Noise Rating	CNR	USA (Military, land use planning)	Perceived Noise Level in PNdB	10
Noise Exposure Forecast	NEF	USA (Civilian, land use planning)	Effective Perceived Noise Level, in EPNdB	10
Noise and Number Index	NNI	United Kingdom	Perceived Noise Level, in PNdB	15
Störindex	Q	Germany	Noise Level, in dBA	13.3
Noisiness Index	NI	South Africa	Noise Level, in dBA	10
Annoyance Index	AI	Australia	Perceived Noise Level, in PNdB	10

* See Appendix D for equations giving specific definitions of the various composite noise scales.



Note: • Time Mix: 70% Daytime, 23% Evening, 7% Night
• Effective Duration, 15 seconds
• 200 Flights per Day

Figure 15. APPROXIMATE COMPARISON OF THE MAJOR COMPOSITE RATING SCALES

Table 7

DEFINITIONS OF THE VARIOUS ZONES IN THE MAJOR COMPOSITE RATING SCALES

Scale	Zone or Note	Meaning as Related to Residences
CNEL	1	Recommended limit for residential use (normal construction), for new airports and for all existing airports after 1985.
	2	Recommended interim limit for residential use (normal construction), for existing airports.
NEF	A	No problems with residential use.
	B	Individuals in private residences may complain, perhaps vigorously; concerted group action is possible. New single-family dwelling construction should be avoided. If apartments are constructed, noise control features should be included in their design.
	C	Residential use is incompatible.
Q	1	No restrictions, except no new hospitals should be built near boundary with zone 2.
	2	Residential construction will require some noise control measures in the design.
	3	Residential construction should be permitted only in urgent cases; and strong noise control measures are required in the design.
	4	Residential use is incompatible, regardless of building design.
NNI	A	Probable threshold for beginning of annoyance.
	B	Approximate limit beyond which the noise exposure is unacceptable (daytime).
CNR	1	Essentially no complaints expected, but the noise may occasionally interfere with certain activities of some residents.
	2	Individuals may complain, perhaps vigorously; concerted group action is possible.
	3	Individual reactions will include repeated, vigorous complaints. Concerted group action is probable.

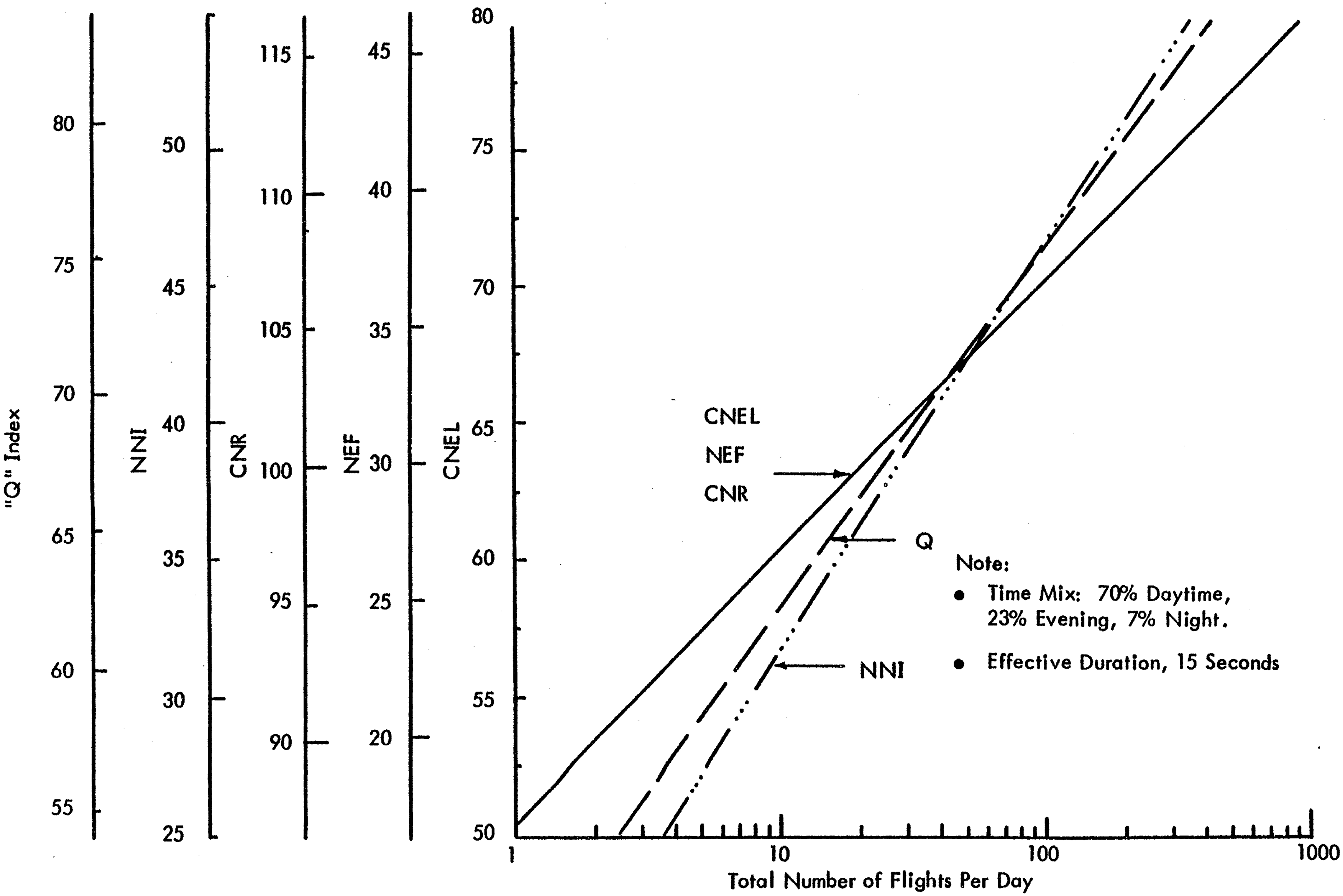


Figure 16. NOISE EXPOSURE LEVELS FOR TYPICAL JET AIRCRAFT FLIGHT OPERATIONS FOR A MAXIMUM PEAK NOISE LEVEL OF 85 dBA

For any given value of CNEL, one can estimate the average maximum noise level (in dBA as would be read on a sound level meter using the A-weighting circuit), provided the mix of aircraft, their distribution among the three daily time periods, and the approximate duration of the sound at the boundary are known. To understand what the recommended limit value of CNEL 65 and the interim value of 70 mean in terms of measurable, single flyby noise levels, consider the simple example where all aircraft are equally noisy, the mix is such that there is equal contribution to the daily CNEL from each of the three time periods, and a specified time duration for the noise of each flyby. The distribution of flights among the three time periods, to give equal contribution to the daily CNEL, is

Day	0700 - 1900	70 percent
Evening	1900 - 2200	23 percent
Night	2200 - 0700	7 percent

This distribution is fairly close to actual experience at large airports. Using all the foregoing (plus typical flyby noise durations at the noise impact boundary) as inputs to our simplified example, we can calculate the following average maximum sound levels (per flyby) at the boundary for various numbers of total flights per 24-hour period, as follows.

Table 8

TYPICAL MAXIMUM NOISE LEVELS ALONG NOISE IMPACT BOUNDARY ASSOCIATED WITH TAKE-OFFS

CNEL, dB	Total Flights Per Day	Average Maximum Noise Level, dBA
65 (criterion value)	10	89
	100	79
	1000	69
	2000	66
70 (interim value at most existing airports)	10	94
	100	84
	1000	74
	2000	71

For reference, these values may be compared with 68 dBA at 50 feet produced by the average passenger car at 35 mph, and 85 to 90 dBA at 50 feet which are typical sound levels produced by many diesel trucks and motorcycles.

It should be realized that the number of flights per day to be used in the estimate is not necessarily the total number of flights for the airport, but is the number of flights affecting the noise level at the region of the boundary under consideration. For some regions of the boundary, the influence may be entirely from one runway, while in others (as between paths from parallel runways) it may be a composite result of operations from two runways.

Figure 17 shows the relation between average maximum noise level and total number of flights per day based on the above assumptions, and also adds an approximate scale for the convenience of those who may be more familiar with noise levels in PNdB. Correction factors are also given which could be applied for other extreme cases of time mixes:

- All flights occurring in the daytime (0700 - 1900): Add 3 dBA to the levels shown.
- All flights occurring in the evening (1900 - 2200): Subtract 2 dBA.
- All flights occurring at night (2200 - 0700): Subtract 7 dBA.

Any mix of flights between the mix on which Figure 17 is based and any of these extremes will have a correction factor within the range bracketed by the corrections stated for the extremes. That is, in no case can the average maximum noise level (per flyby) at the boundary be more than 3 dB higher or more than 7 dB lower than the values given in the curves, for the given values of CNEL and duration.

It is important to realize the way the CNEL scale (or any of the other composite noise scales) works, in that for a given value of CNEL, a decrease in the noise of the individual flybys must be achieved if an increase of flight frequencies is to occur. This property of the composite scale is apparent from Figure 17. Conversely, a person standing at a point on the ground (with a given CNEL value) near a small airport with infrequent jet flights will hear a higher noise level per flight than someone standing at a corresponding CNEL-valued point near a busy airport. Another way to visualize this is that, as more flights are added at an airport the size of a given CNEL contour expands outward, so that the location of a listener on the boundary is farther from the airport, and hence the noise levels experienced are lower.

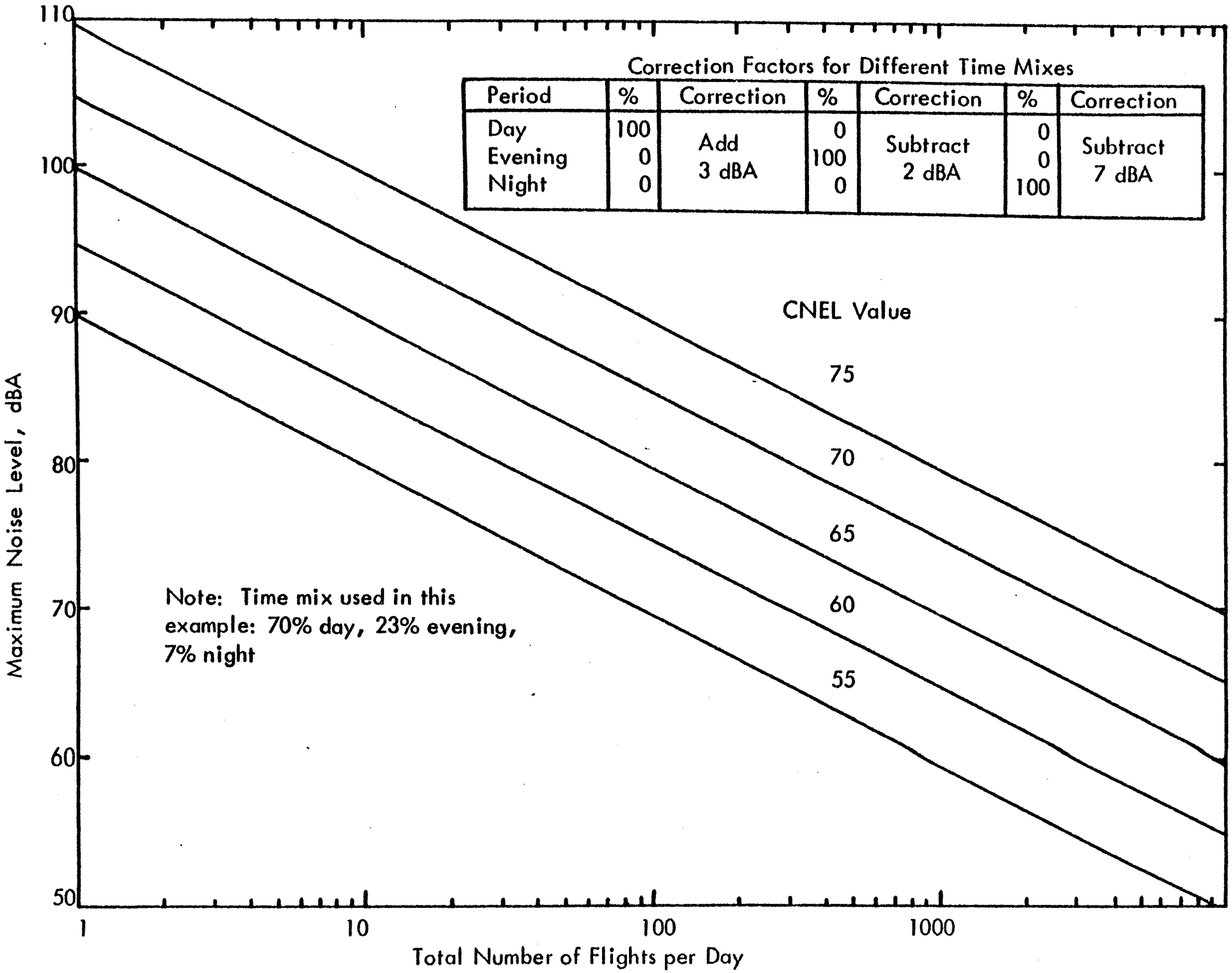


Figure 17. TYPICAL MAXIMUM NOISE LEVELS ALONG VARIOUS CNEL CONTOURS

The next question is how do the maximum flyby levels (e.g., in Table 8) compare with the single event limits one might tend to apply, based on the human factors data in Section 4.1. We have concluded that a desirable limit for people asleep inside their homes appears to be 45 dBA and that normal houses provide 28 dBA protection with doors and windows closed or 20 dBA (for rooms on the aircraft side) with some windows partially open. This corresponds to exterior limits of 65 dBA and 73 dBA.

For anyone living right at the CNEL 65 noise impact boundary, this tentative sleep criterion is met (for closed windows) if the number of flights is about 300 or more per 24-hour period, for the aircraft mix assumed for the curves. For the nine hours which comprise the night period, this means approximately two flights per hour which are marginal enough in the case of sensitive sleepers to cause them to close their bedroom windows at least on the aircraft side of the house. This means the CNEL 65 boundary may be marginal at night for noise-sensitive persons, and the interim CNEL 70 value would be even more marginal if night jet operations are permitted by the airport operator. Hence there are indications, from the sleep data, that all possible speed in the production of quieter aircraft should be encouraged, in order to achieve the CNEL 65 criterion at existing airports at the earliest possible date.

Comparing the single flyby values against the speech communication limit of 56 dBA (for a speaker-listener distance of 10 feet and normal noise level), we find that indoors, with windows open, a resident at the boundary CNEL 65 will have the interior noise limited to this value if there are more than about 200 flights per day. This corresponds to between eleven and twelve flights per hour in the daytime and about 15 flights per hour in the evening. If there are fewer flights per day (and hence the given CNEL location lies nearer the airport) some of them will be noisy enough to interrupt conversation indoors unless the windows are closed, and the frequency with which the interruptions may occur (depending on what fraction of the time is spent in conversation or TV or radio listening) is as high as 15 times per hour in the evening. Outdoor conversations would be interrupted by the noise of flybys for residents living at the boundary in all possible cases. Clearly, the speech communication criteria tell us that even the CNEL 65 value is a compromise away from the ideal condition.

On the question of hearing conservation, Figure 17 shows that there should be no problem regarding hearing conservation anywhere outside the noise impact boundary, even for a number of flights as low as one per day. The recommended limit value of 110 dBA for total daily exposure times of 15 minutes or less is well above the values of approximately 100 dBA (for CNEL 65) and 105 dBA (for CNEL 70).

However, the reader is reminded that the noise standard is intended to protect residences and schools only, and that we are referring here to values at the boundary. Since other land uses are permitted inside the boundary which imply the presence of people outdoors, a serious look should be taken at the single event noise contours produced by any markedly noisier aircraft before it is permitted access to any airport which has people inside the noise impact boundary, regardless of whether the land is in residential use or not. Further, until significant noise reductions are actually achieved, proprietors of airports with residences very near their property boundaries would be well advised to limit their operations below combinations of level and total duration which could lead to hearing impairment.

4.3 Conclusions

As a result of reviewing the above human factors (single event) bases and the community annoyance reaction bases, the following conclusions are drawn:

- The CNEL = 65 dB value is recommended as the limit in residential areas associated with all new airports and as the goal for all existing airports by the end of 1985. This is approximately equivalent to the recommendations in effect in other countries regarding an aircraft noise limit for residential areas with homes of normal construction. The CNEL value of 70, proposed as an interim limit for existing airports, is less restrictive than recommendations in effect in other countries for residential areas with buildings of normal construction.

- Based on the average maximum noise levels at the boundary (as one might measure from individual flybys with a sound level meter), the CNEL = 65 dB limit is marginal with respect to some of the human factors bases and the CNEL 70 limit is even more so. In particular, residents of homes at the CNEL = 70 dB boundary may still experience some sleep problems if night jet operations are permitted, and will definitely experience interruptions of outdoor conversations during aircraft flybys.

- Planners of new airports and their adjacent land uses should be encouraged to exercise their option to utilize lower limits.

It is apparent that there is a basic disagreement between the (single event) human factors data and the body of data on community annoyance. The human factors data, in its present state of knowledge, does not permit a direct cause-and-effect assessment of the importance of flight frequency. However, the community annoyance data does.

We have made a decision to base the CNEL limits on the community annoyance data as cross-checked by standards in effect in other countries. This decision is made with the realization that further human factors research (when a way is found to establish the effect of flight frequency) may show the CNEL limit of 65 to be somewhat too high. When that occurs, the CNEL limits in the noise standard should be lowered accordingly. We therefore strongly recommend that:

- The CNEL 65 limit should be periodically reviewed by the State with a view to the possible necessity of reducing the limit in light of any new human factors research results which may become available.

- The timetable for reduction to the CNEL 65 criterion at existing airports should be periodically reviewed by the State, with a view to accelerating the schedule as advances in aircraft noise abatement technology permit.

It is our opinion that these reviews should be conducted at an interval of five (5) years as a maximum, to take advantage of advances in research in the effects of noise on people and advances in the technology of aircraft noise reduction.

5.0 IMPLEMENTATION OF THE COMMUNITY NOISE EQUIVALENT LEVEL CONCEPT

The foregoing section has established the basis for selection of limits for community exposure to noise in terms of the quantity "community noise equivalent level." This section illustrates the implementation of this scale. Noise exposure is specified in terms of the noise impact area within a boundary or contour having a constant value of community noise equivalent level. The significance of the noise impact boundary is illustrated, strategies for reduction of the noise impact area reviewed, and means of establishing the noise impact boundary outlined.

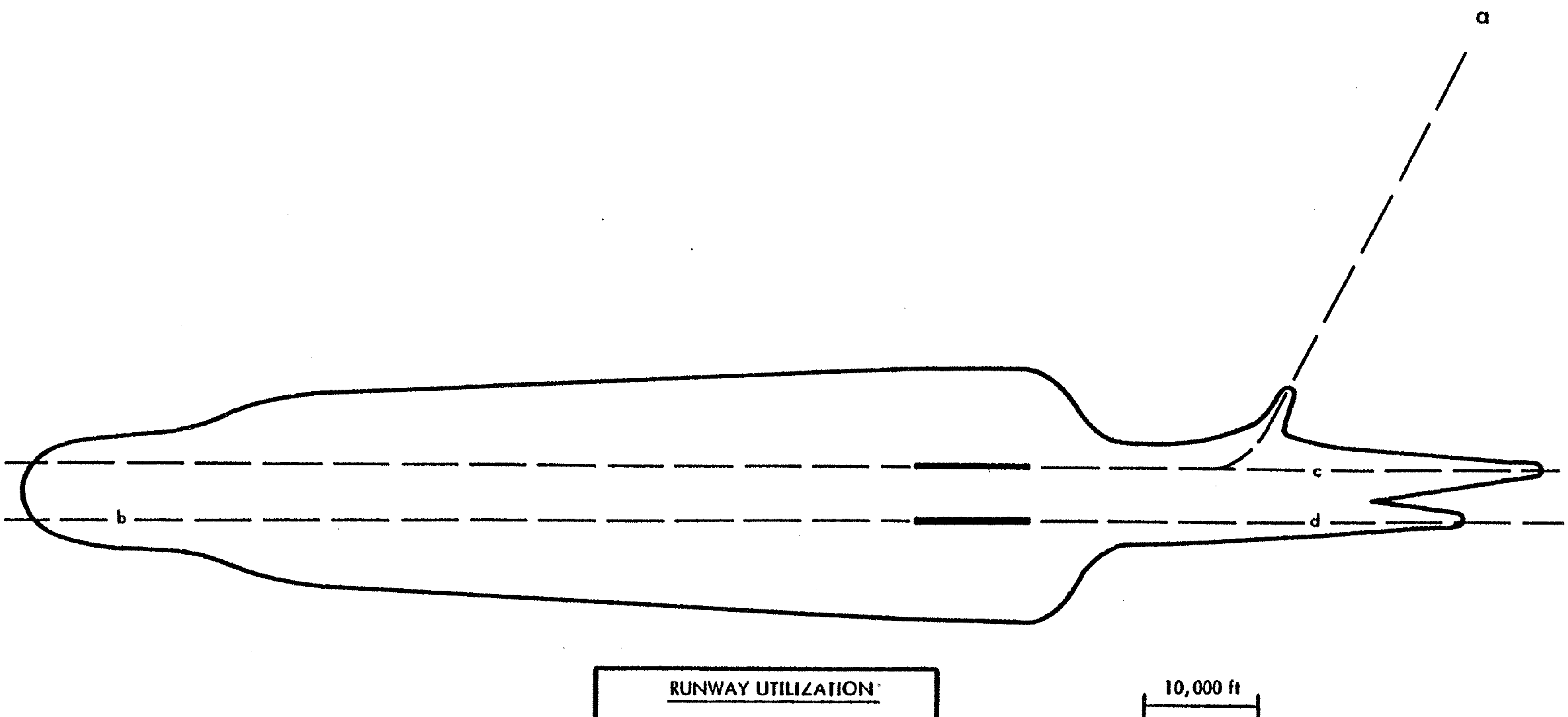
5.1 Examples for Hypothetical Airports

The implications of applying the community noise equivalent level limits outlined in the preceding sections can best be illustrated by examples. Representative locations of the noise impact boundary have been estimated for three hypothetical airports corresponding to (1) a high-density air carrier airport, (2) a low-density air carrier airport with and without jet aircraft, and (3) a medium density general aviation airport with and without jet aircraft. The general types of aircraft and frequencies of flight operations by time period are summarized for these examples in Table 9.

The estimated location of the noise impact boundary, for a community noise equivalent level (CNEL) equal to 70 dB, is shown in Figures 18, 19, and 20 for these examples. For the second example, Figure 19 shows the influence of changing from non-jet to jet air carrier operations, assuming the same schedule of flight operations. For the third example, Figure 20 shows the influence of adding a small number of business jet flights to existing propeller-driven aircraft traffic.

It must be emphasized that the contours are only approximate and do not apply to any particular existing airports. The figures serve, nevertheless, to illustrate representative situations and demonstrate the approximate size and shape of the noise impact boundary for various types of airports. The general types of aircraft considered are by no means complete; only some of the common representative types have been considered for these examples.

The contours illustrated in Figures 18 through 20 have been constructed with the use of standard, available aircraft noise data of the type given in Appendix D, from sources noted therein. These data provide estimates of the single event noise exposure level (SENEL) as a function of position relative to the flight path for various types of aircraft, which can be grouped



RUNWAY UTILIZATION

Flight Track	Take-off	Landing
a	50%	____
b	50%	____
c	____	60%
d	____	30%
e	____	10%

Figure 18. ESTIMATED LOCATION OF CNEL = 70 dB BOUNDARY FOR A HYPOTHETICAL HIGH DENSITY AIR CARRIER AIRPORT (See Table 9 for Schedule of Flight Operations)

RUNWAY UTILIZATION		
Flight Track	Take-off	Landing
c	50%	---
b	50%	---
c	----	50%
d	----	50%

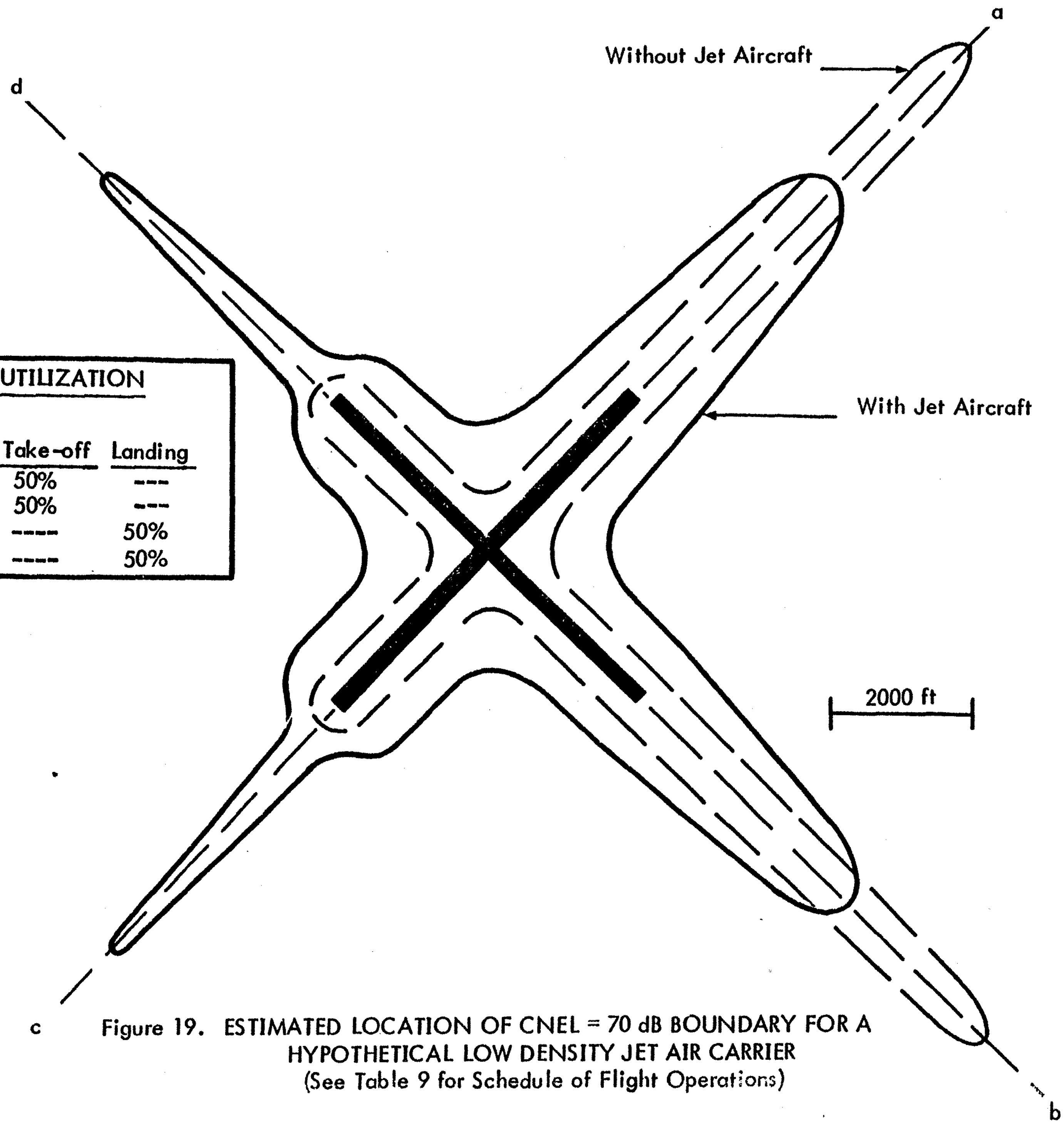
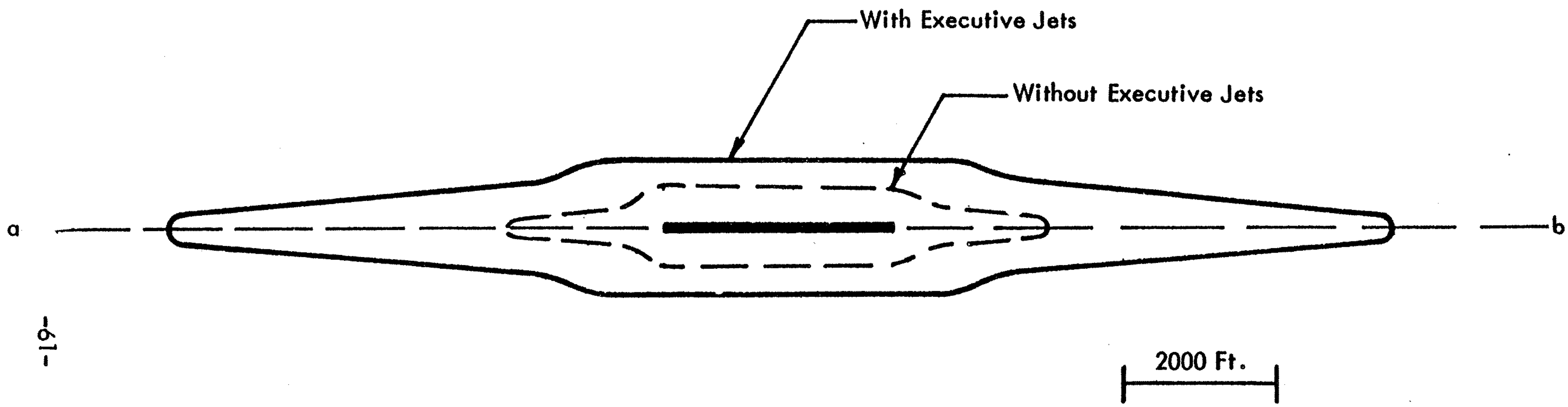


Figure 19. ESTIMATED LOCATION OF CNEL = 70 dB BOUNDARY FOR A HYPOTHETICAL LOW DENSITY JET AIR CARRIER
(See Table 9 for Schedule of Flight Operations)



RUNWAY UTILIZATION

Flight Track	Take-off	Landing
a	50%	50%
b	50%	50%

Figure 20. ESTIMATED LOCATION OF CNEL = 70 dB BOUNDARY FOR A HYPOTHETICAL GENERAL AVIATION AIRPORT
(See Table 9 for Schedule of Flight Operations)

according to their average noise and flight characteristics. A single representative model for each of these types of aircraft is indicated in Table 9 for illustration only. The estimated contours are intended to apply to all similar aircraft within each type, not to just the particular models indicated in Table 9.

To provide some basis for comparison of these examples, the approximate total area enclosed by the CNEL = 70 dB boundary and the boundary perimeter lengths are given in Table 10. The actual noise impact area in each case would be the area specified less the airport area and other compatible (non-residential) land areas as specified in Section 5014 of the noise standard.

Table 9

TYPE AND SCHEDULE OF FLIGHT OPERATIONS ASSUMED
FOR THREE HYPOTHETICAL AIRPORTS

Example (Figure Number)	Aircraft Type	Representative Model	Number of Flights Per Day: Day (0700-1900)	Evening 1900-2200)	Night (2200-0700)
18	4 Engine Jet (S.H.)[1]	720	50	10	15
	4 Engine Fan (L.H.)[2]	DC-8-61	100	15	30
	4 Engine Fan (S.H.)[1]	707-120B	200	30	60
	2/3 Engine Fan	DC-9, 727	150	25	10
19 With Jet Aircraft	2/3 Engine Fan	DC-9, 727	20	2	0
	Executive Jets	Lear Jet	5	1	1
	Turbo Prop STOL	Twin Otter	5	1	1
Without Jet Aircraft	4 Engine Prop	DC-7	20	2	0
	2 Engine Prop	Convair 440	5	1	1
	Turbo Prop STOL	Twin Otter	5	1	1
20 With Executive Jet Aircraft	Executive Jets	Lear Jet	5	1	1
	2 Engine Prop	Beech Queen Air	80	20	10
	1 Engine Prop	Cessna 172	60	20	3
Without Executive Jet Aircraft	2 Engine Prop	Beech Queen Air	80	20	10
	1 Engine Prop	Cessna 172	60	20	3

1) S.H. - Short Haul, Trip Less than 1,000 miles

2) L.H. - Long Haul, Trip Greater than 1,000 miles

Table 10

AREA WITHIN AND PERIMETER LENGTH OF CNEL = 70 DB BOUNDARY FOR EXAMPLES ILLUSTRATED IN FIGURES 18 THROUGH 20

Airport Type	Figure Number	Area, Square Miles	Perimeter, Miles
High Density Air Carrier	18	62*	56
Medium Density Air Carrier (Jet)	19	1.3	10.0
Medium Density Air Carrier (Non-Jet)	19	0.76	9.6
General Aviation Airport with Jets	20	0.60	6.6
General Aviation Airport without Jets	20	0.17	3.0

*Note this is a hypothetical airport: no existing airport in California has an impact area of this magnitude.

5.2 Potential Methods of Controlling and Reducing the Noise Impact Area

It is clear from the preceding examples that many of the currently operational airports in California would be initially in violation of the noise standard since the noise impact boundary will enclose residential land. In a very few cases, the provision outlined in the standard for allowing a 15 dB higher value of CNEL for acoustically treated homes may apply, thus tending to reduce the size of this noise impact area. (See Section 5014 of the noise standard.) This will be the exception rather than the rule, however, so that it is necessary to consider what steps are available to an airport operator to reduce the noise impact area of his airport to zero, and maintain this "zero impact."

There are, of course, several steps for reducing aircraft noise which are not the direct responsibility of an airport operator. These involve technological advances underway or under consideration by various government agencies, the aircraft and engine manufacturers, and the airlines. Noise reduction benefits that may be provided by these agencies as well as the direct measures more readily controllable by the airport operator are considered in the following paragraphs.

5.2.1 Reduction of Noise Emission by Aircraft

Normally, the most effective method for alleviating any noise problem is to reduce noise at the source -- in this case the aircraft itself. Significant improvements in this direction are under development by the federal government and the aircraft industry. By encouraging continuation of this effort and encouraging the use of quieter aircraft by airlines servicing his airport, the operator will reap the significant benefits of these noise reduction developments.

Some of these (government-funded) programs, and their potential reduction goals, can be categorized as follows (References 44 through 48). We have not included the substantial noise reduction efforts being sponsored by industry.

- Development of High Bypass Ratio Turbofan Engines to Replace Existing Low Bypass Ratio Turbofan Engines
  - Noise Reduction (Approximate Values for 4 Engine Turbofan Aircraft)

Along runway during take-off	4 dB
Underneath take-off path	4 to 15 dB
Underneath approach path	6 to 11 dB

  - Status

    Concept employed for Boeing 747, Douglas DC-10, and Lockheed L-1011

- Retrofit Engine Nacelle with Acoustic Treatment

  - Noise Reduction (Approximate Values for 4 Engine Turbofan Aircraft)

During take-off	2 to 5 dB
Under approach path	5 to 13 dB

  - Status

    Prototype units tested in 1969 provided 10 to 15 dB noise reduction on approach. Further development underway to obtain economically feasible configuration. FAA announced in 1970 "Advance Notice of Proposed Rule Making" covering potential retrofit.

- Development of "Quiet Engine"

  - Noise Reduction (Approximate Values for 4 Engine Turbofan Aircraft)

Along runway during take-off	10 dB
Under take-off path	10 to 19 dB
Under approach path	12 to 23 dB

  - Status

    Under development by NASA (Reference 46)

One strong incentive for continuing efforts to reduce aircraft noise at the source recently has been provided by the federal government. The FAA has recently established a noise standard for aircraft type certification under Public Law 90-411 applicable to all future subsonic jet aircraft or existing subsonic jet aircraft which are modified in any way which can influence their noise characteristics (Reference 1). In essence, this standard specifies the maximum effective perceived noise level, in EPNdB, that can be generated by the certified aircraft at particular measurement points when the aircraft is operated in a standard manner for both take-off and approach. The maximum noise levels allowed by the FAA standard vary with certified gross take-off weight for the aircraft, as shown in Figure 21.

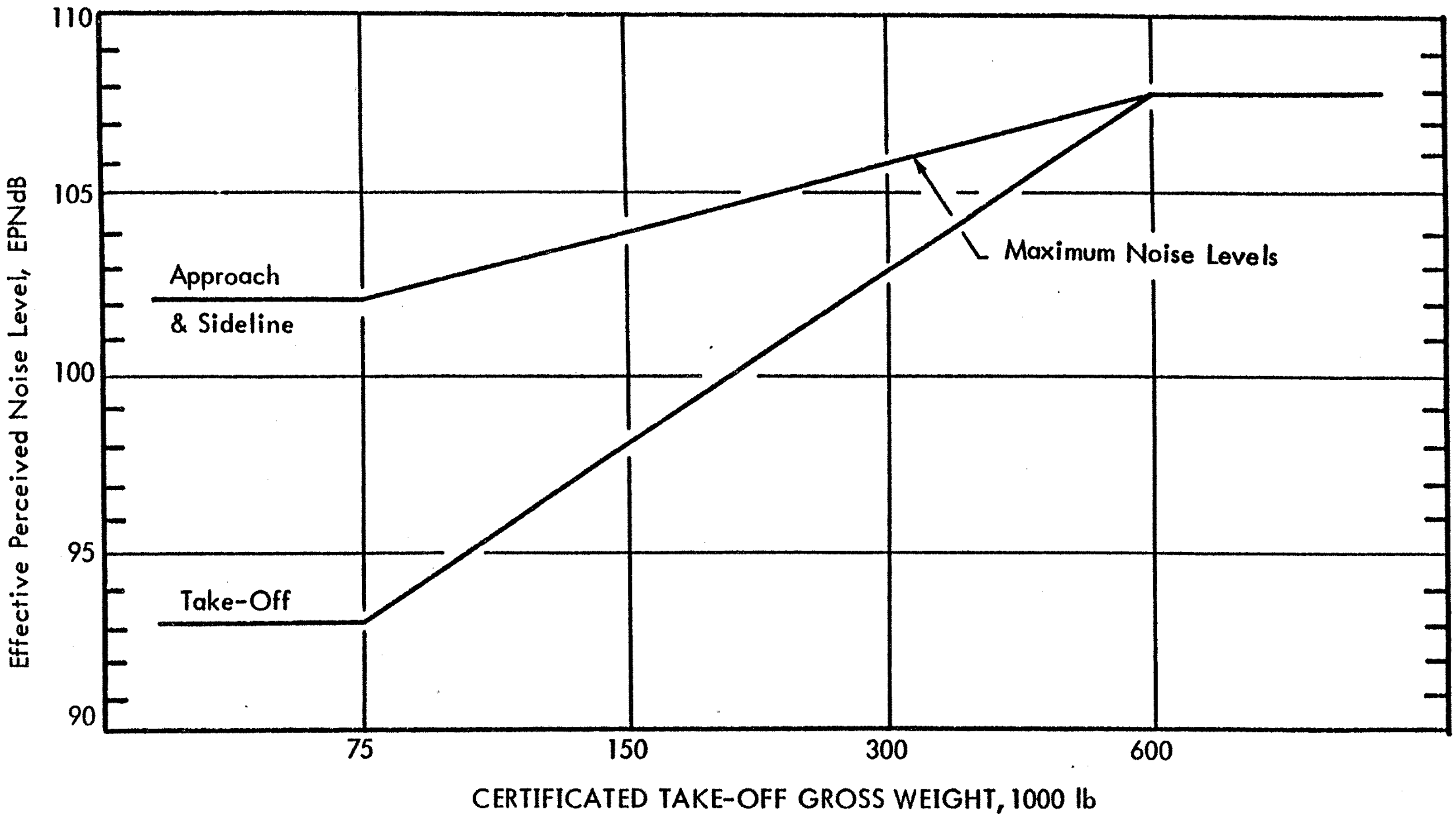


Figure 21. FAA MAXIMUM NOISE LIMITS FOR CERTIFICATION (Measurement Points: Approach, 1 N. Mile from landing threshold; Take-Off, 3.5 N. Miles from Brake Release; Sideline, 0.35 N. Mile from runway at point where noise is greatest).

The effective perceived noise level, in EPNdB, is an integrated measure of noise level for a single event similar in principle to the SENEL used for the noise standard. However, due to differences in the specific measurement methods for these two integrated noise level scales, the effective perceived noise level in EPNdB is, numerically, from 2 to 6 dB higher than the corresponding value of the single event noise exposure level in dB. (The different noise scales are considered in more detail in Appendix D.)

The approximate reduction in maximum noise level in dBA that would be achieved if current aircraft were modified to comply with the FAA noise certification standard is summarized in Table 11. It is apparent from this table that substantial noise reductions would be required for current conventional 4-engine type of aircraft. The new "jumbo" jets will be required to comply with the FAA noise certification limits.

Table 11

APPROXIMATE REDUCTION IN PEAK NOISE LEVEL IN dBA THAT WOULD OCCUR IF CURRENT JET AIRCRAFT WERE MODIFIED TO COMPLY WITH FAR PART 36 - NOISE STANDARD[2]

Type of Aircraft	Maximum Gross Weight 1000 lbs	Noise Reduction, dBA[1] Take-Off	Landing
4 Engine	320-345	13-15	10-12
3 Engine	230-250	7-10	8-10
2 Engine	85-170	2-4	5-7
Business Jets	20-65	0-13	0-11

(1) As measured at FAA Noise Certification points (See Figure 21).

(2) Estimated from data in Reference 44.

Several points become clear. Technical advances in engine design in the last ten years have been successful in reducing jet engine noise by about 10 dB. Even greater advances in noise reduction may be required for new aircraft, to achieve compliance with the FAA noise certification requirements. Airlines will be encouraged to change to the quieter engines on new or existing aircraft in order to respond to the intent of this FAA noise standard. Although initial costs of the quieter engines will be higher, they can offer potential savings in more efficient engine performance (Reference 46). This noise restriction imposed on new aircraft by the FAA will assist the airport operator in the future in achieving compliance with the noise standard for California airports.

5.2.2 Reduction of Noise Impact by Flight Procedures

More direct methods for reducing noise impact can be initiated by an airport operator and implemented through cooperation with the FAA and aircraft operators. These include the following (References 44 and 45).

- Power Cutback on Take-off
  - Noise Reduction Under Take-off Path

4 Engine Turbojet Aircraft	
Long haul flights	4 to 7 dB
Short haul flights	6 to 8 dB
4 Engine Turbofan Aircraft	
Long or short haul flights	1 to 2 dB
2/3 Engine Turbofan Aircraft	
Long or short haul flights	4 to 8 dB

  - Status

    Many airports impose this type of procedure now. As indicated in Figure 22, it can provide a significant benefit for areas starting at 14,000 to 25,000 feet from the beginning of take-off roll and extending over the area for which noise reduction is desired. Note that after normal climb power is resumed, or the reduced elevation of the aircraft offsets the reduction in noise generation by the aircraft, the noise exposure under the flight path will be higher than for a normal

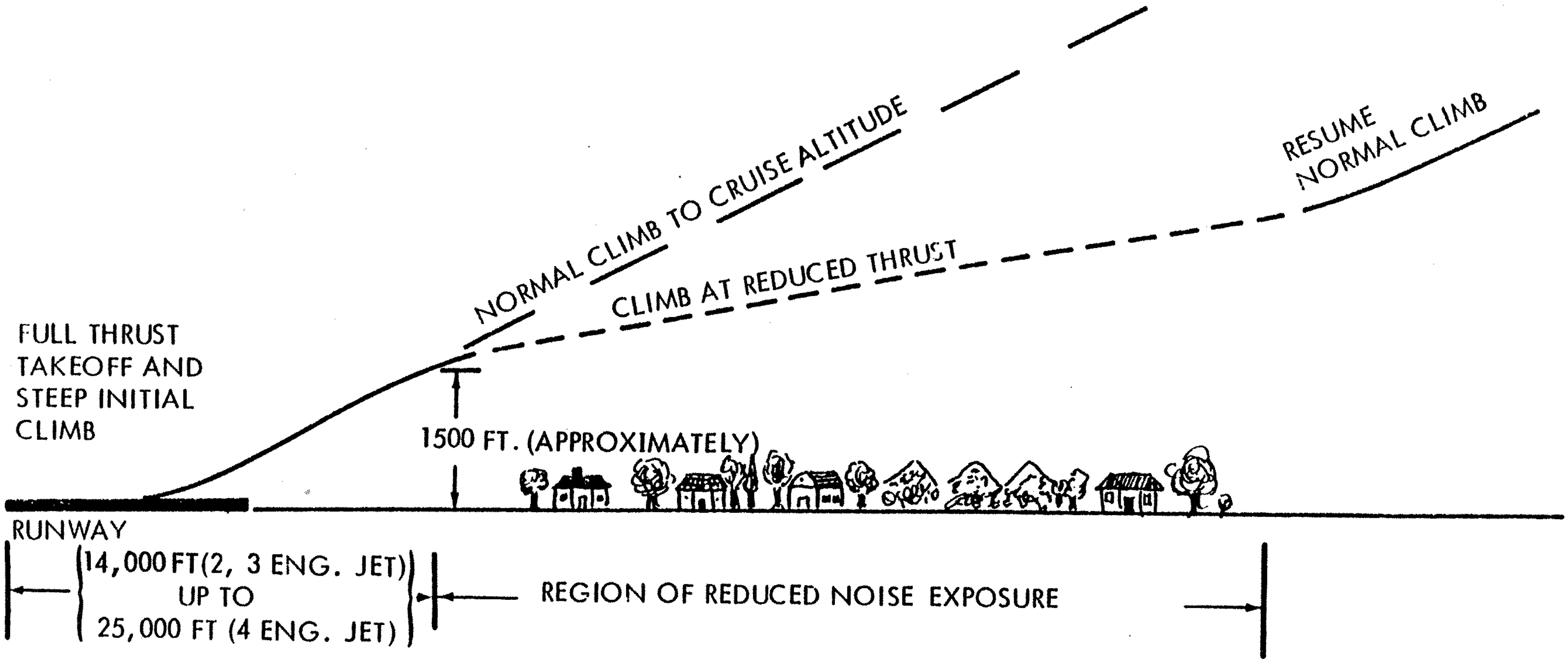


Figure 22. NOISE ABATEMENT TAKEOFF PROCEDURE
(MANDATORY AT SOME AIRPORTS)

climb out at full power. However, by this point, the noise level is usually well below the criteria limits so that the net effect of power cut-back on take-off is a reduction in noise impact area close to the airport, and a reduction in noise for those nearest the airport where reductions are most needed.

- Modified Approach Path (2 Segment Glide Slope, Reference 49)

  - Noise Reduction Under Approach Path

    For distances greater than 3 nautical miles from landing threshold 3 to 10 dB

  - Status

    This 2 sement landing profile, illustrated in Figure 23, is under consideration by the FAA. Proposals have also been made to increase the glide slope angle during approach all the way to the final landing flare-out. These procedures would require modifications to the ground-based Instrument Landing System (ILS) or the development of on-board navigational devices now in the experimental stage. The noise reduction cited above is due to both the increased altitude of the aircraft over the flight track and the additional noise reduction achieved due to lower engine power requirements of higher approach angles.

The potential reduction of noise impact area within the CNEL = 70 dB contour that could be achieved by various combinations of the noise abatement steps outlined above is illustrated in Figure 24 for land area under the take-off path and Figure 25 for land area under the approach path. These were calculated for a hypothetical medium density airport with about 200 air carrier operations per day (100 take-offs and 100 landings) operating from a single runway along one flight path. The relative values shown in these figures underestimate the true relative noise impact area, since compatible land (i.e., airport area) is included within the contour. For this reason, the actual change in noise impact area would tend to be even greater. However, the results illustrate, at least qualitatively, the potential effects of various noise abatement techniques. Clearly, for this example, the greatest reduction in noise impacted area is achieved by reducing noise at the aircraft itself. It should be emphasized that no changes in flight operation may be

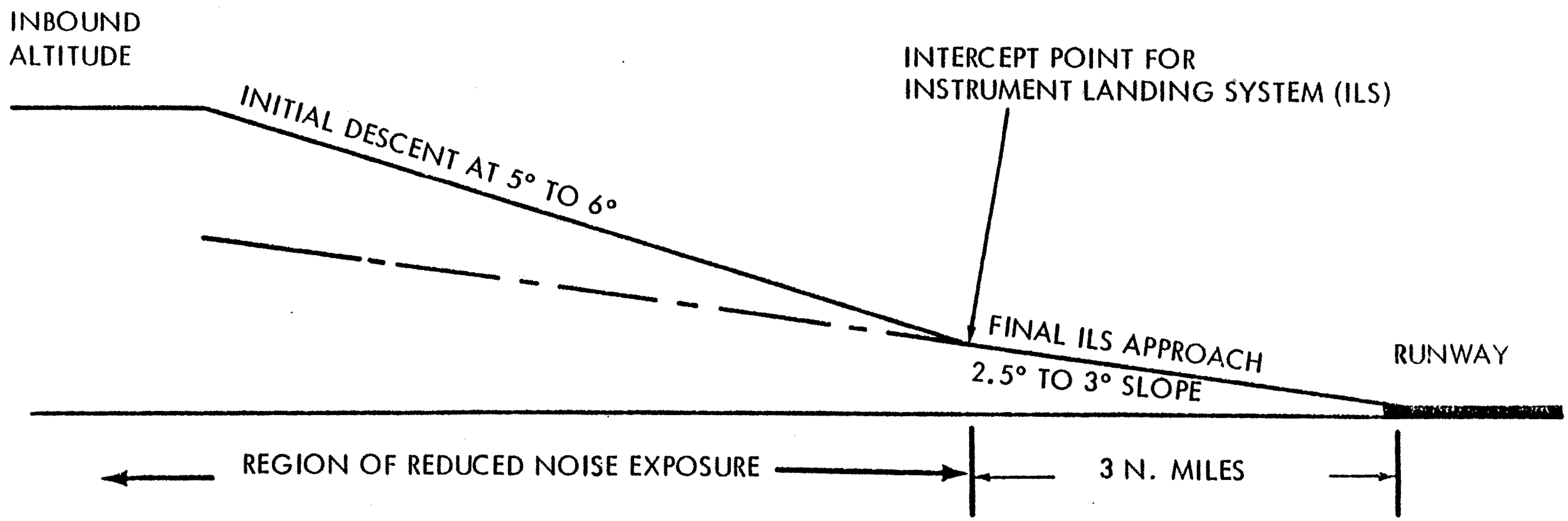


Figure 23. TWO SEGMENT NOISE ABATEMENT APPROACH PROCEDURE
(UNDER CONSIDERATION BY FAA)

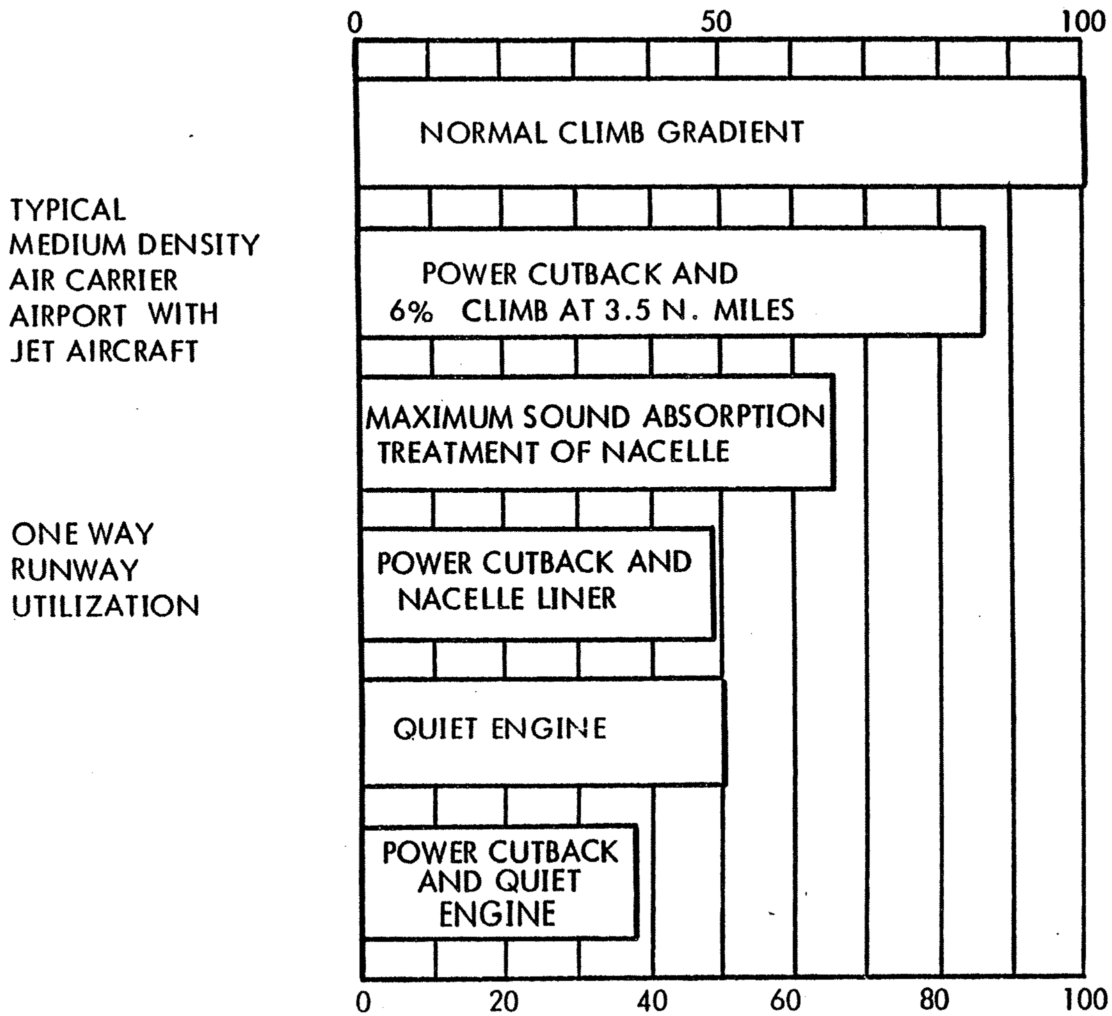


Figure 24. RELATIVE LAND AREA (PERCENT) BEYOND THE TAKE-OFF END OF THE RUNWAY ENCLOSED BY THE CNEL = 70 dB CONTOUR
(Adapted from Reference 50)

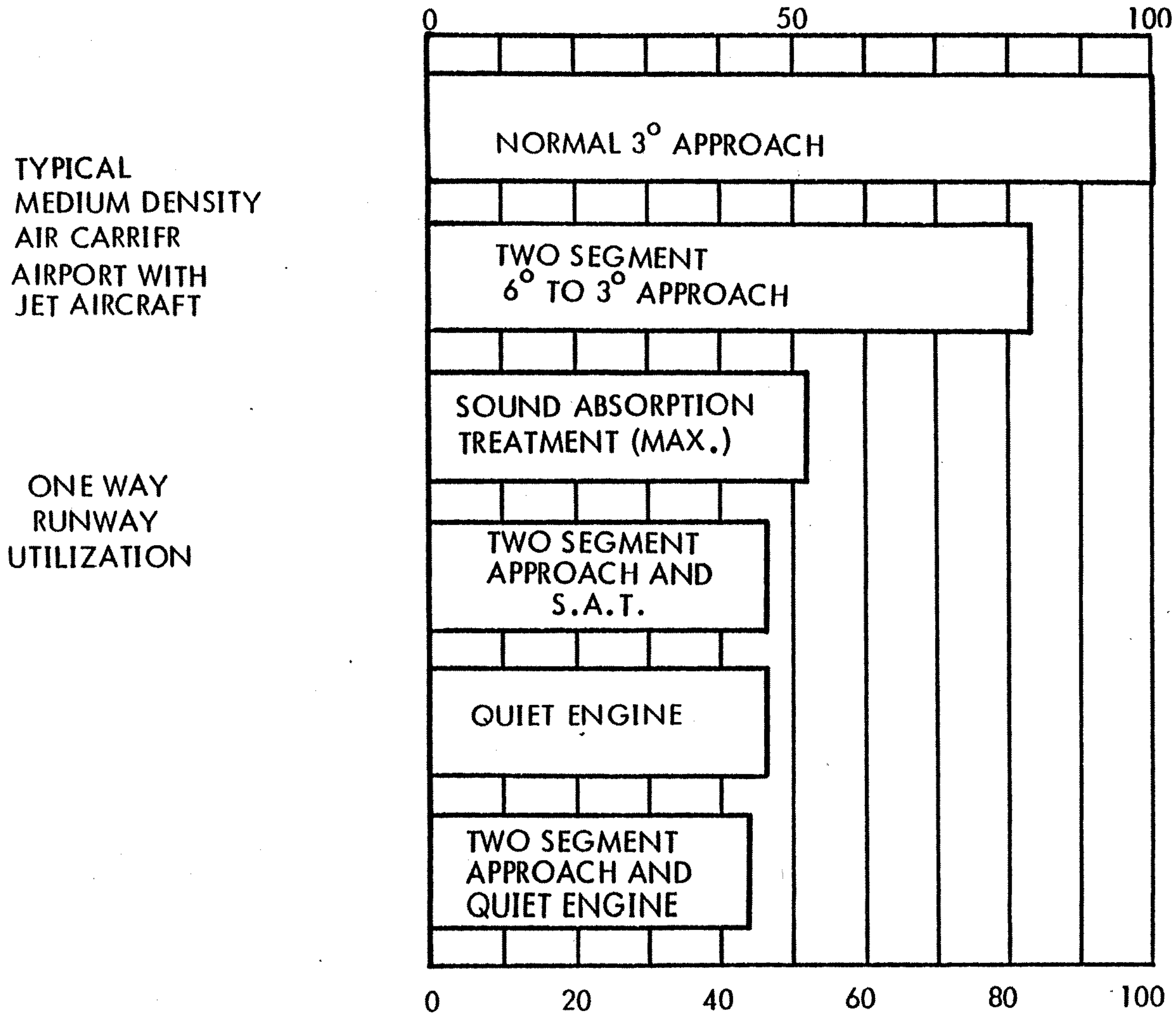


Figure 25. RELATIVE LAND AREA (PERCENT) BEYOND THE LANDING END OF THE RUNWAY ENCLOSED BY THE CNEL = 70 dB CONTOUR

(Adapted from Reference 50)

made to reduce the noise impact area which require unsafe procedures. For example, restrictions on the use of power cutback procedures may occur for certain airports due to the local terrain.

5.2.3 Reduction of Noise Impact Area by Changes in Flight Tracks, Flight Frequency, or Flight Schedules

5.2.3.1 Flight Track Effects

Perhaps one of the most effective and direct methods of reducing noise impact area for a given airport is by modification of take-off or landing flight tracks to increase the separation distance between the airplane and a residential area. There is no general way to predict the reduction in noise or in noise impact area, since the results will vary with each airport. However, typical examples are shown in Figures 26 and 27 to illustrate the concepts. Figure 26 shows how a change in the departure flight track could be used to substantially reduce the noise impact area over a residential area lying under a normal straight-out take-off path. Figure 27 illustrates the reduction in noise impact area that could be achieved for a two-runway airport by changing the relative utilization of runways. As indicated for this case, reduction of impact area under one flight path would be achieved at the expense of an expansion of the noise impact boundary for the other flight path. If the latter also falls on a residential area, power cut-back procedures could be employed on take-off to avoid an increase in noise impact area.

5.2.3.2 Flight Frequency Effects

The effect of decreasing flight frequency for a given runway on the corresponding noise impact area will vary with the initial frequency of operations (since the change in CNEL is dependent on the percentage change in frequency) and with the type of aircraft involved. For a given time mix of operations during the day, evening, and night periods, the value of the community noise equivalent level (CNEL) at a given point will decrease as the flight frequency decreases. This change in CNEL can be expressed quantitatively since (all other things being equal) the CNEL at a given point changes numerically by a value equal to ten times the logarithm, to the base 10, of the weighted number of total flights per day. For example, if the total weighted number (e.g., 1 times daytime flights plus 3 times the evening flights plus 10 times the night flights) of flights per day of a given mix of aircraft changes from 100 to 30 to 10, the CNEL at a given point will decrease by about 5 dB (30 to 10 flights) or 10 dB (100 to 10 flights).

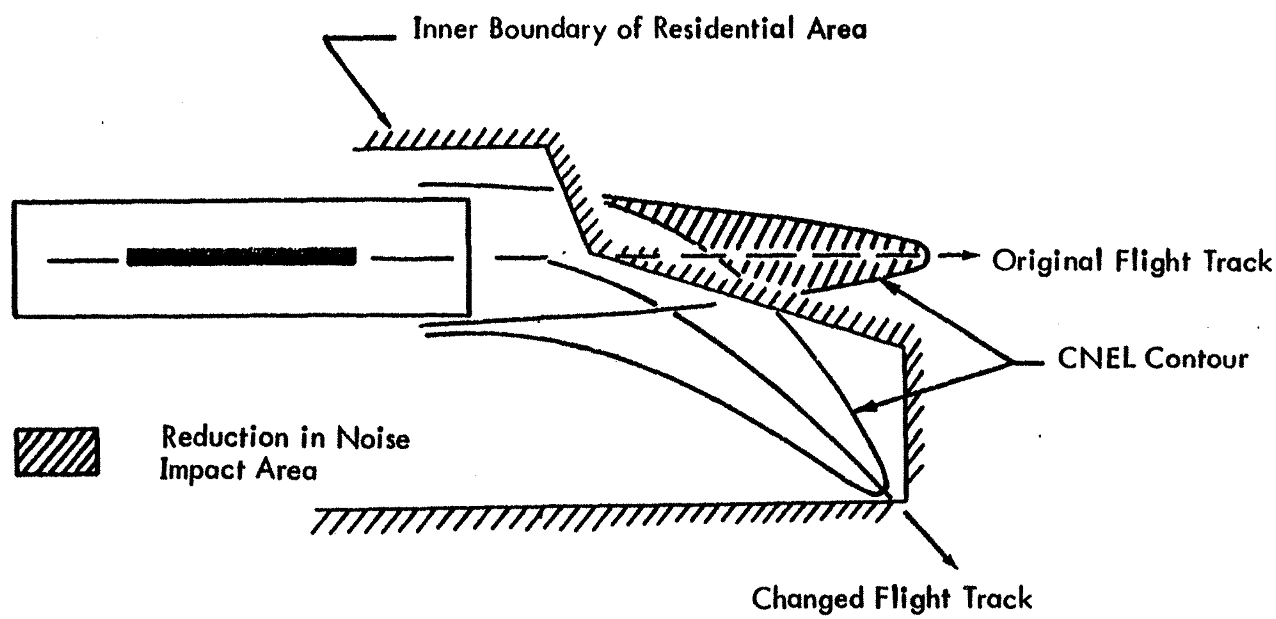


Figure 26. REDUCTION IN NOISE IMPACT AREA BY CHANGE IN FLIGHT TRACK

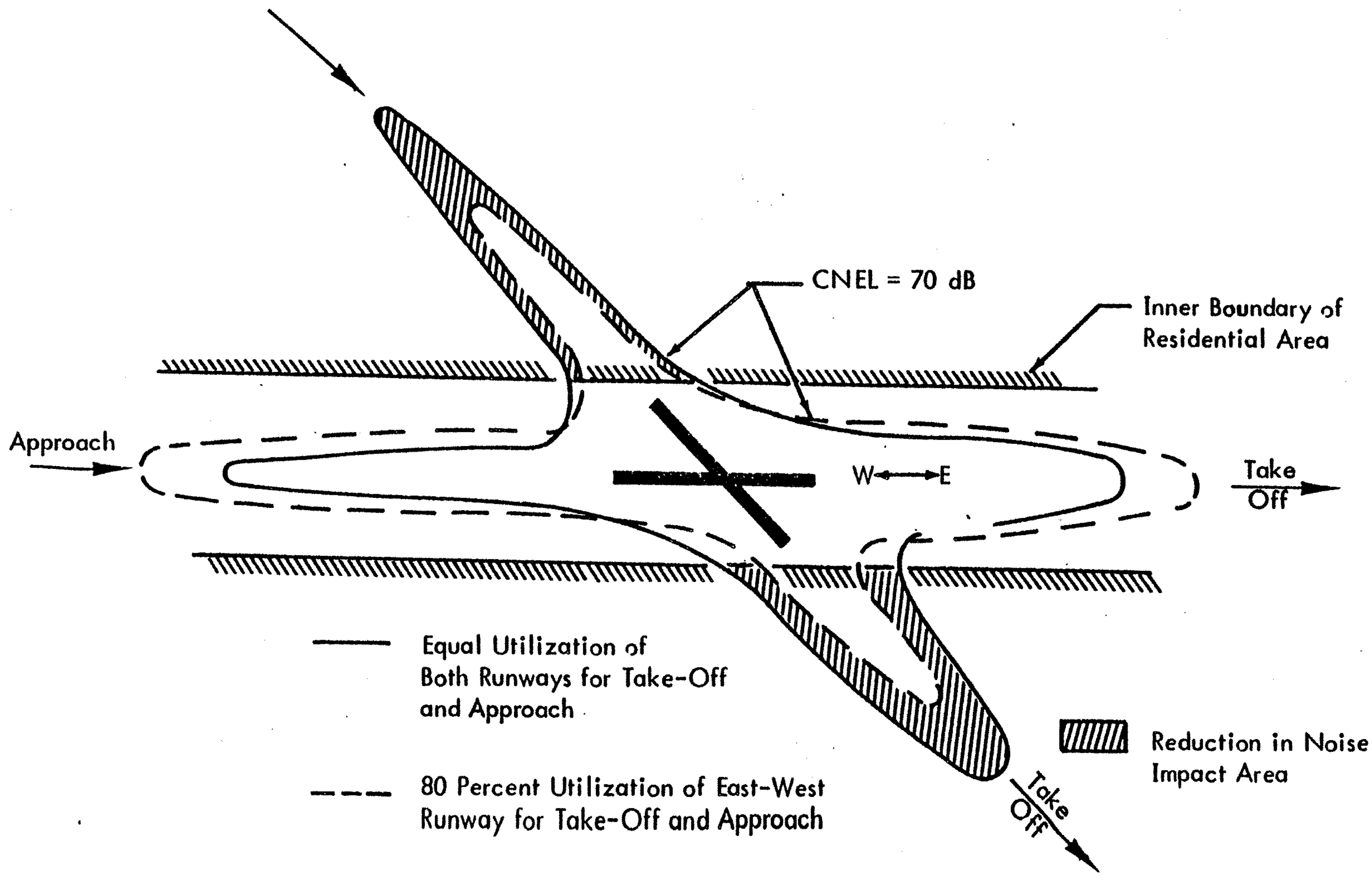


Figure 27. CONCEPTUAL ILLUSTRATION OF REDUCTION IN NOISE IMPACTED AREA BY CHANGE IN RELATIVE UTILIZATION OF RUNWAYS

Now if the CNEL is reduced at the measurement points due to a decrease in flight frequency or for any other reason, there will be a corresponding decrease in the total area enclosed within a given CNEL contour. This decrease in enclosed area as a function of change in CNEL at the measurement points is illustrated in Figure 28 and is based on analyses of several noise exposure contours.

Note that if flight frequency, based on the weighted number of flights, is decreased to 50 percent from a reference condition of 100 percent, the area enclosed within a given contour would decrease to about 55 percent of its initial value. The noise impact area will be less than the total area within a given CNEL contour since the latter encloses some compatible land (e.g., at least the airport property).

5.2.3.3 Flight Schedule Effects

Some decrease in noise impact area can also be achieved by shifting the schedule or time distribution of a given number of total flight operations for the 24-hour day. The following table illustrates the change in CNEL at a given point and the approximate decrease in total area within the noise impact boundary for various apportionments of flight operations among the three daily time periods. The example shown is for an airport with all operations from one runway and one type of aircraft which dominates the noise exposure level. The baseline condition is the same one as defined in Section 4.2.3, which gives an equal contribution to the total daily CNEL from each time period.

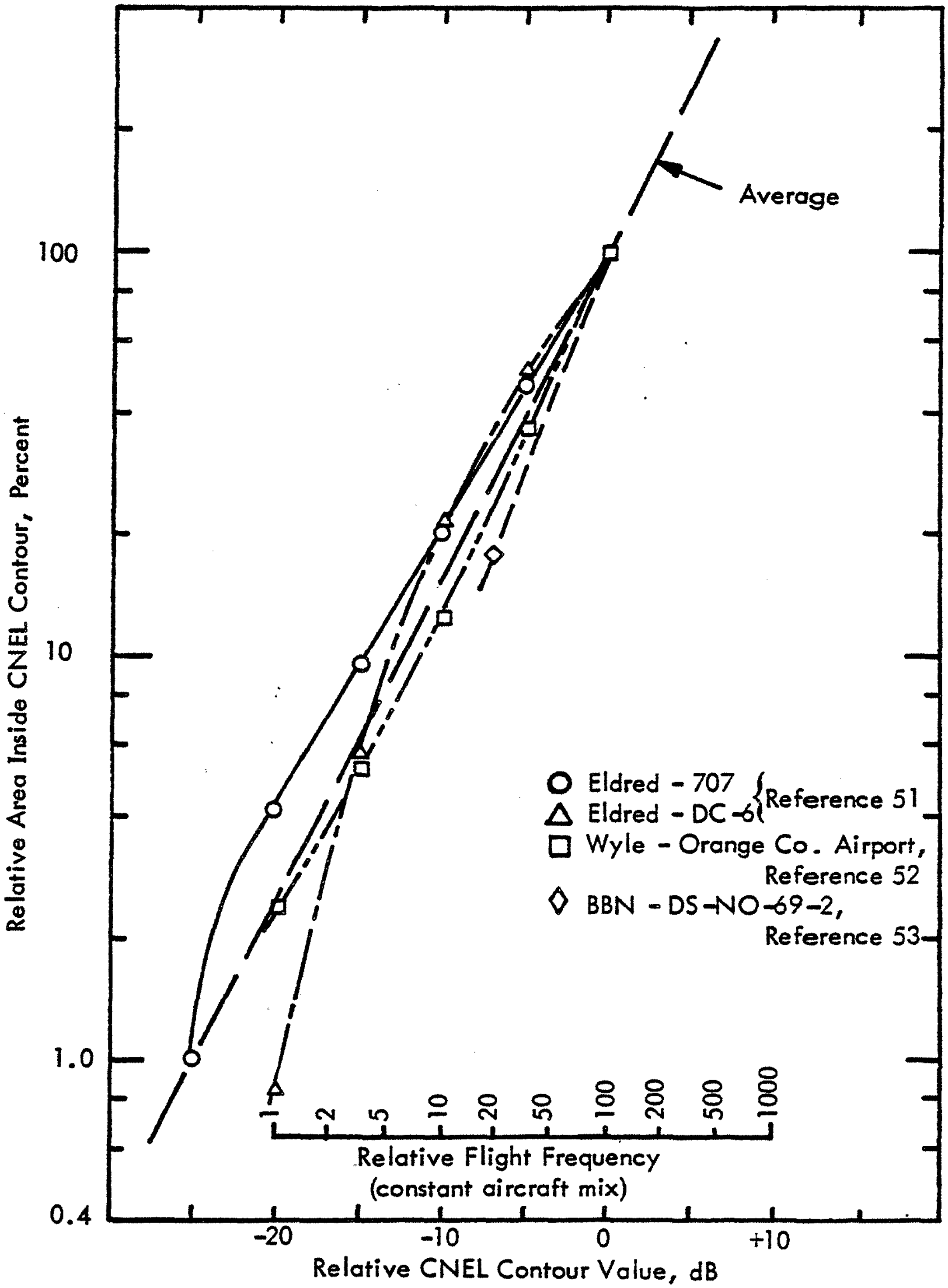


Figure 28. APPROXIMATE CHANGE IN NOISE IMPACT AREA VS CHANGE IN CNEL CONTOUR VALUE OR RELATIVE FLIGHT FREQUENCY

Table 12

POTENTIAL REDUCTIONS IN AREA
WITHIN THE NOISE IMPACT BOUNDARY
BY ADJUSTING TIME DISTRIBUTION
OF FLIGHTS

Relative Number of Flights Daytime	Evening	Night	Relative Reduction in CNEL, dB	Approximate Relative Area within CNEL = 70 dB Contour
70%	23%	7%	0	100%
70%	27%	3%	-0.6	90%
70%	30%	0%	-1.2	78%
85%	15%	0%	-2.1	68%
100%	0	0%	-3.2	56%

It must be emphasized that these estimates of changes in CNEL and relative area within the noise impact boundary are only approximate values for this idealized case and should not be used to predict the actual performance of a particular airport. However, the values do provide an indication of the reduction in noise impact by changing the time mix of flight operations.

5.2.4 Reduction of Noise Impact by Shielding

For residential areas located near that portion of a runway where aircraft are not airborne (i.e., after landing touch down or before lift-off), some reduction in noise and hence potential noise impact area is possible through shielding by natural or man-made obstructions. The noise attenuation that can be achieved will vary widely with each location and with weather conditions. However, an order of magnitude estimate of the potential effect of shielding by buildings is indicated by the following. For distances greater than about 1000 feet from a 20-foot high building, with a length parallel to the runway much greater than 20 feet, and which is located 1000 feet from the runway, sideline noise levels for an outdoor observer on the shadow side of the building could be attenuated by at least 2 dBA. Increasing the building height to 50 feet, or 100 feet with corresponding increases in length, the noise reduction could be about 10 dBA or 16 dBA respectively.

These substantial noise reductions would, of course, be limited to areas for which the noise exposure is controlled primarily by sideline noise generated by the aircraft on the ground. Economically practical utilization of this technique for noise reduction, and minimization of noise impact area, would normally be limited to situations where natural obstructions or airport facility buildings could be conveniently utilized for this effect without actually requiring special construction. The concept can be most effectively employed in the planning of new airports. However, a large sound barrier to achieve noise reduction by shielding has been employed at one major European airport (Reference 53).

5.2.5 Noise Control by Soundproofing of Structures

The criteria for an acceptable noise environment in communities around airports is based, primarily, on acceptable noise levels inside typical single-family residences. Within limits, therefore, higher external noise levels from aircraft may be tolerated in a given residential community if the normal noise reduction performance of such residences is increased by the addition of soundproofing treatment. While this does not represent a real form of "aircraft noise reduction," it does represent one method for improving compatibility of residential land near an airport. Thus, a provision has been made in the noise standard (see Section 5014 of Appendix B) to allow the community noise equivalent level in a residential area to be increased by up to 15 dB above the baseline criterion value providing a corresponding increase in noise reduction performance is provided in the residences. This increase in noise reduction of up to 15 dB is the maximum increment permitted above a baseline noise reduction (without soundproofing) of 20 dB. Although a greater total noise reduction than 35 dB is technically possible for residences, it has been found that external noise levels in outdoor recreation areas around the house become unacceptable when an attempt is made to allow higher external noise levels by increasing the noise reduction of the residence beyond about 35 dB (Reference 21).

The above figures are specified in terms of the reduction in A-weighted sound level (exterior to interior) as would be measured by two microphones simultaneously, one inside and the other outside the building. Representative noise reduction values for average residences and buildings with various degrees of soundproofing treatment are summarized in the following table.

Table 13

NOISE REDUCTION PERFORMANCE (EXTERIOR TO INTERIOR) OF VARIOUS BUILDING CONSTRUCTIONS

		Approximate Noise Reduction, dB
1.	Typical Southern California wood frame construction, some windows open	20
2.	Typical Southern California wood frame construction, air supply (e.g., windows closed)	28
3.	Modified wood frame construction (acoustical doors, double-glazed windows, air supply, et cetera)	35
4.	Normal concrete construction with fixed plate glass windows and air supply	35
5.	Normal concrete construction with air supply, and with double-glazed windows	45

Data for types 1, 2 and 3 comes from field measurements during aircraft flybys, taken in more than 100 rooms of 20 homes (Reference 21), supplemented by a few measurements in apartments near Los Angeles International Airport. The values for types 4 and 5 were obtained by standard acoustical calculations using measured transmission loss properties of building components. Naturally, there will be some variation about these averages from one building to another, in some cases as much as 5 dBA.

5.2.6 Reduction of Noise Impact Area by Changes in Land Use

When all of the methods of reducing the noise impact area cited in the preceding paragraphs are not sufficient to achieve a noise area impact of zero, conversion of land use is necessary as a last resort. This will generally involve coordinated action by the residents in the areas involved, the airport operator and the government agencies responsible for land use planning and zoning. Residential land within the noise impact boundary can be removed from the latter by converting the land use to one or more of the compatible land uses specified in Section 5011 of the noise standard. It must be emphasized, however, that this method of reduction in impact area does not achieve a true reduction in noise. It should be considered as the least desirable solution for achieving compatibility of an airport and its surrounding community.

5.3 Establishing and Validating the Noise Impact Boundary

Analytical methods can be used for making rough estimates of the location of a noise impact boundary. Application of such methods is, in fact, part of the process which can be utilized by the county responsible for enforcement to evaluate whether an airport has a "noise problem." When such estimated contours or other information results in a decision by a county that, indeed, a "noise problem" exists, then a noise monitoring program is required to establish and validate the actual location of the noise impact boundary. The fundamental reasons for requiring the measurement procedure are to:

(1) Properly define the actual magnitude of the noise problem in quantitative terms.

(2) Provide a continuing base of data against which an airport proprietor can measure his progress in reducing his noise impact area.

The following paragraphs outline some of the rationale for the noise impact boundary monitoring requirements specified in the standard.

5.3.1 Tolerances on CNEL Measurements

The basic constraint on the accuracy of the CNEL boundary measurement is imposed by the specified accuracy (±1.5 dB of the noise measurement system. The latter accuracy is, in turn, constrained by state-of-the-art technology in acoustic measurement systems. Thus, regardless of the repeatability or consistency of daily CNEL measurements, it is not feasible, at this point, to specify an absolute accuracy in the CNEL measurement greater than that required for the measurement system, or ±1.5 dB. This, then, is the tolerance defined in the standard for the measurement of a noise impact (CNEL) boundary.

Based on the relationship between area enclosed within a CNEL contour and the contour value illustrated in Figure 28, a tolerance of ±1.5 dB corresponds to a tolerance of about ±25 percent in impact area. This corresponds approximately to a tolerance of about ±12 percent in the linear dimensions of a CNEL contour.

Although the absolute accuracy of the CNEL measurement may not be better than ±1.5 dB at any one monitor position, the variation with time at a given monitor position can be expected to be substantially less. This observation is based on results of a recent pilot study of airport noise monitoring conducted by the Northrop Corporation at Orange County Airport (Reference 54). Results of this pilot study will be discussed in more detail in Section 7.3 of this report. It is sufficient to point out here that the results of the pilot study indicate that, normally, measurement of an annual CNEL boundary should be repeatable to within ±0.5 dB or better. This would correspond to a maximum variation in impact area of about ±10 percent and variation in linear dimensions of the boundary position of about ±5 percent.

5.3.2 Measurement Locations

The basic objective of CNEL measurements is to define the maximum extent of the noise impact boundary around an airport. Based on an evaluation of anticipated CNEL contours around several types of airports, it was determined that at least 12 measurement positions located no further than 1.5 statute miles apart should be used in order to adequately define the maximum extent of the noise impact boundary around a typical jet airport.

Some exceptions to this requirement for the number or spacing of monitor positions can be expected. This includes such cases as where flight tracks lie over bodies of water or where the noise impact boundary falls on land which will clearly remain compatible.

5.3.3 Frequency of Measurement in Community Locations

In order to minimize the number of monitoring systems required for noise impact boundary measurements around most airports, the statistical sampling method outlined in Section 5022(b) of the standard was developed. It was designed to provide a minimum acceptable sample to cover systematic variations in CNEL during days of the week and during seasons of the year. Thus, four samples obtained during the four seasons of the year are specified. Each sample should consist of daily CNEL's from the seven days of the week (not necessarily consecutive days). The overriding concept in the intermittent monitoring, however, is to conduct the measurements such that the results correspond as closely as possible to an annual CNEL value that would be obtained from a system operated continuously.

Figure 29 shows the variation in measured daily CNEL values and a running 7-day average over nearly a two-month period, according to results of the pilot study cited earlier (see Reference 54 and Section 7.3). During this

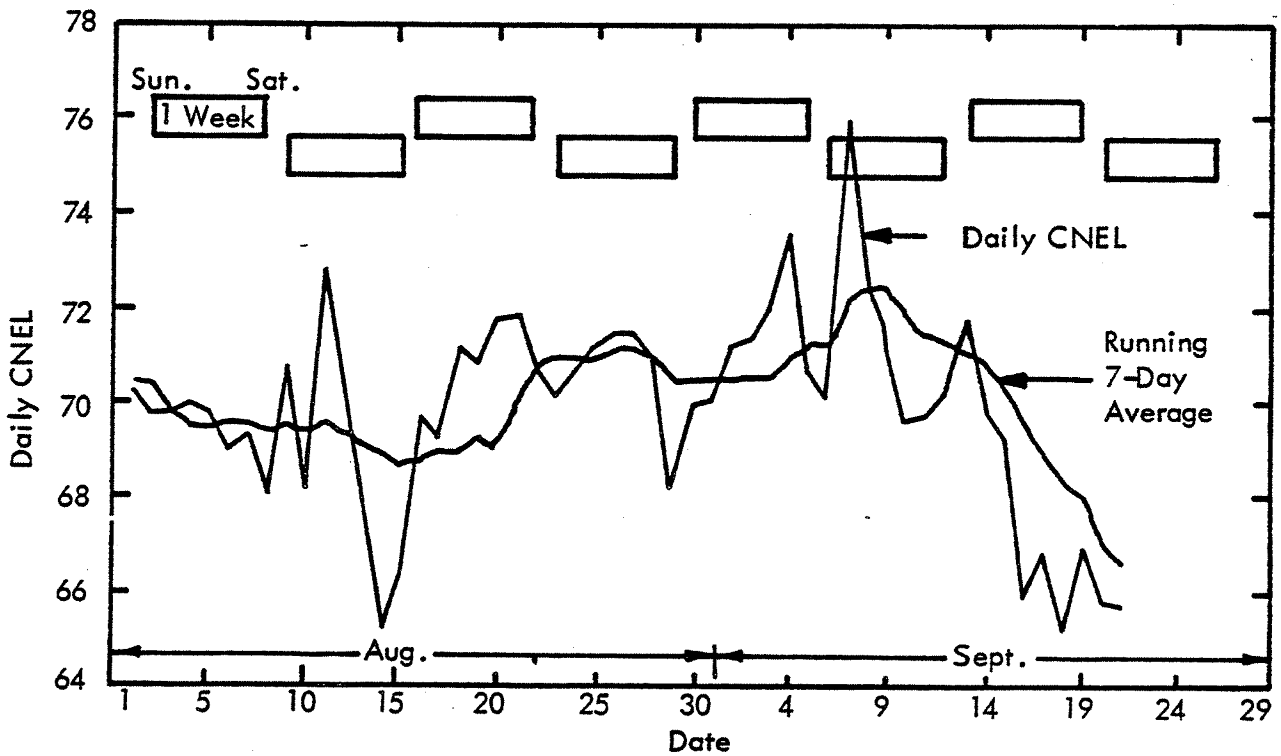


Figure 29. MEASURED VARIATION IN DAILY CNEL AND RUNNING 7-DAY AVERAGE
(Data From Reference 54)

pilot program, the greatest deviation in the daily CNEL from the weekly average occurred generally on weekends, thus reflecting one characteristic type of weekly cycle in jet operations at the particular airport studied. Therefore, a minimum sample of CNEL values for one season must be based on measurements over the seven days in a week.

An extreme example of the potential seasonal variation in CNEL is illustrated in Figure 30. This is an estimate for an airport which markedly changes its preferred direction for take-off during the year due to seasonal changes in weather (Reference 55). This demonstrates the need to include four seasons in the statistical sampling of the noise impact boundary.

5.3.4 Initial Establishment of the Noise Impact Boundary

Once a commitment is made by an airport to carry out noise monitoring of its noise impact boundary, it becomes highly desirable to locate monitor positions as effectively as possible. Several objectives should be met:

- The monitor locations (whether for continuous or intermittent monitoring) should be positioned on or near the anticipated noise impact boundary with adequate precision to provide a clear definition of the noise impact boundary.

- Optimum measurement locations should be determined by a combination of initial estimates of contour position and trial measurements to roughly locate the noise impact boundary.

- The measurement positions should remain fixed, to the greatest extent possible, once routine continuous or intermittent monitoring is initiated.

The second point is important to development of the initial monitor positions. This trial measurement concept, involving short samples taken along lines at right angles to and on either side of the anticipated boundary, is illustrated in Figure 31.

Note that once a permanent monitor location has been established, changes in airport operations may cause a gradual change in the noise impact boundary, based on annual CNEL data. In order that the position of the noise impact boundary (CNEL = 65 dB, for example) be known within ±1.5 dB, if the monitor position falls outside this tolerance, the monitor position should be relocated. However, subject to approval by the Department of Aeronautics, extrapolation methods, such as illustrated in Figure 31(a), may be

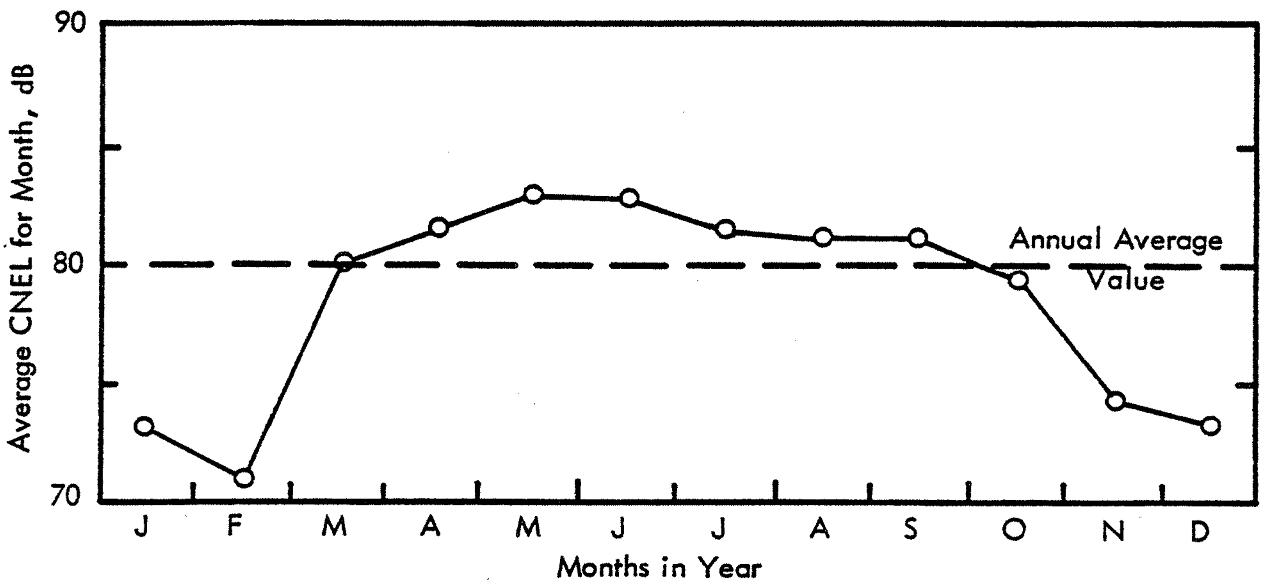
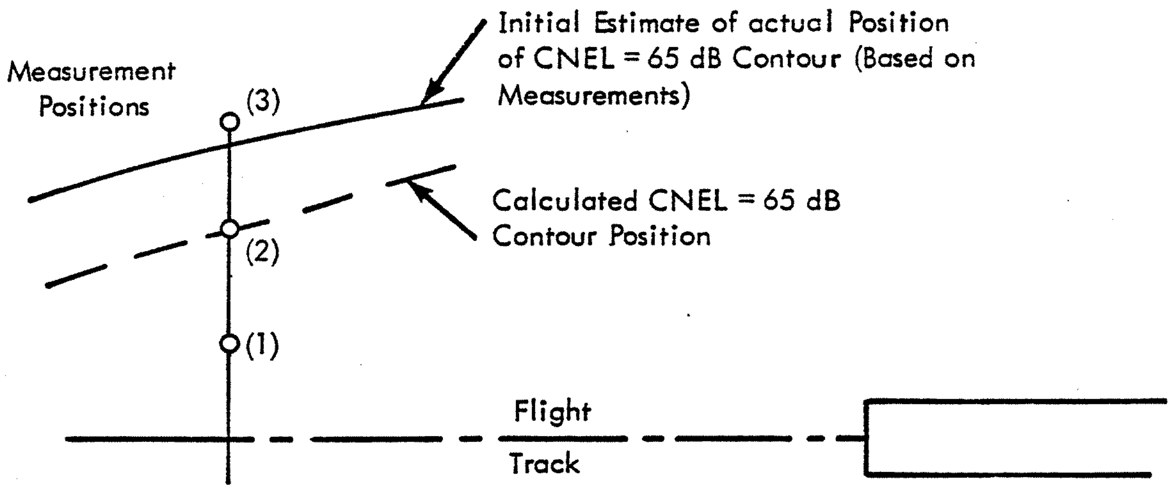
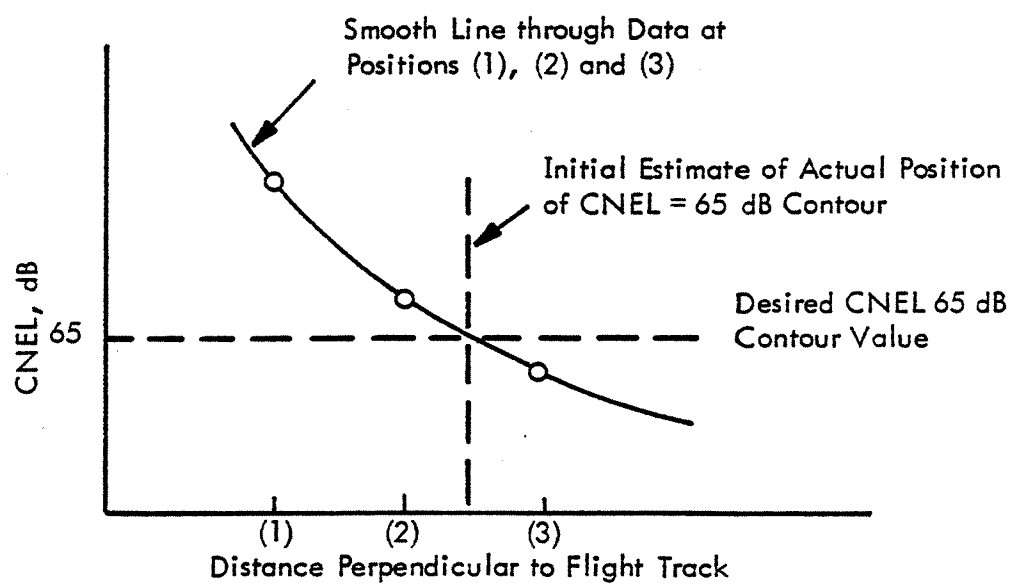


Figure 30. EXAMPLE OF POTENTIAL SEASONAL VARIATION IN AVERAGE MONTHLY CNEL AT AIRPORT WITH SEASONAL CHANGE IN TAKE-OFF PATTERN (Reference 55)



(a) Trial Measurement Positions



(b) Graphical Interpolation of Trial Measurement

Figure 31. ILLUSTRATION OF INTERPOLATION CONCEPT FOR INITIAL ESTABLISHMENT OF NOISE IMPACT BOUNDARY

used to correct measured CNEL data to establish a noise impact boundary when the tolerance criteria of ±1.5 dB is exceeded.

6.0 BASIS FOR THE RECOMMENDED LIMITS ON SINGLE EVENT NOISE EXPOSURE LEVEL

The noise impact generated by any particular aircraft operating out of an airport is determined by its noise signature on the ground for a single flyby. This signature is quantified in terms of its single event noise exposure level (SENEL), which is a time-integrated measure of the noise level for a single event. Maximum limits for the single event noise exposure level have been established in the noise standard for various types of jet aircraft. These limits are equal to the SENEL expected to occur less than 5 percent of the time for each type of aircraft operating under maximum gross weight conditions. The various factors that were used to establish these single event noise limits and the method of monitoring for compliance with these limits are reviewed in this section.

6.1 Basis for the Measurement of Single Event Noise Exposure Level

The general nature of the noise level time history for an aircraft flyby past a given point has already been outlined in Section 2.1 of this report. Frequently, a clearly identifiable maximum level is not present in such a time history record. This is due to the presence of short time fluctuations in level that occur during a single flyover which are the result of fixed noise radiation characteristics of the aircraft and randomly fluctuating noise transmission characteristics of the atmosphere. These latter fluctuations are essentially unpredictable at any given point and time. However, like any normal random disturbance, their "long time" average value is zero. Thus, by integrating a single event time history of noise level over a length of time comparable to the significant duration of the event, the influence of the random fluctuations tends to be averaged out, providing a more stable and reliable measure of the noise signature of each event.

If this integration is carried out on a signal which is proportioned to the square of the instantaneous sound pressure, the resulting integral is proportional to the energy within a complete time history. This energy integral, normalized to a reference duration of one second and expressed in decibel form, is the single event noise exposure level (SENEL). There is a more basic reason for measuring the noise of a single event in terms of an integrated noise level. This type of measurement includes the effects of the maximum value and the duration of a single event time history. The majority of experimental data currently available indicates that subjective reaction to aircraft noise is dependent on both of these parameters (References 56 and 57). Specifically, the data indicate that for typical aircraft sounds, it is the "noise energy," (as measured, for example, by the SENEL scale) which is critical for subjective response to a single event. This same concept is also recognized by the FAA by their use of a similar time-integrated scale of noisiness called effective perceived noise level (EPNL), (References 1 and 45). However, the latter scale involves a more complex frequency weighting, since it includes corrections for the presence of pure tones. Consequently, it requires more sophisticated instrumentation and therefore was not adopted for the measurement requirements in the state standard. Fortunately, however, it is possible to approximately relate SENEL and EPNL values by simple correction factors which vary slightly according to aircraft type and operation. Such a set of correction factors is included in Appendix D.

A reference duration of one second for SENEL was chosen to be consistent with current thinking for similar proposed integrated measures of the noise exposure for any type of single event (Reference 58). To provide practical limits on the length of time the integration of noise level is carried out, an integration threshold noise level has been set at 30 dB or more below the numerical value of SENEL limits defined for each type of aircraft and monitoring position (see Article 5 of the noise standard).

A graphical interpretation of the SENEL for a typical flyby time history is illustrated in Figure 32. Note that the value of SENEL for a given flyby can be interpreted as numerically equal to the maximum noise level in dB for a rectangular "pulse" of noise with a one second duration and the same energy as in the integrated portion of the actual noise level time history.

It should be pointed out that since the integration time is based on a fixed threshold level for a given monitoring point, whereas the actual peak value of any single time history of noise level will fall at various levels above this threshold point, the actual time of integration relative, say, to the "10 dB down" duration of the time history will vary. This means that the measured SENEL at a given point will vary only slightly relative to the value obtained if integration time were fixed by a period corresponding, for example, to the "10 dB down" duration. The latter concept is employed for standard noise certification measurements specified by FAA (Reference 1). As indicated by Table 14, this variation in the measured SENEL is very small, even when the peak noise level is only 5 dB above the integration threshold limit.

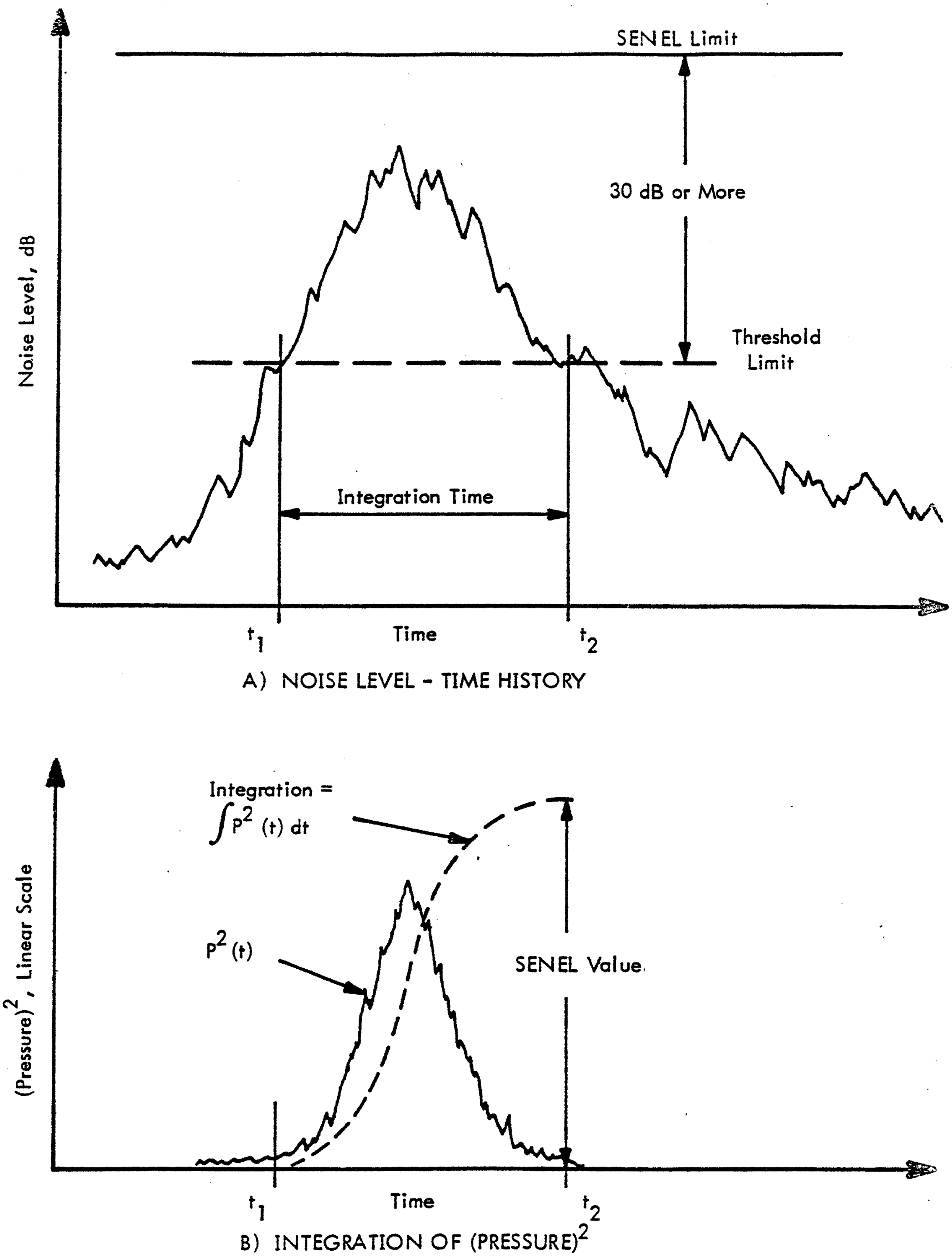


Figure 32. ILLUSTRATION OF MEASUREMENT OF SINGLE EVENT NOISE EXPOSURE LEVEL

Table 14

TYPICAL VARIATION IN MEASURED SENEL DUE TO DIFFERENCE BETWEEN MAXIMUM NOISE LEVEL AND INTEGRATION THRESHOLD LIMIT

Maximum Noise Level Minus Integration Threshold Level	Measured SENEL(1) Re: Maximum Value
20 dB	0 dB
15	-0.1
10	-0.3
5	-1.0

(1) For threshold level 30 dB below SENEL limit.

6.1.1 Locations for SENEL Measurements

Limits for the single event noise exposure level have been specified for two general locations: on the centerline of the nominal flight tracks for take-off and for landing of jet aircraft. Considerable latitude has been provided for in the actual position of the SENEL monitor points along the flight track. For landing, the minimum distance from the landing threshold is less than the maximum extent (2800 feet) of a standard Instrument Landing System (ILS) installation. This would make it possible to install the SENEL monitor on property already available to the proprietor of ILS-equipped airports. In the case of most large airports, the minimum distance from brake release for an SENEL monitor under the take-off path will lie within airport property. The upper bound for the distances of the SENEL monitor positions of 3.5 nautical miles for take-off and 1.0 nautical mile for landing (see Figure 3, Appendix B) is equal to the corresponding positions specified by the FAA for type certification of aircraft noise (Reference 1). The range of allowable SENEL measurement positions is sufficient to allow symmetrical measurement positions off each end of a runway so that one position could be used to monitor both landing and take-off levels.

SENEL measurements should not be required for flight tracks over water or any other areas for which aircraft operations do not contribute to the noise impact boundary. For example, flight operations on the east-west runway of the airport illustrated in Figure 27 would not contribute to the noise impact area, since the impact boundary under the corresponding flight track lies totally within compatible land. Therefore, SENEL monitors would not be required for the east-west flights.

6.1.2 Frequency of SENEL Measurements

A major objective of measuring single event noise exposure levels is to control the maximum noise levels experienced by an airport for any single aircraft. Thus, it is logical that SENEL monitoring be essentially continuous. This is specified by the regulation with the exception that four weeks of the year are left free of the measurement requirement in order to provide some allowance for downtime and system maintenance.

6.2 Basis for the Selection of Limit Values of SENEL

The limit values of SENEL have been set forth in Article 5 of the regulation according to aircraft type and measurement position. The SENEL limits have been determined by the application of standard aircraft noise prediction techniques (e.g., References 59 and 60). The resulting average single event noise levels under the flight path are given in Appendix D. The limit values are shown on Figure 3 of the noise standard. They are equal to the average expected value (50 percent probability) plus 5 dB. The 5 dB margin approximately corresponds to the 95 percent probability point so that, for the flight profile specified, the SENEL limits would be exceeded approximately 5 percent of the time. Representative data on the cumulative distribution of measured SENEL values for several types of aircraft during both landing and take-off are shown on Figure 33. As indicated, a level of 5 dB above the average (50 percent) is exceeded about 5 percent of the time.

6.3 Alternate Limits and Locations for SENEL Measurements

The preceding paragraphs have outlined the basis for the minimum requirements for SENEL monitoring as specified in the regulation. In order to respond to the intent of the regulation, it will frequently be desirable for an airport proprietor to set lower SENEL limits for his airport. For example, consistent flight operations by aircraft at less than the maximum gross weight would make it necessary to reduce the SENEL limits correspondingly. This flexibility is provided by the regulation so that reduced SENEL limits, approved by the Department of Aeronautics, can be imposed with the full enforcement provisions of the regulation.

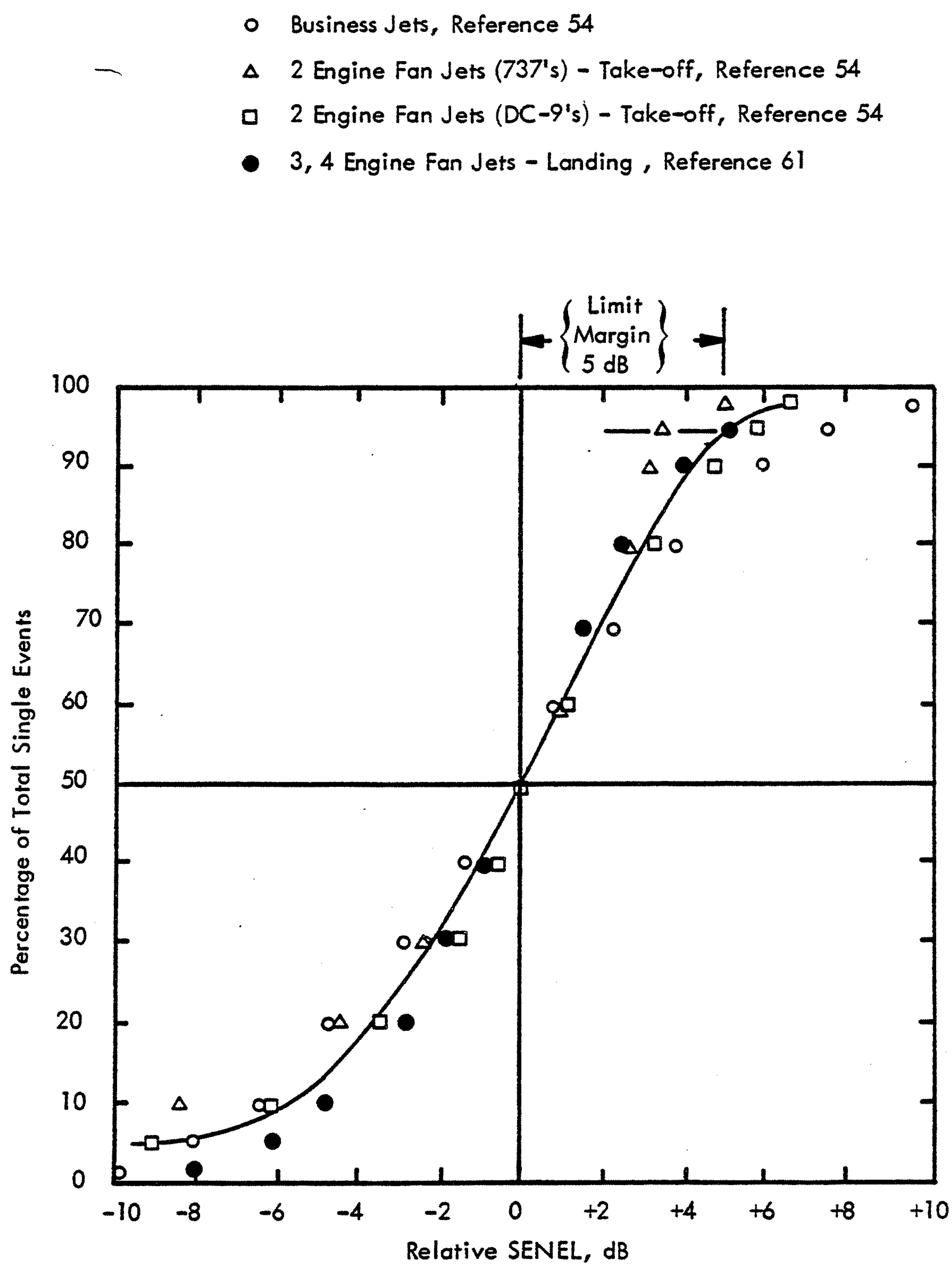


Figure 33. CUMULATIVE FREQUENCY DISTRIBUTION FOR MEASURED SENEL VALUES

Some simplifications of the SENEL monitoring system requirements can be achieved through the variance procedure in special cases not covered by the standard. This could include a special SENEL monitor system off one end of a single runway to make it possible to detect violations of the SENEL limits for both landing and take-off with only one SENEL monitoring system. Another possible simplification would involve the use of only one SENEL monitoring position for landing or take-off monitoring midway between the extended centerlines of two closely adjacent runways. Such a variance should only be permitted, however, if there is no possibility of both runways being used simultaneously, since this would prevent clear identification of a single aircraft violator of the SENEL limits. Furthermore, such a procedure would require a reduction in the allowable SENEL limits at the single monitoring position to account for the increased distances to the flight paths for each runway.

Any request for the type of variances suggested above for SENEL monitoring should be carefully reviewed by the Department of Aeronautics to insure that the intent of the regulation is not compromised.

7.0 IMPLEMENTATION OF THE SINGLE EVENT NOISE EXPOSURE LEVEL CONCEPT

The primary benefit of the SENEL monitoring system is to prevent inherently noisier aircraft from operating into a given airport, and to provide the airport proprietor a direct tool for controlling the noise environment emanating from his airport. The effectiveness of this element of the standard depends in part on the enforcement of the SENEL limits, which involves levying of a punitive fine for violation as specified in Article 8 of the noise standard. In addition, the ability to detect a violation and the degree of restriction implied in the SENEL limits are key elements in the effectiveness of this portion of the regulation.

7.1 Identification of SENEL Violations

Operation of aircraft noise monitoring systems has shown that aircraft which violate noise limits can be identified on the basis of time-of-flight records normally available in manned flight control towers.

The SENEL monitoring system is required to identify the time when any SENEL measurement exceeds the prescribed limits. The specified accuracy of this time identification allows an error of not more than 20 seconds within any 24-hour period, and a time discrimination of 1/2 second. (See Section 5080.3 (b) (3) of the noise standard.)

The maximum frequency of flight operations from a given runway would be on the order of one flight every 60 seconds, so that normally it will not be difficult to accurately define and identify the time of a given flight on the SENEL record.

Identification of aircraft which violate SENEL limits at airports lacking tower personnel at the time of violation may be possible through knowledge of the time of the violation. However, a foolproof violation detection method for unmanned airports will require further evaluation by the enforcing agencies, with adequate attention to the specific problems within their jurisdiction.

Final responsibility for establishing requirements for identification of aircraft operators whose aircraft exceed the single event noise exposure level limit rests with the county, as specified in Article 7 of the noise standard.

7.2 Degree of Noise Control Achieved by SENEL Limits

The difference between the average expected value of SENEL for a given type of aircraft and the maximum probable value has been selected to provide a practical limiting gate which is a compromise to allow continuation of the basic level of existing service at an airport but prevent any trend towards noisier aircraft and prevent typical operations of currently operating aircraft which lead to excessive noise. Such operations include excessive power during approach and lower than normal climbout profile. It must be emphasized, however, that the SENEL limits would be waived when a violation occurs as the result of special flight procedures required by emergency or other unusual flight safety reasons.

The degree of restriction represented by the recommended limits for SENEL for each type of airport can only be accurately assessed from a statistically reliable set of SENEL measurements. Analysis of the limited data available at this time indicates that the specified SENEL limits could be exceeded by about 5 percent of the noisiest aircraft currently operating out of an airport, until the pilot procedures become more uniform. If a new class of aircraft which makes more noise is introduced, its percentage of violations is expected to be much higher.

It should be emphasized that there is no practical method available within current technology for establishing a single event noise limit system which could accommodate the natural variation in noise levels for a given type of aircraft and provide a completely 100 percent effective go/no-go noise gate to exclude a noisier aircraft. The normal variations in noise level for a single class of aircraft are due in part to variations in weather conditions and to normal variations in flight operational techniques by pilots. Noise level variations due to the former are unavoidable. Variations due to pilot techniques are partially controllable and will tend to be modified by pilots to avoid occasional and unnecessary violations of the SENEL limits. An indication of the significant effect of different flight techniques on noise from a given type of aircraft is apparent from the data discussed in the following section.

7.3 Summary of Results from Noise Monitoring of Orange County Airport

In support of the development of the noise regulation, the California Department of Aeronautics sponsored a pilot program of airport noise monitoring conducted by the Northrop Corporation at Orange County Airport, Reference 54. Some of the key results from this 66 day test program, which was monitored by Wyle Laboratories by direction of the Department of Aeronautics, are summarized here.

7.3.1 Monitor System Configuration

The airport noise monitoring system consisted of five fixed measuring stations for measuring noise level, located essentially on or around the take-off flight path of Orange County Airport as shown in Figure 34. As explained in more detail in Reference 54, each monitor station consisted basically of a microphone, pre-amplifier, A-weighting network, and amplitude-to-frequency converter. The frequency modulated signal, representing the instantaneous amplitude of the noise level, was transmitted over leased telephone lines to a centrally located digital acquisition system and multi-channel incremental digital tape recorder. Data was accumulated on tape for about one week, then removed and processed directly through a digital computer to provide histograms of noise level as well as tabulations of SENEL and maximum noise level for each event (jet aircraft flyover) and measurement station, along with a record of the time of occurrence. Daily and weekly average values of CNEL were also computed and printed out. Equivalent acoustic calibration signals were generated remotely and recorded daily to provide an end-to-end check on system accuracy. Although the performance specifications of the system differed slightly from those given in the state regulation (see Article 14 of the noise standard), the data obtained can be considered as representative results for the measurement of SENEL and CNEL values.

7.3.2 Airport Operations During Test Period

Data were reported for 66 days during a 3-month period from June 21, 1970, to September 21, 1970. The expected schedule of commercial and private jet aircraft traffic during this period is compared (Table 15) with the average actual traffic observed during the 66 days reported. The actual average daily departures were 82 percent of the estimated traffic, which was based for the most part on published airline schedules. The weighted or effective number of departures is the sum of the daytime departures plus three times the evening departures (7:00 p.m. to 10:00 p.m.) plus ten times the night departures (10:00 p.m. to 7:00 a.m.). The average measured value for the weighted number of departures was 39.3 per day or 76 percent of the expected number (51.5 per day). For this case, therefore, the expected value of the community noise equivalent level (CNEL) would have been equal to about 10 log (51.5/39.3) or 1.0 dB high, just due to overestimating the flight traffic based on published flight schedules. This, of course, is only one source of error in any estimated value of CNEL but is considered representative of the variation attributable to scheduled vs actual flight traffic.

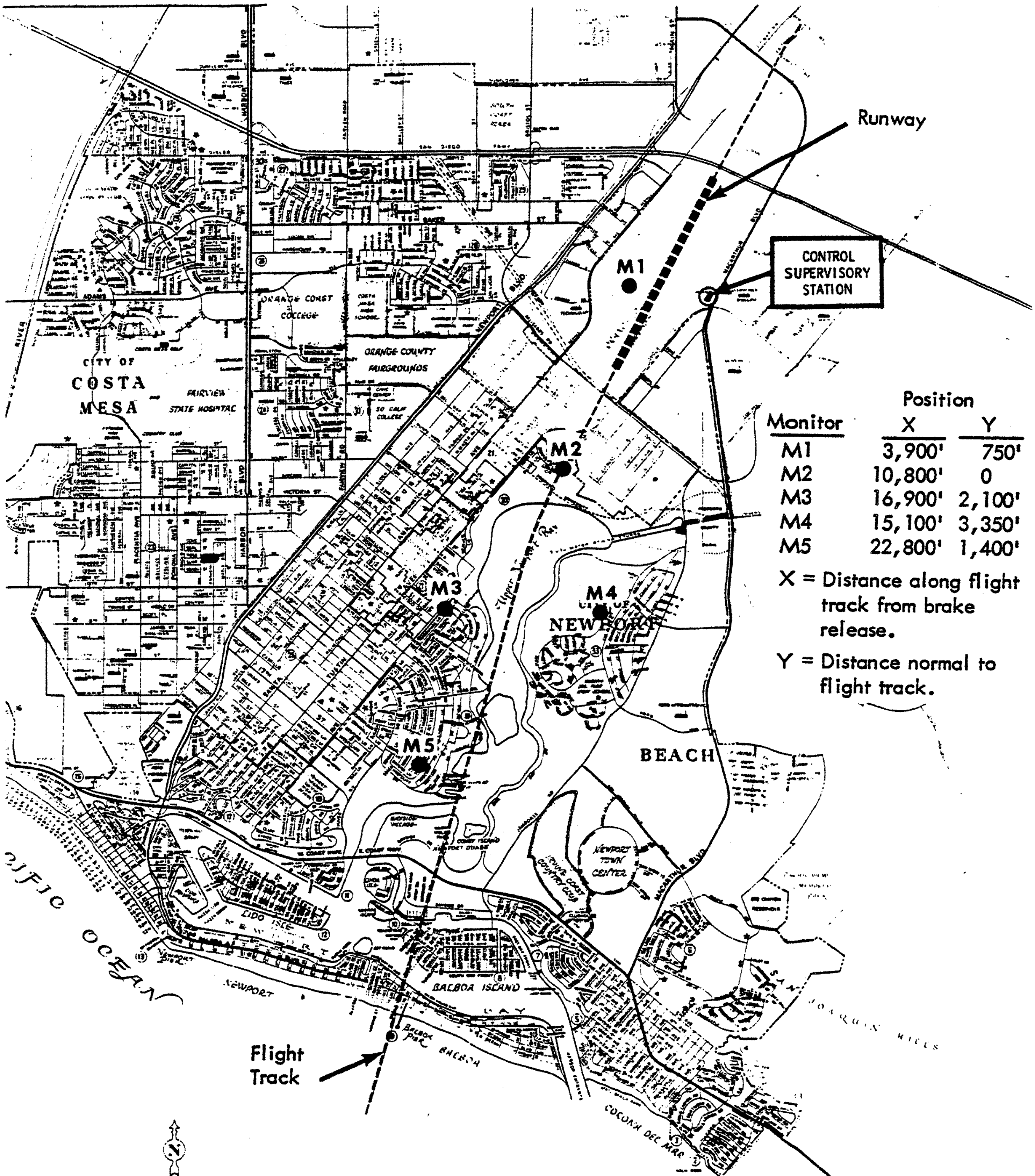


Figure 34. LOCATION OF NOISE MONITORING STATIONS AT ORANGE COUNTY AIRPORT (Adapted From Reference 54)

Table 15

EXPECTED VS MEASURED AVERAGE NUMBER OF DEPARTURES
PER DAY DURING TEST PERIOD AT ORANGE COUNTY AIRPORT

TRAFFIC	Daytime (0700-1900)	Evening (1900-2200)	Night (2200-0700)	Weighted Total[3]
Expected				
Commercial Jets[1]	21	4.8	0	
Private Jets[2]	3	1	1	
Total	24	5.8	1	51.5
Measured[4]	20.4	4.3	0.6	39.3

1 - According to Published Airline Schedules, August 1, 1970

2 - According to Estimated Traffic, Airport Manager

3 - Weighted Total = Daytime Flight + 3 (Evening Flights) + 10 (Night Flights)

4 - Average Total Daily Departures During Test Period

7.3.3 CNEL Measurements

The hourly noise level (HNL) is the basic measurement utilized for computing a daily CNEL at a given station (see Section 5006 (f) of the noise standard). The HNL is the average value (on an energy basis) of the A-weighted sound level over a given hour. To a close approximation, this quantity can be expressed in mathematical form as the summation of the SENEL's measured during one hour by

$$HNL = 10 \log \left[\frac{1}{3600} \sum_{n} \text{antilog} \frac{SENEL\ (n)}{10} \right]$$

$$= \overline{SENEL} + 10 \log n - 35.6$$

where SENEL (n) = the n^{th} SENEL measurement during one hour

$\overline{SENEL}$ = the energy-average SENEL during the hour

n = the total number of single events (flights) in one hour.

Figure 35 illustrates the variation in HNL measured during a typical day for the pilot measurement program at monitor positions 2 and 3.

By carrying out the energy summation of HNL values during the entire day, employing the weighting values for the evening and night time periods according to the definition in Section 5006(f) of the noise standard, the daily CNEL values for these three samples were computed. These values, shown in Figure 35, were found to agree exactly with the tabulated values published in Reference 54. Thus, the expected relationship between the measured values of SENEL and CNEL, as published in Reference 54, was verified exactly for this random sample.

The wide variations in the HNL values for this pilot test can be attributed to the wide variations in the low traffic rate. As indicated on the figure, the number of flights per hour varied from 0 to 4 during the hours 7:00 a.m. to 10:00 p.m. This variation also points out one method of reducing noise impact - adjusting the schedule of departures. It is interesting to note, for example, that if the three flights occurring from 9:00 to 10:00 p.m. had been distributed over the 4:00 to 7:00 p.m. period, one could expect the daily CNEL to decrease by approximately 1 to 1.5 dB. Had all the evening flights actually occurred before 7:00 p.m., the CNEL values would have decreased by about 2 dB.

7.3.4 Statistical Results from CNEL Measurements

Some of the most important results obtained from the pilot study at Orange County Airport are embodied in the statistical data on the CNEL and SENEL measurements. These data provide a measure of the relative stability of CNEL boundary measurements and an indication of the potential effectiveness of given SENEL limits for noise control of individual aircraft.

An indication of the variation in daily CNEL values at two of the monitor positions was shown earlier in Figure 29. More pertinent, however, to the statistical sampling method for intermittent CNEL boundary measurements is the validity of a 7-day sample as a measure of the CNEL over one quarter. This validity can be tested by examining the results of the 3-month pilot

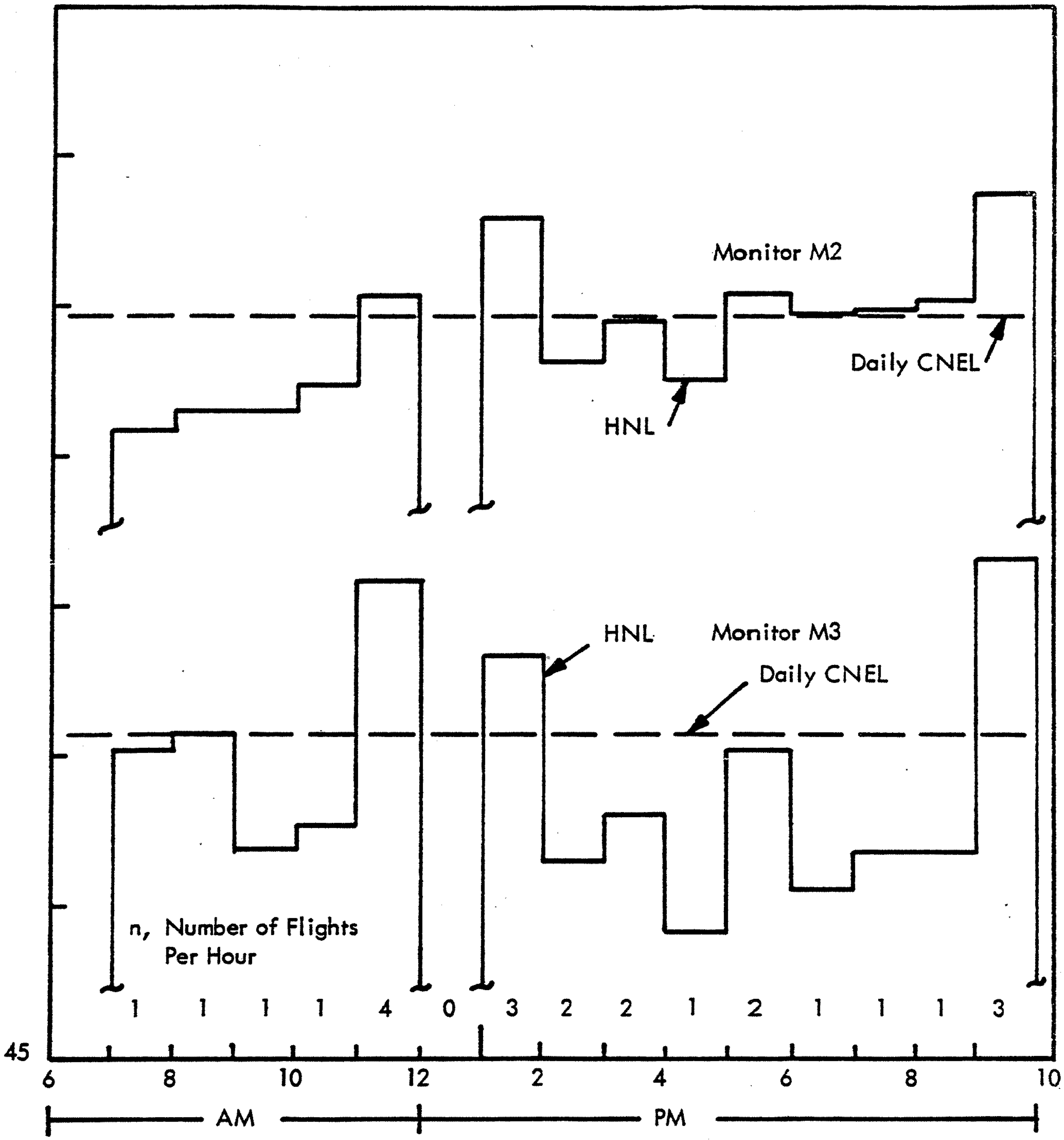


Figure 35. TYPICAL VARIATION IN HOURLY NOISE LEVEL (HNL) - MEASURED ON AUGUST 2, 1970 AT ORANGE COUNTY AIRPORT (Data From Reference 54)

test. The difference between the average CNEL values for "continuous" (66 days of data out of 92 days possible) monitoring and the average for any one 7-day sample during this period will provide an indication of the potential accuracy of such a 7-day sample. This comparison is made in Table 16 for four monitor points for which five continuous 7-day samples could be obtained. The second column shows the average CNEL based on the 66 days of data. The next five columns show the difference between this average and each of the five weekly samples.

A more complete evaluation of the probable stability in CNEL boundary determinations can be made by examining the statistics of the CNEL measurements in greater detail. If all of the daily CNEL values are normally distributed about their true mean value with a standard deviation of σ, then the standard deviation for the difference between any one 7-day sample and the true mean of the daily CNEL values will be equal to $\sigma/\sqrt{7}$ (Reference 62). The probability that the CNEL from any one 7-day sample will fall within a defined tolerance range can then be determined. For example, 90 percent of the time, a 7-day CNEL sample would be expected to fall within a range of about $1.65\sigma/\sqrt{7}$ or 0.62σ, where σ is the standard deviation of the daily CNEL values.

Figure 36 shows the statistical distribution of the daily CNEL values, for all four measurement positions, relative to their corresponding mean values. The data shown are from the daily CNEL values for monitor positions 1, 2, 3, and 5. The standard deviations of the daily CNEL's for each position, computed separately, were 1.9, 2.2, 2.6, and 2.7 dB respectively. Since the slant range between the aircraft flight path and the measurement point increases progressively for points 1 through 5, this shows (as expected) that the variation in CNEL will tend to increase as this slant distance increases. However, for purposes of this analysis, the data from all four positions were lumped together to give an overall standard deviation (σ) of 2.4 dB for the daily CNEL values. Based on this value the expected probability that a 7-day CNEL sample will fall within a specified tolerance range is listed in Table 16 (Reference 62). For comparison, the data in Table 16 have been used to show, in the last column of Table 17, the actual percent of time that the measured weekly CNEL values fell within the specified tolerance range. As expected, this shows that the measured variation in the five weekly CNEL samples was approximately the same as or less than the expected variation.

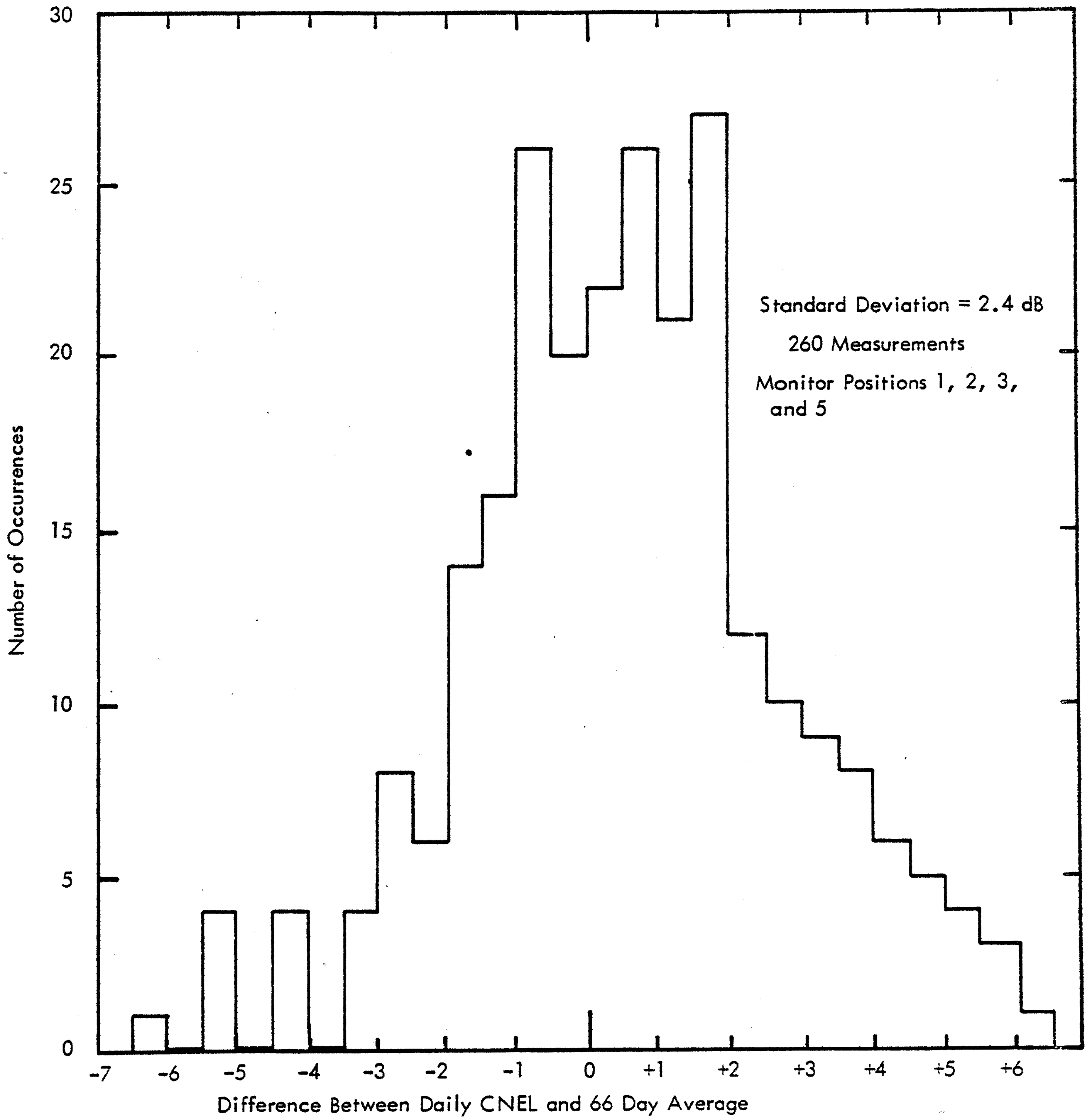


Figure 36. STATISTICAL DISTRIBUTION OF DAILY CNEL VALUES FROM 4 MONITOR POSITIONS OVER 66 DAYS OF MEASUREMENTS AT ORANGE COUNTY AIRPORT (Data From Reference 54)

Table 16

COMPARISON OF 66 DAY AVERAGE CNEL VALUES
AND 7 DAY SAMPLES (REFERENCE 54)

Monitor Position	66 Day Average CNEL, dB	Week 1	Week 2	Week 3	Week 4	Week 5
1	73.7	-0.1	-0.9	+0.2	+0.1	-0.4
2	70.6	-0.4	-1.2	+0.3	0	0
3	57.1	0	-2.0	-0.7	-0.6	-0.3
4	56.4	+0.9	-1.0	-0.6	-2.0	0.2

Table 17

PROBABILITY THAT 7 DAY CNEL SAMPLE WILL FALL WITHIN
SPECIFIED TOLERANCE LIMITS ABOUT THE TRUE MEAN VALUE

Tolerance Limits	Estimated Probability	Measured Distribution
±0.5 dB	42%	55%
±1.0 dB	73%	85%
±1.5 dB	90%	90%
±2.0 dB	97%	100%

These observed variations in CNEL measurements from day-to-day are the result of several factors including

- Number and schedule of flight operations
- Aircraft type and flight profile
- Pilot techniques
- Atmospheric sound propagation anomalies
- Instrumentation stability

Only the first source of variation in this list is predictable. During the pilot program at Orange County Airport, variation in this factor was equivalent to a standard deviation in CNEL of about ±1.2 dB. Assuming no correlation between this variation and the other random variables, the estimated standard deviation in daily CNEL due to all the latter would be about

$$\left[(2.4)^2 - (1.2)^2\right]^{1/2} = 2.1 \text{ dB}$$

Finally, it should be recognized that for airports without radical seasonal changes in flight operations, an even smaller deviation can be expected for measurement of an annual CNEL along a noise impact boundary since the latter would be based on the average of at least four weekly samples. However, specific numerical values for statistical behavior of annual CNEL measurements should await results of a complete record for at least one year.

It is sufficient to summarize these data on CNEL measurements by indicating that the specified tolerance of ±1.5 dB for an annual CNEL determination appears reasonable and readily attainable at least 90 percent of the time. The potential maximum error in noise impact boundary position for two different types of aircraft operating at two different levels of traffic is shown in Table 18 for noise impact boundary positions along the sideline and at the contour closure point under a maximum gross weight take-off path. Values are shown for a tolerance in CNEL values of 0.5, 1,0, and 1.5 dB. A more precise definition of variation in CNEL boundary position for a wide range of airport sizes must await new data. It is entirely reasonable to expect, for example, that the variation in CNEL at a given distance from a runway will tend to decrease for very large airports where the large number of flights will have a smoothing effect on the integrated noise exposure levels on the ground.

Table 18

POTENTIAL VARIATION IN NOISE IMPACT BOUNDARY POSITION (CNEL = 65 dB) DUE TO VARIATION IN CNEL MEASUREMENTS

Airplane Type and Traffic	Deviation in CNEL, dB	Contour Deviation	
		Sideline, ft	Take-off [1] (Closure Point), ft
30 Daytime Departures			
4 Engine Turbofan	±0.5	±125	±1300
	±1.0	±250	±2700
	±1.5	±360	±3900
2 Engine Turbofan	±0.5	± 90	± 650
	±1.0	±175	±1300
	±1.5	±250	±1800
300 Daytime Departures			
4 Engine Turbofan	±0.5	±400	±4400
	±1.0	±850	±9300
	±1.5	±1300	±14,200
2 Engine Turbofan	±0.5	±225	±1700
	±1.0	±475	±3500
	±1.5	±700	±5100

(1) Take-off Profile for Maximum Gross Weight

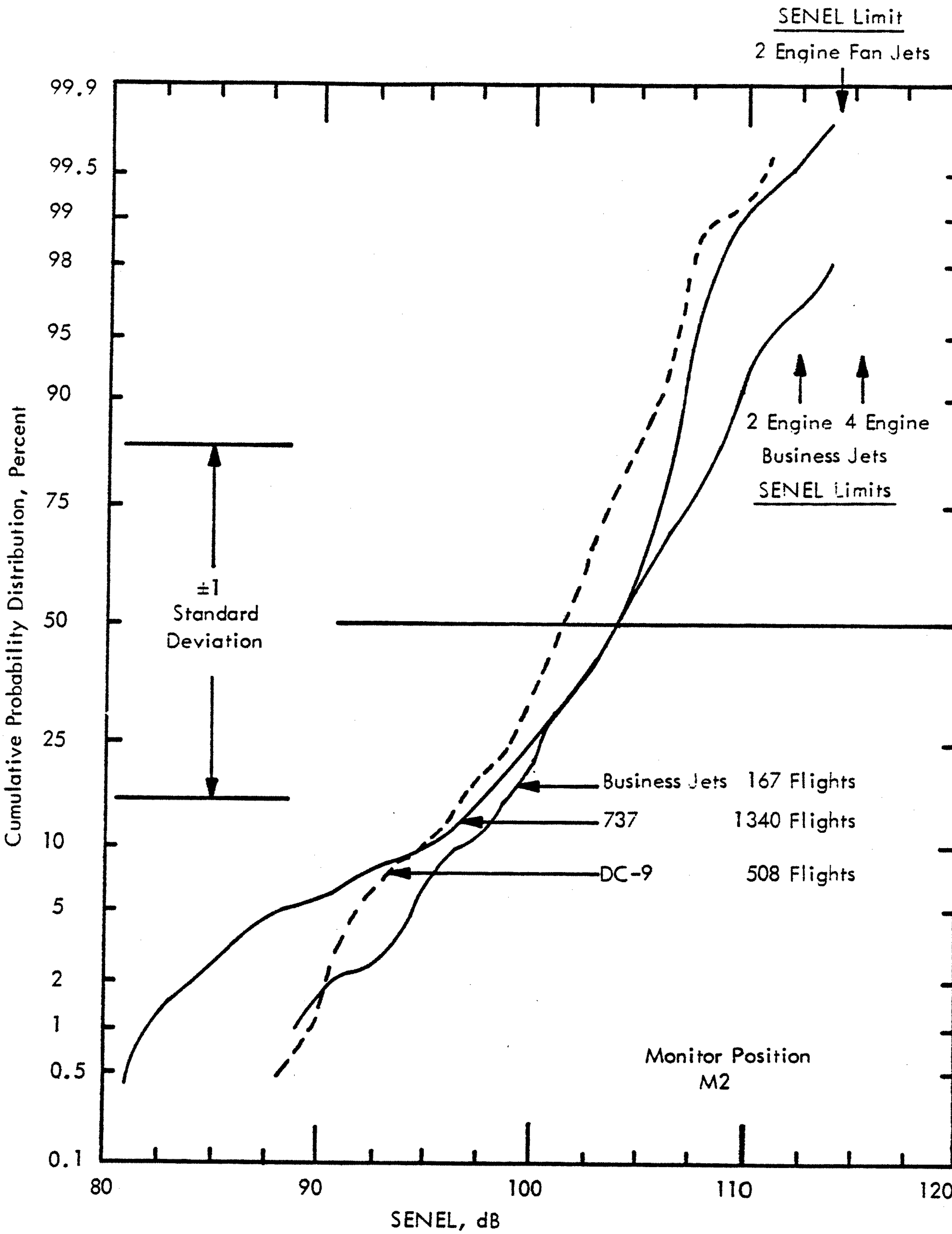


Figure 37. CUMULATIVE PROBABILITY DISTRIBUTION OF SENEL MEASUREMENTS AT ORANGE COUNTY AIRPORT (Data From Reference 54)

7.3.5 Statistical Results from SENEL Measurements

Results from approximately 2000 measurements of the single event noise exposure level (SENEL) at the five monitor positions at Orange County Airport are reported in Reference 54. These include SENEL data for departures of Douglas DC-9 and Boeing 737 two-engine turbofan aircraft (92 percent of the data) and a variety of business jets. The results from monitor position M2 are representative of SENEL measurements made in compliance with Article 4 of the state regulation. This position was located approximately 10,800 feet from the brake release point directly under the take-off path. (See Figure 34.)

The statistical results for SENEL measurements are best illustrated by plotting a normalized cumulative distribution of the measurements on probability graph paper. Such a plot is shown in Figure 37 for the SENEL data from monitor position M2. Also shown are the appropriate SENEL limits for this monitor position, according to Article 5 of the regulation. For this position, the SENEL limits are:

2 Engine Fan Jets (DC-9, 737)	114.5 dB
2 Engine Business Jets	112.5 dB
4 Engine Business Jets	115.5 dB

It is apparent from Figure 37 that for the 2-engine fan jets, about 0.15 percent of the 737 flights should have exceeded the limits. In fact, one out of the 1340 (0.07 percent) flights of the 737 did exceed the SENEL limits during the 66 days of measurements. This very small rate of violation for the commercial flights is due to the fact that the SENEL limits specified in the regulation are based on a maximum gross weight take-off profile whereas the operations of 2-engine fan jets out of Orange County Airport are limited by runway load limits to about 85 percent of their maximum gross weight. This fact, coupled with the short-haul traffic pattern, (tending to result in even lower gross take-off weights) and combined with the effect of initiating power cut back near position M2, results in lower SENEL values. This is an example of an airport where the airport proprietor may find it desirable to adopt lower SENEL limits than the maximum limits set forth in the noise standard.

For the business jets, approximately 3.5 percent of the flights would be expected to exceed the SENEL limits (according to Figure 37), assuming the jets are 2-engine type. In fact, 5 out of 167 flights (3 percent) of business jets did exceed these limits during the 66 day period. In this case, the wider range of noise and flight profile characteristics encountered tended to increase the apparent violation rate.

Figure 37 also shows the theoretical values for ±1 standard deviation about the mean value (50 percent point) assuming the data are normally distributed. The linear constant-slope shape of the distribution curve signifies that the data would display a normal distribution. Such a normal distribution is observed approximately for only the business jets, for which the standard deviation in SENEL is ±5.0 dB.

More significant, however, is the difference in SENEL values between the 50 percent and 95 percent points. This varies for the three groups of data from 3.6 dB to 7 dB with an average value of 5.3 dB. This corresponds closely to the 5 dB margin between an expected value for the average SENEL and the limit values established in the regulation.

The preliminary draft of the noise regulation had included provisions for monitoring and enforcing SENEL limits on the sideline. This was finally eliminated due, in part, to the lack of discrimination of this position for SENEL variations which were under the control of the aircraft operator. In other words, along the sideline, the SENEL values will tend to vary much less and be almost totally dependent on the type of aircraft and generally independent of piloting techniques. This trend is borne out by the statistical distribution for the SENEL measurements made at monitor position M1, shown in Figure 38. In this case, the distinction between the two types of 2-engine fan jets is much less, as expected. The average difference between the median or 50 percent point and the 95 percent points for these data at position M1 is 3.3 dB.

In summary, the SENEL measurements support the choice of a limit margin selected for the SENEL monitor positions chosen. The low SENEL violation rate experienced for departure of commercial flights at Orange County Airport is due to the particular type of operations at this airport. As provided for in the regulation, lower SENEL limits could be established by the airport operator, and,. upon state approval, enforced to achieve better control of noise at his airport.

7.3.6 Evaluation of Operational Procedures for the Monitoring System

At Orange County Airport, monitor systems were generally located on 20-foot poles near residences in a satisfactory manner consistent with the requirements of the regulation. The microphones were provided with windscreens

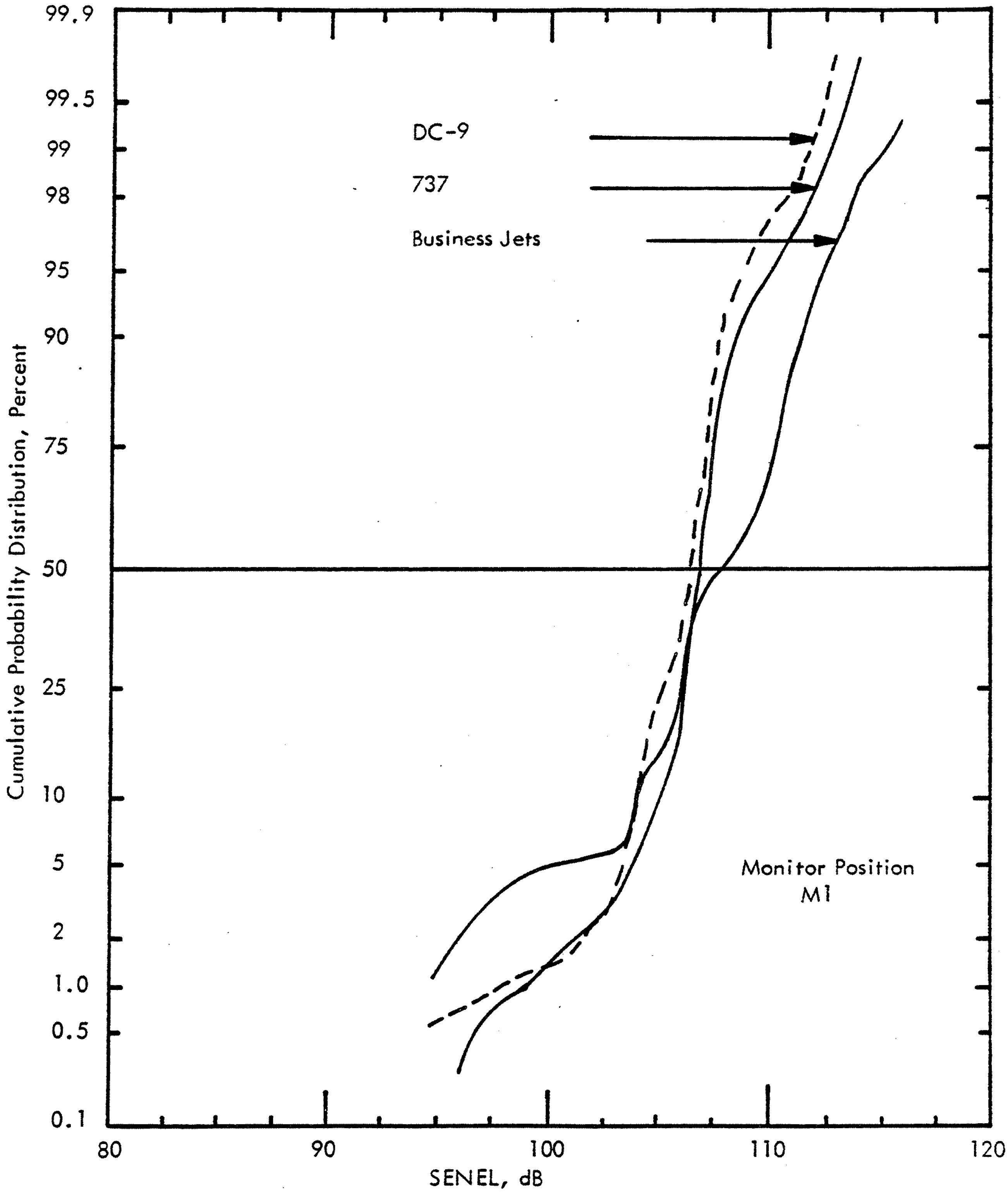


Figure 38. CUMULATIVE PROBABILITY DISTRIBUTION OF SENEL MEASUREMENTS AT ORANGE COUNTY AIRPORT (Data From Reference 54)

and were calibrated daily with an electrostatic actuator in accordance with the required procedures. The day-to-day variation in the resulting calibration figures was no more than 1 dB except when calibration equipment malfunctioned. The overall downtime of the system during the 3-month trial period was more than desired for a system required to operate "continuously" (i.e., 48 weeks out of 52). However, the downtime presumably can be reduced substantially as more operating time and experience are gained with the system. As reported in more detail in Reference 54, valuable experience was obtained during the pilot program concerning other details on system installation and transmittal of data by telephone lines. The need to allow flexibility in setting threshold limits for the monitoring system to accommodate varying ambient noise levels was also demonstrated. This flexibility is provided in the monitoring system performance requirements as specified in Article 1 (Definitions) and Article 14 (Noise Monitoring System Specification) of the regulation.

The experience and data gained from this pilot program were helpful in validating many of the concepts developed in the noise regulation. Additional information from the results of other noise monitoring systems, installed for some time at several European airports (References 63 to 67), will also provide useful background information for development and implementation of airport noise monitoring systems in the State of California. Several major manufacturers of acoustic measurement systems are currently engaged in developing systems capable of satisfying the monitoring system specifications outlined in the regulation. These specifications are discussed in more detail in the following chapter.

8.0 NOISE MONITORING SYSTEM

This section discusses the implementation, operation, and configuration of the noise monitoring system. It also provides cost estimates for the installation and operation of monitor systems for single event noise exposure levels (SENEL) and hourly noise levels (HNL) in accordance with the noise standard.

8.1 Rationale for Monitor System

This noise standard is a specification for the measurement of parameters used to establish a reasonable noise environment at the boundaries of existing and proposed airports. The parameters are based on A-weighted sound level measurements and incorporate integration processes to eliminate uncertainties associated with transient data. The intent of this section is to establish guidelines for the configuration of a noise monitoring system to measure and record these parameters within an overall total system specification.

8.2 Background on Performance Specification

Wherever practical, existing acoustic measurement specifications were utilized in the definition of component and system performance characteristics. The basic specification utilized was taken from ASA S1.4-1961, "American Standard Specifications for General Purpose Sound Level Meters," and the forthcoming revision covering precision sound level meters. As an interim standard for the microphone, the standard entitled, "Precision Sound Level Meters," IEC Publication 179, International Electrotechnical Commission, Geneva, Switzerland, 1965, was used.

In several instances, it was necessary to develop specifications directly associated with the measurement of HNL and SENEL. These specifications are not unduly restrictive and can be satisfied by utilizing proven circuitry and measurement techniques. The techniques utilized to satisfy these specifications are entirely at the option of the responsible airport agency.

It must be emphasized that the SENEL and HNL measurement systems configured in the noise standard were presented for information only, and not as specific design criteria. The single limitation on system performance is set forth in Paragraph 5080.3 - Performance Specifications.

8.3 System Implementation

System implementation by the responsible airport agency will involve the determination of the number of monitoring systems required and the procurement of these monitoring systems. The operational aspects of system utilization are differentiated from the implementation aspects and are discussed in Section 8.4.

8.3.1 Determination of the Number of Monitoring Systems Required

This requirement will be generally established by the size of the airports (i.e., the number of runways), the nature of the surrounding communities, and the extent of the impact boundaries. From these factors the method for determining the number of monitoring systems is defined in the noise standard. In some instances, continuous monitoring is not required. In these cases, consideration should be given to sharing systems and personnel between airports.

8.3.2 Procurement of Monitor Systems

In the procurement of a measurement system two approaches should be considered. First, the system could be leased on a long-term basis. This approach would provide a basis for absorbing the equipment costs as an element of monthly operating expense. It would also place the burden on the supplier for upgrading and replacing equipment. The practicality of this approach will depend on the extent of the monitoring system required.

In many instances, the responsible airport agency may wish to purchase the measurement system. In those instances, a competitive procurement is recommended, open to both acoustic instrument manufacturers and systems manufacturers. Each supplier should be required to itemize all items of hardware and/or services proposed.

8.3.3 Sharing Systems and Personnel

A practical technique for reducing measurement system costs would be to share equipment and personnel among several airports in the same geographical area. This could be done on an individual county basis with a single staff servicing several local airports. This method would eliminate costly duplication in equipment and personnel.

8.4 Operational Considerations

Operational considerations concerning staffing, system maintenance, calibration, and data reduction are discussed in this section.

8.4.1 Personnel Requirements

The monitoring system specified in the noise standard will not impose unreasonable staffing requirements on the responsible airport agency. In instances where only a few systems are utilized, staffing will be limited to the part-time services of a single technician. The skills required of this technician are not complex and could easily be acquired by technical personnel with other responsibilities at an airport.

In instances where several systems are maintained or a computer-based system is utilized, a full-time technician and/or engineer may be required. In these instances, existing airport personnel could be trained to maintain the system, or personnel could be shared between airports for maintaining similar systems.

8.4.2 Maintenance

Maintenance will involve the laboratory calibration of microphones, amplifiers, and analysis equipment on a periodic basis. It will also involve emergency, on-site repair of monitoring systems and system components. The complexity of the system involved and the competence of the operating staff will determine the best approach to this requirement.

In the cost estimates presented in Section 8.6, the requirements for system maintenance will be separated from those of calibration and data processing since maintenance may usually be procured from the manufacturer on a contract basis. Maintenance services purchased on this basis would cost between 10 and 15 percent of the system purchase price per year.

8.4.3 Calibration Requirements

In addition to the requirement for periodic laboratory calibration of system components, a field calibration of all operational systems must be performed on a regular basis. This task will involve introducing a signal into the system microphone and recording the resultant system response. The purpose of this calibration is to verify that the system is performing within the tolerances specified in the noise standard.

8.4.4 Data Reduction Requirements

Data acquired from the monitoring systems must be recorded and submitted in reports to the California Department of Aeronautics. The method for translating the system output to SENEL, HNL, and CNEL is at the discretion of the airport agency.

One approach would involve taking a reading from a meter, converting this reading to SENEL or HNL by the use of tables, and entering it into the appropriate report. It is recommended that a minimum monitoring system be required to provide a permanent output record of SENEL values and time of occurrence. In systems utilizing a computer, it would be feasible to obtain finished processed data output on a system typewriter, which could then be directly incorporated into the report.

8.4.5 Considerations in System Installation

The field installation of SENEL and HNL Monitoring Systems creates requirements not normally encountered in the installation of precision measurement instrumentation. These requirements are summarized below.

8.4.5.1 Environmental Factors

The system microphone, and in many instances the measurement instrumentation, must be suitable for continuous service over almost the entire range of weather conditions encountered within the state of California. Dampness, rain, ice and great changes of temperature must not affect the reliability of the system. Strong winds must not produce extraneous outputs from the system. These requirements dictate the need for highly reliable weather protection, to maintain a completely operable measurement system. Limited information available on airport noise monitoring systems in operation at some European airports indicates current technology can provide weather-reliable systems.

8.4.5.2 System Operating Power

In system installation this requirement will not be a factor of major concern. In many instances, 110-volt ac operating power will be available locally at the site of system installation. In instances where power is not available, it would be practical to utilize rechargeable batteries contained within the system.

8.4.5.3 Signal Transmission

In instances where the monitoring system does not include a recording device, data will be transmitted to a central location for processing. Two techniques for data transmission are possible: transmission (phone) lines and radio links.

In both cases, it is necessary to ensure that the properties of the transmission system do not invalidate the data. The direct transmission of the total noise spectrum by phone lines is feasible, but not economical. The use of radio links is impractical due to the difficulty of obtaining a frequency allocation and loss of data due to interference.

The most suitable transmission technique would be to utilize standard phone lines using an encoding device to ensure the validity of transmitted signals. A practical and proven technique for this task would be the use of level to frequency conversion. With this technique, the signal integrity is not affected by line characteristics.

8.5 System Configuration

In configuring a measurement system, considerable latitude is given to the responsible airport agency. Systems may be configured utilizing new equipment procured for the specific purpose of measuring SENEL and HNL, or existing equipment may be modified or expanded to meet this requirement. In some instances, there will be advantages in utilizing computer-based systems which will simultaneously monitor several runway and community locations.

In the following text, three possible approaches to the configuration of a monitor system are suggested. Estimates are also provided for the cost and staffing associated with the procurement, installation, and operation of these systems. A precise estimate of these costs cannot be established without further study. However, we have developed pricing with an estimated accuracy of ±25 percent.

The following three approaches will be presented:

- Two totally self-contained instruments will be defined, one for performing SENEL measurements and one for performing HNL measurements.

- For airports where periodic sampling of noise levels is sufficient, a portable system is recommended. This approach will involve the self-contained systems defined above.

- A computer-based system capable of performing SENEL and HNL measurements for large airports will be discussed.

The nature of these systems will be discussed in terms of performance capability, and the costs and staffing associated with procurement, maintenance, and operation.

Estimates are not provided for locating the physical position of these systems nor the costs of data reduction beyond the logging of processed SENEL and HNL data.

8.5.1 A Self-Contained SENEL System and a Self-Contained HNL System

Many of the airports subject to the specification will require only a limited number of SENEL and HNL measurement systems. The agencies responsible for these airports will, in all probability, initiate competitive procurements with instrumentation manufacturers and systems suppliers.

We have estimated the procurement costs for these two instruments based on a limited production run of 400 units. Our estimated pricing is based on material costs, labor rates, overhead, G & A, and profit which are all commensurate with industry practices.

8.5.1.1 Description of Self-Contained SENEL and HNL Measurement Systems

Each system, or instrument, will consist of a self-contained, weather-resistant package. The instrument will contain all components, including the measurement microphone necessary to measure and record SENEL and HNL data. This data will be logged on adding-machine-type paper tape.

For the SENEL system, data will be logged whenever a violation occurs. At that time, the magnitude of the violation and its time of occurrence will be recorded. The frequency with which the tape must be replaced in the instrument will depend upon the nature of the particular airport involved. For purposes of estimating staffing requirements, we have assumed that this tape will be removed and transferred to reports once every three days.

For the HNL system, there will be a data printout once each hour. This printout will itemize the magnitude of the HNL measurement and its time of occurrence. This tape will also be removed and the data transferred every three days.

A calibration will be performed on both the SENEL and HNL systems in field operation, once each week.

8.5.1.2 Cost Estimates and Staffing Requirements for the Self-Contained Measurement Systems

The cost to an airport agency to utilize these two systems is estimated to be:

1. Purchased Material and Services

SENEL System	$ 3,500
HNL System	$ 4,000
Installation of Either System	$ 500

2. Maintenance for Either System — $ 500 per year

3. Personnel Required for System Operation — 200 hours per year per system

   Time per system will decrease with an increase in the number of systems - estimate is for one system only.

8.5.1.3 Systems for Periodic Sampling of SENEL and HNL

These systems will be similar to those defined in Paragraph 8.4.1.1. They will, however, incorporate features to facilitate rapid relocation between measurement locations, may utilize self-contained rechargeable batteries, and may also provide refined data reduction techniques.

The cost estimate for an airport agency to utilize these two systems is estimated as follows:

1. Purchased Material and Services

SENEL System (Portable)	$ 4,500
HNL System (Portable)	$ 5,000
Temporary Installation for Either System	$ 250

2. Maintenance for Either System — $ 500 per year

Personnel Required for System Operation — Depends upon logistics of system utilization

8.5.2 Computer-Based System

At airports requiring several SENEL and/or HNL measurement systems, it may be expedient to utilize a central computer which acquires data transmitted through phone lines from remotely located measurement stations. Several techniques for configuring a computer-based system are feasible. We have defined a computer-based measurement system that will accommodate between 10 and 40 channels of SENEL or HNL data.

8.5.2.1 Computer-Based Description

This system will utilize SENEL and HNL field stations (remote systems) which perform the shaping, squaring, and averaging functions associated with the particular measurement. This signal is then encoded and transmitted through telephone lines to the central computer system. At the computer stations, these signals are decoded, converted from analog to digital format, and processed through the central computer. The basic peripheral devices of this processor are a disc storage unit and a teletypewriter.

The data processing necessary to obtain SENEL and HNL information is achieved by computer programming. Formatted data will consist of SENEL versus time, HNL versus time, and community noise equivalent level (CNEL) printed out in tabular form on the teletypewriter. Community noise equivalent level will be calculated by the computer system. The computer could also be used for calculating possible complex interrelationships of data obtained in a multiple runway configuration.

8.5.2.2 Computer-Based System Pricing

The cost for an airport agency to utilize this computer-based system is estimated as follows:

1. Purchased Material and Services

Each SENEL Remote System	$ 2,000
Each HNL Remote System	$ 2,300
Installation for Either Remote System	$ 500
Installed Central Computer System	$50,000 to $65,000 (depending on the number of channels)

2. Annual Maintenance and Service

Phone Lines for Each Remote System	$ 600
Maintenance of Each Remote System	$ 300
Maintenance of Central Computer System	$ 4,800

3. Personnel Required for System Operation

A computer-based system will require a part-time engineer and one technician per shift of operation.

8.6 Application of Estimates to Specific Airports

This section provides two specific examples of ways that the estimated pricing, developed in Paragraph 8.4, might be applied to specific airports in operation in the state of California. The reader is reminded that the figures presented are approximations.

8.6.1 Airport Requiring 8 SENEL and 21 HNL Systems Continuously

These costs will be estimated based on the computer system defined in Paragraph 8.4.2. They specifically relate to the cost of installing and operating a permanent system.

1. Purchased Material and Services

8 Remote SENEL Systems	$ 16,000
21 Remote HNL Systems	48,300
Installation of 29 Remote Systems	14,500
Installed Central Computer System	65,000
Subtotal	$143,800

2. Annual Maintenance and Service

29 Phone Lines for Remote Systems	$ 17,400
Maintenance of 29 Remote Systems	8,700
Maintenance of Central Computer	4,800
Subtotal	$ 30,900

3. Personnel Required for System Operation

A system of this magnitude would require the full-time services of one engineer plus one technician per shift.

8.6.2 Airport Requiring Two Self-Contained SENEL and One Portable HNL Monitor System

1. Purchased Material and Services

2 SENEL Monitor Systems	$ 7,000
1 HNL Monitor (Portable)	5,000
Installation of 2 SENEL Systems	1,000
Temporary Installation of 1 HNL System	250
Subtotal	$ 13,250

2. Annual Maintenance of Three Monitor Systems $ 1,500

3. Personnel Required for System Operation

One technician 35 percent of the time

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APPENDIX A

GLOSSARY OF TERMS

The following explanations of terms commonly employed in this report are provided for the convenience of the reader. For additional formal definitions of terminology utilized in the noise standard, see Sections 5006 and 5080.1 of the noise standard itself.

SOUND PRESSURE

The sound pressure at a point in a sound field is a measure of the change in pressure from the static value (i.e., atmospheric pressure) caused by the presence of the sound field. For most complex sources of sound, the sound pressure contains energy over a broad frequency range audible to humans.

SOUND PRESSURE LEVEL (SPL)

The range in sound pressures from the minimum audible sound waves to those existing in the vicinity of a modern jet airplane is greater than a factor of one million. The sound magnitudes are therefore more conveniently expressed on a reduced scale. Consequently, a logarithmic scale is used in which equal additions correspond to equal multiples of sound pressure; the reference pressure corresponds approximately to the minimum audible sound pressure. This is a convenient scale to use since the ear responds to sound waves in a similar manner. On such a scale, the measurement of sound pressure is termed sound pressure level (SPL), the units being the decibel or dB. From what has been said above, it is obvious that the SPL also varies with frequency. It is usual, when measuring the sound pressure level of noise containing a wide range of frequencies, to measure the energy in fixed bands which cover the audible range. However, it is also possible to measure the overall sound pressure level (OASPL) of noise using a single broad frequency range instrument. This has the advantage of characterizing the sound by a single number.

A-WEIGHTED SOUND PRESSURE LEVEL

The ear does not respond equally to sounds of all frequencies, but is less efficient at low and high frequencies than it is at medium or speech range frequencies. Thus, to obtain a single number representing the sound pressure level of a noise containing a wide range of frequencies in a manner representative of the ear, it is necessary to reduce, or weight, the effects of the low and high frequencies with respect to the medium frequencies. The resultant sound pressure level is said to be A-weighted, and the units are dB. A popular method of indicating the units, dBA, is frequently used in this report. The A-weighted sound level is also called the noise level.

SOUND LEVEL METER

A sound level meter is an instrument that provides a direct reading of the sound pressure level at a particular location. It consists of a microphone and electronic amplifier together with a meter having a scale graded in dB. Using electrical filters, it is possible to directly measure the A-weighted sound pressure level with such an instrument. The meter is normally set to read with a "slow response" which provides a running average measure of the sound with an effective integration time comparable to that of the ear.

PERCEIVED NOISE LEVEL (PNL)

The perceived noise level (PNL) is a sound pressure level weighted so as to correspond to the subjective impression of the "noisiness" of a sound. The unit used is PNdB.

EFFECTIVE PERCEIVED NOISE LEVEL (EPNL)

The effective perceived noise level (EPNL) is similar to the perceived noise level but in addition includes correction terms that relate to the duration of an aircraft flyby and to the fact that there may be some discrete frequencies (such as the whine from a jet aircraft) present in the total noise. The unit used is EPNdB.

NOISE EXPOSURE LEVEL

Noise exposure level is the integrated value, over a given period of time, of a number of different events of equal or different noise levels and durations. The integration may include weighting factors for the number of events during certain time periods for which people are more annoyed by noise. The single event noise exposure level (SENEL) is an integrated average noise level for a single aircraft flyby with a reference duration of one second. The hourly noise level (HNL) is the integrated average noise level over one hour. The community noise exposure level (CNEL) is the integrated average noise level over a 24-hour period with weighting factors for the number of events during evening (7:00 p.m. to 10:00 p.m.) and night (10:00 p.m. to 7:00 a.m.) time periods.

NOISE IMPACT BOUNDARY

The noise impact boundary around an airport is an imaginary line joining all points for which the CNEL, averaged over one year, is equal to the criterion value.

NOISE IMPACT AREA

The noise impact area is the area in square statute miles enclosed by the noise impact boundary less that area of land usage within the boundary that is considered to be compatible with the actual noise environment.

INTEGRATOR/LOGGER SYSTEM

An integrator/logger system takes the output from a sound level meter, averages the signal over a prescribed period of time, converts to a sound pressure level and prints out the level on paper.

LINEARITY

Linearity is the property of a linear electrical system wherein there is a constant relationship between the output and the input of the system at any one frequency regardless of the magnitude of the input. In other words, the output of a linear system is a faithful reproduction of the input.

CREST FACTOR

Aircraft noise, like any random noise signal, contains a number of almost instantaneous peaks, which may overload the input of the amplifiers in the recording system; i.e., they may be too great for the amplifier to handle. One requirement of any recording system must be its capability to record linearly such peaks at least up to a certain magnitude or height. A useful means of specifying this magnitude is the crest factor, which is the ratio of the instantaneous peak value of the signal to its long-time average value.

APPENDIX B

THE ADOPTED NOISE REGULATIONS FOR CALIFORNIA AIRPORTS

SUBCHAPTER 6. NOISE STANDARDS

Article 1. General

5000. Preamble. The following rules and regulations are promulgated in accordance with Article 3, Chapter 4, Part 1, Division 9, Public Utilities Code (Regulation of Airports) to provide noise standards governing the operation of aircraft and aircraft engines for all airports operating under a valid permit issued by the department. These standards are based upon two separate legal grounds: (1) the power of airport proprietors to impose noise ceilings and other limitations on the use of the airport, and (2) the power of the state to act to an extent not prohibited by federal law. The regulations are designed to cause the airport proprietor, aircraft operator, local governments, pilots, and the department to work cooperatively to diminish noise. The regulations accomplish these ends by controlling and reducing the noise in communities in the vicinity of airports.

NOTE: Authority cited: Section 21669, Public Utilities Code. Reference: Sections 21669–21669.4, Public Utilities Code.

History: 1. New Subchapter 6 (§§ 5000–5006, 5010–5014, 5020–5025, 5030–5032, 5035, 5040, 5045–5048, 5050, 5055, 5060–5064, 5065, 5070, 5075, 5080, 5080.1–5080.5) filed 10-25-70; designated effective 12-1-71 (Register 70, No. 48).

5001. Liberal Construction. This subchapter shall be liberally construed and appled to promote its underlying purposes which are to protect the public from noise and to resolve incompatibilities between airports and their surrounding neighbors.

5002. Constitutionality. If any provision of this subchapter or the application thereof to any person or circumstance is held to be unconstitutional, the remainder of the subchapter and the application of such provision to other persons or circumstances shall not be affected thereby.

5003. Provisions Not Exclusive. The provisions of this subchapter are not exclusive, and the remedies provided for in this subchapter shall be in addition to any other remedies provided for in any other law or available under common law. It is not the intent of these regulations to preempt the field of aircraft noise limitation in the state. The noise limits specified herein are not intended to prevent any local government to the extent not prohibited by federal law or any airport proprietor from setting more stringent standards.

5004. Applicability. These regulations establish a mandatory procedure which is applicable to and at all existing and future potential airports in California which are required to operate under a valid permit issued by the department. These regulations are applicable (to the degree not prohibited by federal law) to all operations of aircraft and aircraft engines which produce noise. Only those airports which shall have been determined to have a noise problem (in accordance with Section 5050) will be required to perform noise monitoring.

The regulations established by this subchapter are not intended to set noise levels applicable in litigation arising out of claims for damages occasioned by noise. Nothing herein contained in these regulations shall be construed to prescribe a duty of care in favor of, or to create any evidentiary presumption for use by, any person or entity other than the State of California, the counties and airport proprietors in the enforcement of these regulations.

5005. Findings. Citizens residing in the vicinity of airports are exposed to the noise of aircraft operations. There have been numerous instances wherein individual citizens or organized citizen groups have complained about airport noise to various authorities. The severity of these complaints has ranged from a few telephone calls to organized legal action. Many of these cases have been studied by acoustics research workers under sponsorship of governmental and private organizations. These studies have generally shown that the severity of the complaint is principally associated with a combination of the following factors:

(a) Magnitude and duration of the noise from aircraft operations;

(b) Number of aircraft operations; and

(c) Time of occurrence during the day (daytime, evening or night).

There are many reasons given by residents for their complaints; however, those most often cited are interference with speech communication, TV, and sleep. A number of studies have been made related to speech interference and hearing damage, and some studies have been made related to sleep disturbance and other physiological effects. These studies provide substantial evidence for the relationship between noise level and its interference with speech communication and its effect relative to hearing loss. Significantly less information is available from the results of sleep and physiological studies.

In order to provide a systematic method for evaluating and eventually reducing noise incompatibilities in the vicinity of airports, it is necessary to quantify the noise problem. For this purpose, these regulations establish a procedure for defining a noise impact area surrounding an individual airport. The criteria and noise levels utilized to define the boundaries of the noise impact area have been based on existing evidence from studies of community noise reaction, noise interference with speech and sleep, and noise induced hearing loss.

One of the fundamental philosophies underlying the procedures in these regulations is that any noise quantity specified by these regulations be measurable by relatively simple means. Therefore, these regulations utilize as their basic measure the A-weighted noise level, which is the most commonly accepted simple measure. To insure consistency between criteria and measurement, the units for the criteria are also based on the A-weighted sound level rather than one of the several more complex perceived noise levels.

These regulations provide a procedure to limit the allowable noise for an individual aircraft flyby measured at specified points in the vicinity of the airport. The noise limits are specified in terms of the class of aircraft and measurement location.

The level of noise acceptable to a reasonable person residing in the vicinity of an airport is established as a community noise equivalent level (CNEL) value of 65 dB for purposes of these regulations. This criterion level has been chosen for reasonable persons residing in urban residential areas where houses are of typical California construction and may have windows partially open. It has been selected with reference to speech, sleep and community reaction.

It is recognized that there is a considerable individual variability in the reaction to noise. Further, there are several factors which undoubtedly influence this variability and which are not thoroughly understood. Therefore, this criterion level does not have a degree of precision which is often associated with engineering criteria for a physical phenomenon (e.g., the strength of a bridge, building, et cetera). For this reason, the state will review the criterion periodically, taking into account any new information which may become available.

5006. Definitions. (a) **Sound Pressure Level (SPL):** The sound pressure level, in decibels (dB), of a sound is 20 times the logarithm to the base of 10 of the ratio of the pressure of this sound to the reference pressure. For the purpose of these regulations, the reference pressure shall be 20 micronewtons/square meter (2×10^{-4} microbar).

(b) **Noise Level (NL):** Noise level, in decibels, is an A-weighted sound pressure level as measured using the slow dynamic characteristic for sound level meters specified in ASA S1.4—1961, American Standard Specification for General Purpose Sound Level Meters, or latest revision thereof. The A-weighting characteristic modifies the frequency response of the measuring instrument to account approximately for the frequency characteristics of the human ear. The reference pressure is 20 micronewtons/square meter (2×10^{-4} microbar).

(c) **Noise Exposure Level (NEL):** The noise exposure level is the level of noise accumulated during a given event, with reference to a duration of one second. More specifically, noise exposure level, in decibels, is the level of the time-integrated A-weighted squared sound pressure for a stated time interval or event, based on the reference pressure of 20 micronewtons per square meter and reference duration of one second.

(d) **Single Event Noise Exposure Level (SENEL):** The single event noise exposure level, in decibels, is the noise exposure level of a single event, such as an aircraft flyby, measured over the time interval between the initial and final times for which the noise level of a single event exceeds the threshold noise level. For implementation in this subchapter of these regulations, the threshold noise level shall be at least 30 decibels below the numerical value of the single event noise exposure level limits specified in Section 5035.

(e) **Hourly Noise Level (HNL):** The hourly noise level, in decibels, is the average (on an energy basis) noise level during a particular hour. Hourly noise level is determined by subtracting 35.6 decibels (equal to $10 \log_{10} 3600$) from the noise exposure level measured during the particular hour, integrating for those periods during which the noise level exceeds a threshold noise level.

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For implementation in this subchapter of these regulations, the threshold noise level shall be a noise level which is 10 decibels below the numerical value of the appropriate criterion CNEL which is specified in Section 5012. At some microphone locations, sources of noise other than aircraft may contribute to the CNEL. Where the airport proprietor can demonstrate that the accuracy of the CNEL measurement will remain within the required tolerance in Section 5045, the department may grant a waiver to increase the threshold noise level.

(f) **Daily Community Noise Equivalent Level (CNEL):** Community noise equivalent level, in decibels, represents the average daytime noise level during a 24-hour day, adjusted to an equivalent level to account for the lower tolerance of people to noise during evening and night time periods relative to the daytime period. Community noise equivalent level is calculated from the hourly noise levels by the following:

$$\text{CNEL} = 10 \log \frac{1}{24}\left[\sum \text{antilog} \frac{\text{HNLD}}{10} + 3 \sum \text{antilog} \frac{\text{HNLE}}{10} + 10 \sum \text{antilog} \frac{\text{HNLN}}{10}\right]$$

Where

HNLD are the hourly noise levels for the period 0700–1900 hours;

HNLE are the hourly noise levels for the period 1900–2200 hours;

HNLN are the hourly noise levels for the period 2200–0700 hours; and Σ means summation.

(g) **Annual CNEL:** The annual CNEL, in decibels, is the average (on an energy basis) of the daily CNEL over a 12-month period. The annual CNEL is calculated in accordance with the following:

$$\text{Annual CNEL} = 10 \log_{10}\left[\frac{1}{365} \sum \text{antilog} \left(\frac{\text{CNEL(i)}}{10}\right)\right]$$

Where

CNEL(i) = the daily CNEL for each day in a continuous 12-month period, and Σ means summation.

When the annual CNEL is approximated by measurements on a statistical basis, as specified in Section 5022, the number 365 is replaced by the number of days for which measurements are obtained.

(h) **Noise Impact Boundary:** Noise impact boundary around an airport consists of the locus of points for which the annual CNEL is equal to the criterion value.

(i) **Noise Impact Area:** Noise impact area, in square statute miles, is the total land area within the noise impact boundary less that area deemed to have a compatible land use in accordance with Section 5014.

(j) **Airport Proprietor:** Airport proprietor means the holder of an airport permit issued by the department pursuant to Article 3, Chapter 4, Part 1, Division 9, Public Utilities Code.

(k) **Aircraft Operator:** Aircraft operator means the legal or beneficial owner of the aircraft with authority to control the aircraft utilization; except where the aircraft is leased, the lessee is the operator.

(*l*) **Air Carrier:** Air carrier is any aircraft operating pursuant to either a federal or a state certificate of public convenience and necessity, including any certificate issued pursuant to 49 U.S.C. Section 1371 and any permit issued pursuant to 49 U.S.C. Section 1372.

(m) **General Aviation:** General aviation aircraft are all aircraft other than air carrier aircraft and military aircraft.

(n) **Department:** Department means the Department of Aeronautics of the State of California.

(o) **County:** County, as used herein, shall mean the county board of supervisors or its designee authorized to exercise the powers and duties herein specified.

Article 2. Airport Noise Limits

5010. Purpose. The purpose of these regulations is to provide a positive basis to accomplish resolution of existing noise problems in communities surrounding airports and to prevent the development of new noise problems. To accomplish this purpose, these regulations establish a quantitative framework within which the various interested parties (i.e., airport proprietors, aircraft operators, local communities, counties and the state) can work together effectively to reduce and prevent airport noise problems.

5011. Methodology for Controlling and Reducing Noise Problems. The methods whereby the impact of airport noise shall be controlled and reduced include but are not limited to the following:

(a) Encouraging use of the airport by aircraft classes with lower noise level characteristics and discouraging use by higher noise level aircraft classes;

(b) Encouraging approach and departure flight paths and procedures to minimize the noise in residential areas;

(c) Planning runway utilization schedules to take into account adjacent residential areas, noise characteristics of aircraft and noise sensitive time periods;

(d) Reduction of the flight frequency, particularly in the most noise sensitive time periods and by the noisier aircraft;

(e) Employing shielding for advantage, using natural terrain, buildings, et cetera; and

(f) Development of a compatible land use within the noise impact boundary.

Preference shall be given to actions which reduce the impact of airport noise on existing communities. Land use conversion involving existing residential communities shall normally be considered the least desirable action for achieving compliance with these regulations.

5012. Airport Noise Criteria. Limitations on airport noise in residential communities are hereby established.

(a) The criterion community noise equivalent level (CNEL) is 65 dB for proposed new airports and for vacated military airports being converted to civilian use.

(b) Giving due consideration to economic and technological feasibility, the criterion community noise equivalent level (CNEL) for existing civilian airports (except as follows) is 70 dB until December 31, 1985, and 65 dB thereafter.

(c) The criterion CNEL for airports which have 4-engine turbojet or turbofan air carrier aircraft operations and at least 25,000 annual air carrier operations (takeoffs plus landings) is as follows:

Date	*CNEL in decibels*
Effective date of regulations to 12-31-75	80
1-1-76 to 12-31-80	75
1-1-81 to 12-31-85	70
1-1-86 and thereafter	65

5013. Noise Impact Boundary. The noise impact boundary at airports which have a noise problem as determined in accordance with Section 5050 shall be established and validated by measurement in accordance with the procedures given in Article 3 of this subchapter. For proposed new airports, or for anticipated changes of existing airports, the noise impact boundary shall be estimated by applicable acoustical calculation techniques.

The area of land which is within the noise impact boundary and which has incompatible land use is utilized as a measure of the magnitude of the noise problem at an airport. The concepts of noise impact boundary and noise impact area are illustrated in Figure 1.

5014. Compatible Land Uses Within the Noise Impact Boundary. The criterion for the noise impact boundary was established for residential uses including single-family and multiple-family dwellings, trailer parks, and schools of standard construction. Certain other land uses may occur within the boundary but be compatible with the community noise equivalent level and hence be excluded in the calculation of noise impact area. For this purpose, the following land uses are deemed compatible:

(a). Agricultural;

(b) Airport property;

(c) Industrial property;

(d) Commercial property;

(e) Property subject to an avigation easement for noise;

(f) Zoned open space;

(g) High-rise apartments in which adequate protection against exterior noise has been included in the design and construction, together with a central air conditioning system. Adequate protection

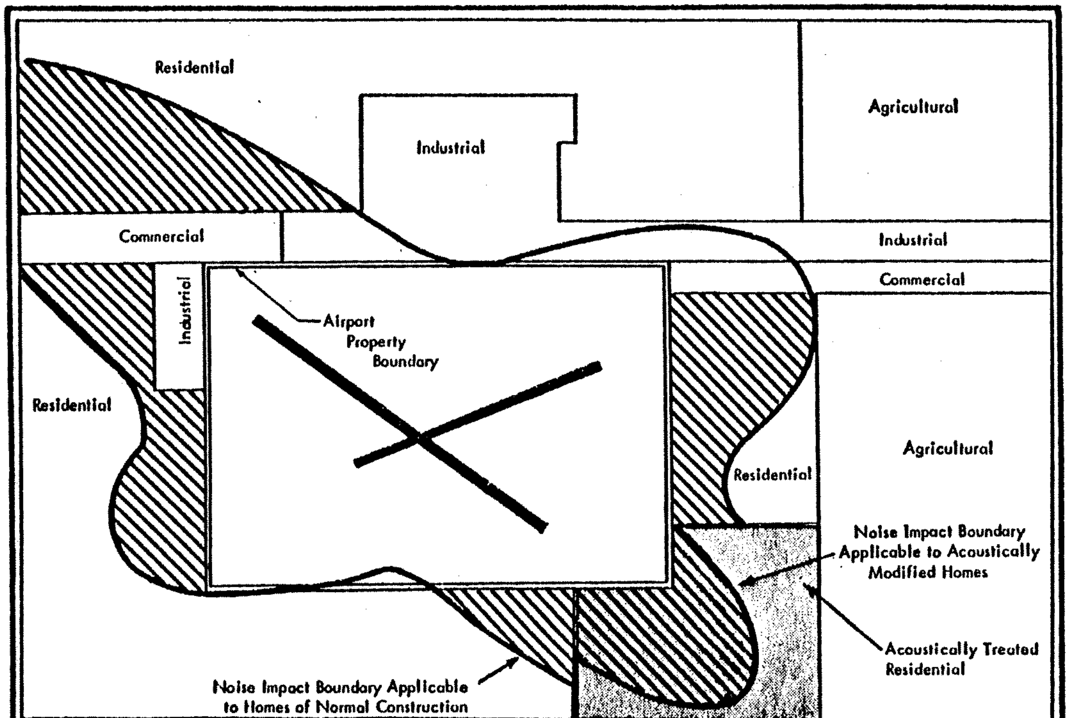


FIGURE 1. CONCEPTUAL SKETCH OF NOISE IMPACT BOUNDARY AND NOISE IMPACT AREA

The noise impact area is the sum of all the cross-hatched areas, in square statute miles.

means the noise reduction (exterior to interior) shall be sufficient to assure that interior community noise equivalent level in all habitable rooms does not exceed 45 dB during aircraft operations. Acoustical performance of the buildings shall be verified by calculation or measured by qualified officials of the building inspection agency of the city or county in which the buildings are situated;

(h) In the case of existing airports and existing homes only, residential areas in which existing homes have been acoutically treated need not be subject to exterior noise limits quite as strict as those for normal residential construction. For this purpose, the community noise equivalent level on the boundary of such a residential area may be increased by as much as 15 dB over the community noise equivalent level criterion for nonacoustically treated homes. The amount of the increase allowed on the boundary is the difference between the noise level reduction of the treated home and the value 20 decibels which is assumed to be the noise level reduction of an average normal residence. The noise level reduction of a home is defined as the average difference between aircraft noise levels in free space outside of the home and the corresponding noise levels in rooms on the exposed sides of the home.

In carrying out this section, the actual use to which the land is put, not the classification for which the land is zoned, is determinative.

Article 3. Establishing and Validating Noise Impact Boundaries for Airports Required to Monitor

5020. Validation of the Noise Impact Boundary. For airports with a noise problem (in accordance with Section 5050), the noise impact boundary shall be validated by measurements made at locations specified in Section 5021 and according to frequency requirements specified in Section 5022. These measurements shall be utilized to calculate the daily community noise equivalent levels. These daily CNEL values will then be averaged (on an energy basis) to obtain the annual CNEL at each of the community measurement locations. The location of the noise impact boundary will be considered valid if the value of the annual CNEL lies within ±1.5 dB of the criterion value.

5021. Community Measurement Locations. At least twelve (12) locations, approximately equidistant, but not exceeding one and one-half (1.5) statute miles separation, shall be selected along the noise impact boundary. The locations shall be selected such that the maximum extent of the boundary be determined with reference to the airport's flight patterns.

5022. Frequency of Measurement at Community Locations. (a) For airports with 1,000 or more homes within the noise impact boundary based on a CNEL of 70 dB, continuous monitoring is required at those monitoring positions which fall within residential areas. Measurement for at least 48 weeks in a year shall be considered as continuous monitoring.

(b) For all other locations and for all locations at other airports, an intermittent monitoring schedule is allowed. The intermittent monitoring schedule shall be designed so as to obtain the resulting annual CNEL as computed from measurements at each location which will correspond to the value which would be measured by a monitor operated continuously throughout the year at that location, within an accuracy of ±1.5 dB.

Thus, it is required that the intermittent monitoring schedule be designed so as to obtain a realistic statistical sample of the noise at each location. As a minimum, this requres that measurements be taken continuously for 24-hour periods during four 7-day samples throughout the year, chosen such that for each sample, each day of the week is represented, the four seasons of the year are represented, and the results account for the effect of annual proportion of runway utilization. At most airports, these intermittent measurements can be accomplished by a single portable monitoring instrument.

5023. Initial Establishment of the Noise Impact Boundary. The method to be used for initial establishment of the noise impact boundary of airports required to monitor will vary depending upon specific situations. The following guidelines represent one possible method:

(a) Calculate the approximate location of the noise impact boundary using applicable acoustic estimation techniques.

(b) Select convenient measurement locations on this estimated boundary according to Section 5021.

(c) Make a suitable series of CNEL trial measurements along lines perpendicular to the estimated noise impact boundary. For example, two to three measurements over a one-to-seven day period along a line perpendicular to the estimated noise impact boundary should provide sufficient data to define, within the required accuracy, the nominal position of the noise impact boundary.

Due consideration should be given to the number and time period of aircraft operations, mix of aircraft classes, average runway utilization and other measurable factors which would cause a difference between the trial measurements of CNEL and the expected annual average.

(d) Initiate validation measurements of the noise impact boundary following selection of permanent or intermittent monitoring locations to comply with the validation accuracy criterion specified in Section 5020. For permanent measurement locations at which the measured CNEL lies outside this accuracy criterion, suitable auxiliary measurements or analytical methods may be used to extrapolate the measured CNEL to determine the value on the noise impact boundary. Such extrapolation procedures are subject to approval by the department.

5024. Deviations from Specified Measurement Locations. Recognizing the unique geographic and land use features surrounding specific airports, the department will consider measurement plans tailored to fit any airport for which the specified CNEL monitoring locations are impractical. For example, monitors should not be located on bodies of water or at points where other noise sources might interfere with aircraft CNEL measurements, nor are measurements required in regions where land use will clearly remain compatible.

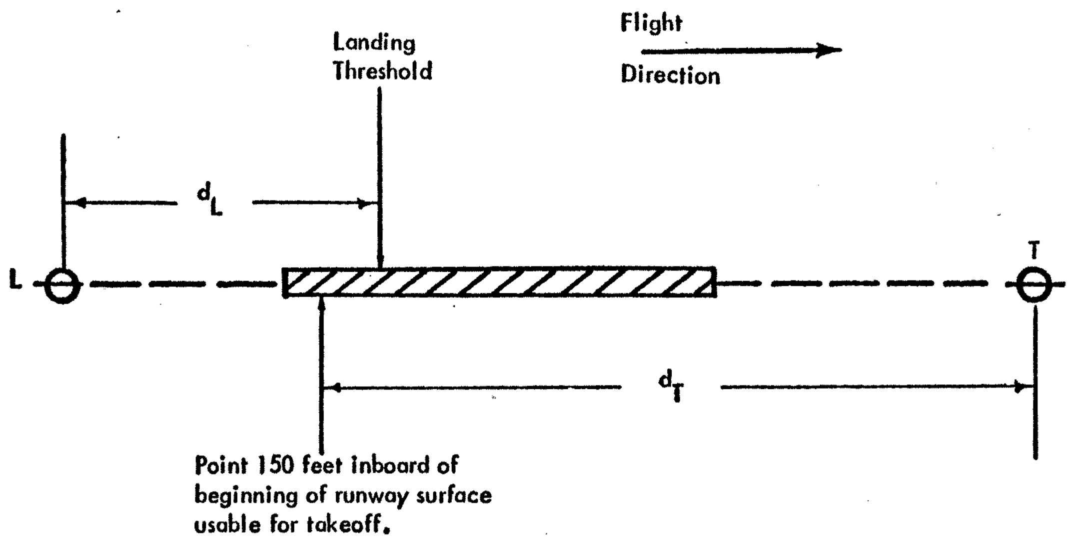
5025. Alternative Measurement Systems. The acquisition of measurement systems that are more extensive or scientifically more refined than those specified herein is encouraged, particularly at airports with a major noise problem, where compliance with the intent of Section 5075(a)(4) requires more comprehensive noise monitoring, particularly to monitor noise abatement procedures. Airports contemplating the acquisition of such monitoring systems may apply to the department for exemptions from specific monitoring requirements set forth in this subchapter of these regulations.

Article 4. Measurement of Single Event Noise Exposure Level

5030. Measurement Requirements. Measurements of the single event noise exposure level (SENEL) shall be made in the vicinity of airports with a noise problem as determined in accordance with Section 5050. These measurements are intended to monitor the noise of aircraft to insure compliance with the noise limits recommended by the airport proprietor and approved by the department in accordance with Article 5.

5031. Measurement Locations. Measurements shall be made on the centerline of the nominal takeoff and landing flight tracks for air carrier jet aircraft and private jet aircraft at the locations specified in Figure 2. The nominal flight track is the line projected on the ground under the nominal flight path of the aircraft. Measurements will not be required for landing or takeoff flight tracks associated with aircraft operations which do not contribute to the noise impact area of the airport.

5032. Frequency of Measurement. At each microphone location, single event noise exposure level measurements shall be made continuously for a minimum of 48 weeks per year. The remaining 4 weeks are intended to allow for intermittent periods of down-time for equipment maintenance and calibration.



O Microphone Locations

L - Landing

T - Takeoff

d_L = 2500 feet to 1.0 Nautical Mile

d_T = 10,000 feet to 3.5 Nautical Miles (see Figure 3a.)

—— —— Centerline of Nominal Takeoff or Landing Flight Track

FIGURE 2. SINGLE EVENT NOISE EXPOSURE LEVEL MONITORING POSITIONS

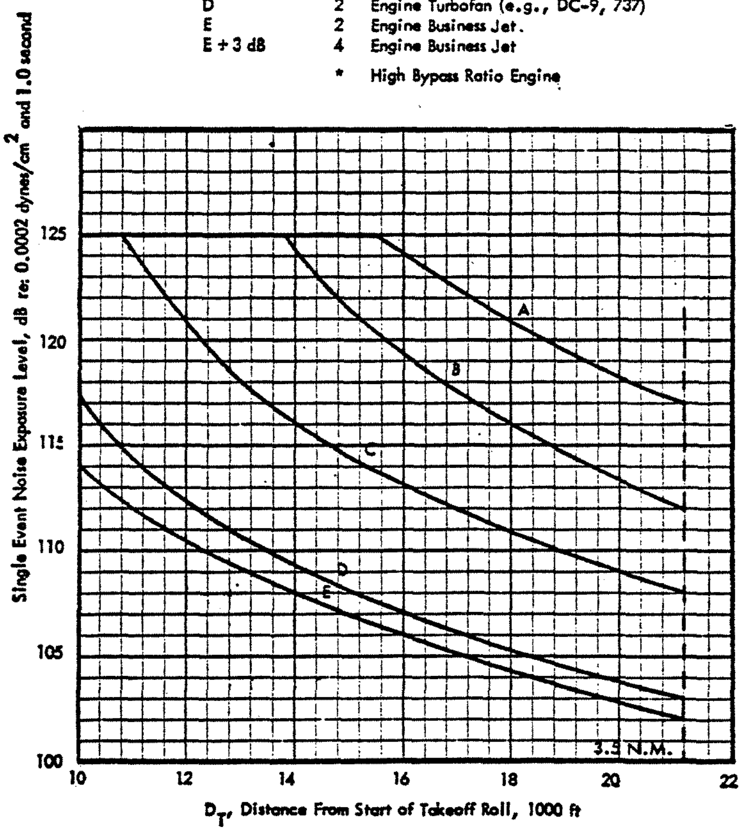
Article 5. Single Event Noise Limits

5035. Maximum Single Event Noise Exposure Levels. The proprietor of each airport which is required to perform noise monitoring shall recommend to the department the single event noise exposure level limits appropriate to his airport. In no event shall the limits recommended by the airport proprietor exceed the values in Figures 3A and 3B which correspond to the noisiest aircraft class utilizing the airport on a recurrent basis (which shall mean an average of at least two aircraft operations per day) during the six-month period prior to the determination that the airport has a noise problem (Section 5050). The values in Figures 3A and 3B are based on maximum gross weight operation without noise abatement flight procedures under standard atmospheric conditions at sea level. Airport proprietors are therefore encouraged to recommend lower limits. Upon approval of such limits at a specific airport, those limits will be enforced by the county in accordance with this entire subchapter of these regulations.

Article 6. Additional Monitoring Locations

5040. Additional Monitoring Locations. For airports which are required to monitor, additional monitoring locations may be useful in some cases. These additional locations may be utilized for measurement of either single event noise exposure levels (such as monitoring of noise abatement flight procedures) or community noise equivalent levels (such as at fixed points in high noise level residential areas). The frequency of measurement at these additional monitoring locations should be determined on the basis of each specific situation.

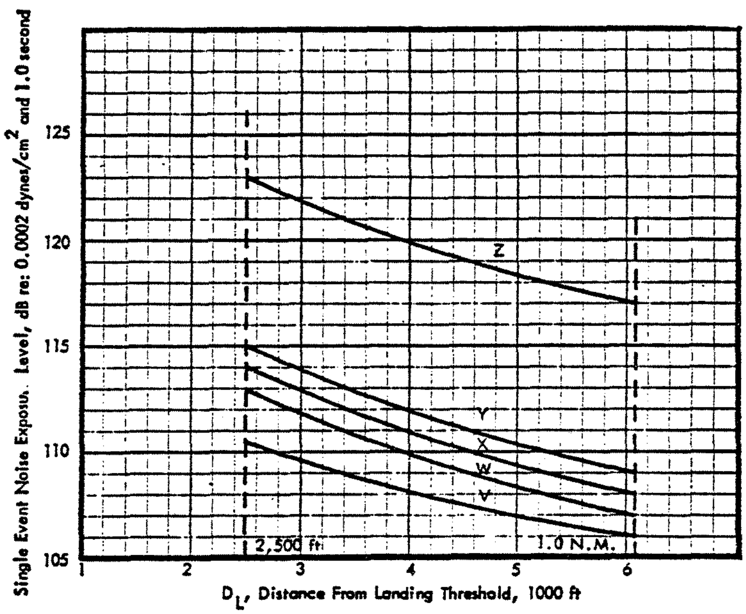
Curve		Aircraft Class
A	4	Engine Turbojet Turbofan (e.g., 707, 720, DC-8)
B	4	Engine "Jumbo" Turbofan* (e.g., 747)
C	3	Engine Turbofan and Airbus*(e.g.,727,DC-10,L-1011)
D	2	Engine Turbofan (e.g., DC-9, 737)
E	2	Engine Business Jet.
E + 3 dB	4	Engine Business Jet
	*	High Bypass Ratio Engine



a) Takeoff

FIGURE 3A. MAXIMUM LIMITS FOR SINGLE EVENT NOISE EXPOSURE LEVEL

Curve	Aircraft Class
Z	4 Engine Turbojet and Turbofan (e.g., 707,720,DC-8)
Y	2,3 Engine Turbofan (e.g., 727,737,DC-9)
X	4 Engine "Jumbo" Turbofan* (e.g., 747)
W	3 Engine Airbus Turbofan* (e.g., DC-10, L-1011)
V	2 Engine Business Jet
V+3 dB	4 Engine Business Jet
	* High Bypass Ratio Engine



b) Landing

FIGURE 3B. MAXIMUM LIMITS FOR SINGLE EVENT NOISE EXPOSURE LEVEL

Article 7. Noise Monitoring System Requirements

5045. General Specifications. (a) The noise monitoring system shall provide for the following outputs:

(1) In the vicinity of airport (see Article 5). Single event noise exposure levels exceeding the maximum limits, together with their time of occurence.

(2) In community (see Section 5020). Hourly noise level for each hour of the day, together with identification of the hour.

(b) The overall accuracy of the noise measurement system shall be ± 1.5 dB, determined in accordance with the procedure of the noise measurement system specification given in Sections 5080 through 5080.5 of these regulations.

5046. Detailed Specifications. Noise monitoring systems shall be in accordance with detailed specifications given in Sections 5080 through 5080.5 of these regulations.

5047. Field Measurement Precautions. Specific locations of the monitoring system, particularly for the community measurement locations, shall be chosen, whenever possible, such that the community noise equivalent level at the location from sources other than aircraft in flight be equal to or less than 55 dB. This objective may be satisfied by selecting the location such that it is in a residential area not immediately adjacent to a noisy industry, freeway, railroad track, et cetera. The measurement microphone shall be placed 20 feet above the ground level, or at least 10 feet above neighboring roof tops, whichever is higher. To the extent practicable, the following precautions shall be followed:

(a) Each SENEL monitor location shall be in an open area surrounded by relatively flat terrain, having no excessive sound absorption characteristics such as might be caused by thick, tall grass, shrubbery, or wooded areas.

(b) No obstructions which significantly influence the sound field from the aircraft shall exist within a conical space above the measurement position, the cone being defined by an axis along a line of sight normal to the aircraft path and by a half angle of 75 degrees from this axis.

(c) When the foregoing precautions are not practicable, the microphones shall be placed at least 10 feet above neighboring buildings in a position which has a clear line-of-sight view to the path of the aircraft in flight.

5048. Number of Measurement Systems. The frequency of measurement specified in Sections 5022 and 5032 has been designed to limit the number of monitoring systems required. The minimum number of systems required per airport is:

(a) One for intermittent measurements of the noise impact boundary, plus

(b) One for continuous measurement of the single event noise exposure level for each landing or departure flight track as specified in Section 5031.

This minimum number will increase where necessary to conform to the requirement that separation distance between monitoring positions on the boundary not exceed one and one-half (1.5) statute miles or when continuous measurements are required on the measurement boundary in accordance with Section 5022.

Article 8. Implementation by Counties

5050. Counties. (a) The county wherein an airport is situated shall enforce this subchapter of these regulations.

(b) In recognition of the requirement to allow the maximum amount of local control and enforcement of this regulation, the county shall determine which of the airports within its boundaries are required to initiate aircraft noise monitoring in accordance with these regulations. The county shall require noise monitoring by the airports within its boundaries that are deemed to have a noise problem as determined by the county. For airports with joint use by both military and civilian aircraft operations, the determination of the existence of a noise problem shall be based upon the civilian operations. In making a determination that a noise problem exists around an airport, the county shall:

(1) Investigate the possible existence of a noise impact area greater than zero based on a CNEL of 70 dB, and determine whether or not people actually reside inside the noise impact boundary;

(2) Review other information that it may deem relevant, including but not limited to complaint history and legal actions brought about by aircraft noise; and

(3) Coordinate with, and give due consideration to the recommendations of, the county airport land use commission (as defined in Public Utilities Code Section 21670).

(c) Any affected or interested person or any government agency disagreeing with the county's findings regarding the existence of a noise problem at a given airport may file an appeal with the department. Upon receipt of such an appeal, the department shall make an investigation and determination as to the validity of the county's findings. The department shall serve by mail the written record of such investigation and determination to the county, the airport proprietor, and the affected or interested person or governmental agency. If the department finds that the county's determination does not correspond to the facts, the county shall adhere to the determination of the department. Whenever the department has served such record, the county, airport proprietor, affected or interested person, or government agency may in writing within 10 days demand a hearing. In such case, the department shall file a statement of issues and shall conduct proceedings in accordance with the Administrative Procedure Act (Chapter 5, Part 1, Division 3, Title 2, Government Code).

(d) For all airports required to perform noise monitoring, the counties shall validate monitoring data supplied by the airport proprietor and shall enforce these regulations in all respects.

(e) The county shall submit quarterly reports to the Department of Aeronautics. Each report is due 45 days after the end of the quarter of the calendar year covered in the report. The report shall contain at least the following information on each airport within the county covered by these regulations:

(1) A map illustrating the location of the noise impact boundary, as validated by measurement, and the location of measurement points, in the four preceding quarters;

(2) The annual noise impact area as obtained from the preceding four calendar quarters, and as obtained in accordance with Article 2 of this subchapter of these regulations;

(3) The daily CNEL measurements, together with identification of the dates on which each measurement was made, number of total aircraft operations during the quarter, estimated number of operations of the highest noise level aircraft class in the quarter, and any other data which is pertinent to the activity during the quarter. In addition, the HNL data shall be retained for at least 3 years, and made available to the department upon request; and

(4) The total number of recorded violations of the single event noise exposure level limits, subtotals of such violations categorized by aircraft class, a list of the names of the aircraft operators in question, the number of violations by each, the single event noise exposure level corresponding to each violation, and the disposition made or fine collected for each violation.

(f) The counties shall establish the requirements for identification of aircraft operators whose aircraft exceed the single event noise exposure levels in Article 5 of Subchapter 6 of these regulations.

(g) The department will maintain in file, for a period of at least 3 years, all the noise data received pursuant to these regulations. These records shall be maintained in accordance with the provisions of the California Public Records Act (Chapter 3.5, Division 1, Title 1, Government Code).

Article 9. Implementation by Aircraft Operators

5055. Aircraft Operators. No operator of an aircraft shall operate any aircraft in excess of the single event noise exposure level limits adopted in accordance with Article 5 of this subchapter of these regulations. No violation exists if the operator establishes that such operation is the direct result of the pilot's exercise of his responsibility for safety of the passengers, crew, cargo and aircraft or of his emergency authority. Violation of such limits is punishable as prescribed in Public Utilities Code Section 21669.4.

Article 10. Implementation by Airport Proprietors

5060. Monitoring Requirements. (a) All airport proprietors shall cooperate with the county in the county's investigations to determine the existence of a noise problem, and shall furnish such data as the county may require.

(b) Each airport proprietor whose airport is determined to have a noise problem shall measure, establish and validate noise impact boundaries, monitor as required in Articles 3, 4 and 7 of this subchapter of these regulations, and shall furnish such data as the county may require.

5061. Single Event Noise Limit Violations. No airport proprietor shall knowingly permit any aircraft operator to exceed the single event noise exposure level limits established in accordance with Article 5 of this subchapter of these regulations.

5062. Noise Impact Area Violations. No airport proprietor shall operate his airport with a noise impact area of other than zero unless said operator has a variance as prescribed in Article 13 of this subchapter of these regulations.

5063. Submittal of Monitoring Plan. Each airport proprietor who is required to perform noise monitoring shall submit a description of his monitoring plan to the county and to the department for approval. Such descriptions shall contain at least the following information:

(a) The general monitoring system plan, including at least locations and instrumentation;

(b) Justification for any proposed deviations from the measurement system locations specified in these regulations;

(c) Statistical sampling plan proposed for intermittent monitoring at community locations;

(d) The proprietor's recommended single event noise limits for his airport; and

(e) Additional information as pertinent or as requested by the department.

5064. Grounds for Approval. Failure of the airport proprietor to comply with the provisions of Subchapter 6 of these regulations constitutes a ground for denial of approval of an airport site within the meaning of Public Utilities Code, Section 21666.

Article 11. Implementation by the Department

5065. Implementation by the Department. The department will review the data submitted quarterly by the counties for the purpose of assessing the degree of compliance with this subchapter of these regulations. The department's review will include, but not be limited to, observation of any changes in boundary monitor positions and any changes in numerical values of CNEL.

Article 12. Schedule of Implementation

5070. Schedule of Implementation. (a) For airports in existence on the effective date of this subchapter of these regulations, counties shall complete their determination of whether or not a noise problem exists within the shortest feasible time after the effective date of these regulations. In no event shall the time for completion of this determination exceed 6 months from the effective date of these regulations.

(b) Each proprietor of an airport that has a noise problem, upon receipt of notification from the county, shall initiate noise monitoring within the shortest feasible time not to exceed 6 months in accordance with this subchapter of these regulations and concurrently shall make application to the department for a temporary variance in accordance with Article 13.

Article 13. Variances

5075. Variances. (a) In granting variances, the department shall be guided by the underlying intent of these regulations as follows:

(1) That the noise impact area surrounding proposed new airports be zero;

(2) That the proprietor of each existing airport having a surrounding noise impact area of zero based on a CNEL of 70 dB take actions to prevent a noise impact area of greater than zero;

(3) That the proprietor of each existing airport having a surrounding noise impact area of greater than zero based on a CNEL of 70 dB take actions to prevent an increase of the airport's noise impact area; and

(4) That the proprietor of each existing airport having a surrounding noise impact area of greater than zero based on a CNEL of 70 dB be required to develop and implement programs to reduce the noise impact area of the airport to an acceptable degree in an orderly manner over a reasonable period of time.

(b) An airport proprietor may request variances from the requirements of any or all of these regulations, except for Sections 5012 and 5013, for periods of not exceeding one year as set forth hereinafter:

(1) The airport proprietor shall apply to the department for a variance.

(2) Such application for variance shall be made upon a form which the department shall make available.

(3) Such application shall set forth the reasons why the airport proprietor believes said variance is necessary. The application shall state the future date by which the airport proprietor expects to achieve compliance with the regulations from which a variance is sought. The application shall set forth an incremental schedule of noise impact area reductions for the intervening time.

(4) The department may grant a variance if the public interest would be satisfied by such a variance. In weighing the public interest, the department's considerations include but are not limited to the following:

(A) The economic and technological feasibility of complying with the noise standards set by these regulations;

(B) The noise impact should the variance be granted;

(C) The value to the public of the services for which the variance is sought; and

(D) Whether the airport proprietor is taking *bona fide* measures to the best of his ability to achieve the noise standards set by these regulations.

(5) The burden of proof shall be upon the applicant for a variance.

(6) On its own motion, or upon the request of an affected or interested person, the department shall hold a public hearing in connection with the approval of an application for a variance. Any interested person may obtain from the department information on pending requests for variances at any time.

(7) The department in granting a variance may impose reasonable conditions which it deems necessary to effectuate the purposes of this subchapter of these regulations.

Article 14. Specification: Noise Monitoring System

5080. Purpose and Scope. (a) **Purpose.** This specification establishes the minimum requirements for instrumentation to be utilized by agencies required to monitor aircraft noise in accordance with Articles 1 through 13 of this subchapter of these regulations.

(b) **Scope.** Two measurement systems are defined herein. One system shall be utilized to monitor the noise at specifically-designated locations adjacent to airport runways. The second system shall be utilized to monitor noise levels at specifically-designated locations in the community surrounding the airport.

(c) **Design Goals.** The design goals for the monitor system are accuracy, reliability, and ease of maintenance. The measurement techniques set forth are sufficiently uncomplicated so that current state-of-the-art instrumentation equipment may be utilized to configure the two systems. Analysis and recording techniques between community and runway monitor systems vary; however, this specification delineates a procedure whereby maximum commonality of systems elements may be achieved.

The monitor system specifications are not intended to be unduly restrictive in specifying individual system components. The specifications allow the utilization of equipment ranging from analog systems to automated computer systems. The exact configuration will depend upon the specific monitoring requirement and the nature of existing user instrumentation.

This is a total systems specification. It is the prerogative of the user to configure the system with components which will be most compatible with his existing equipment and personnel.

5080.1. **Additional Definitions Applicable to Article 14.** (a) **Field Instrumentation.** Refers to those elements of a noise monitoring system that are exposed to the outdoor environment in the vicinity of the measurement microphone. This equipment must function within specification during exposure to a year-around environment adjacent to any airport licensed by the state of California.

(b) **Centralized Instrumentation.** Refers to those elements of the noise monitoring system which will be contained in an environmentally-controlled room.

(c) **SENEL Monitoring System.** The SENEL monitoring system shall measure single event noise exposure levels exceeding the maximum allowable single event noise exposure level and shall log the time of occurrence of each such event. An SENEL system consists of two subsystems: a noise level subsystem and an integrator/logger subsystem.

(d) **HNL Monitoring System.** The HNL monitoring system shall measure the hourly noise level and shall provide identification of the hour. This system shall be deployed as a community monitoring system. An HNL system consists of two subsystems: a noise level subsystem and an integrator/logger subsystem.

(e) **Noise Level Subsystem.** This term defines a subsystem composed of a microphone, an A-weighted filter, a squaring circuit and a lag network. This subsystem is used to derive a signal representing the mean square, A-weighted value of acoustic pressure.

(f) **Integrator/Logger Subsystem.** This term defines a subsystem composed of a threshold comparator, an integrator, a clock, an accumulator, a logger or printer, an SENEL comparator (SENEL system only), and a logarithmic converter. This subsystem shall be used to transform the output from a noise level subsystem in excess of a pre-set threshold into SENEL or HNL.

5080.2. **Examples of Possible System Configurations.** (a) **Approach.** Two systems have been defined: (1) the SENEL monitoring system, and (2) the HNL monitoring system. There are many possible methods of configuring systems to produce SENEL data and HNL data. These systems may be analog systems, digital systems, or combined analog and digital systems. Figures 4 and 5 illustrate two configurations which can provide SENEL and HNL measurements. The system configurations described herein are presented for information only and not as specific design criteria.

(b) **SENEL System Configuration.** An SENEL system may be composed of the following elements:

(1) **Noise Level Subsystem.**

(A) **Microphone.** The microphone converts acoustic data to an equivalent electrical voltage.

(B) **A-Weighting Filter Network.** This filter modifies the voltage from the microphone system so that its frequency characteristics are shaped to an A-weighted, relative response in accordance with weighting curve A in ASA S1.4-1961, or latest revision thereof.

(C) **Squaring Circuit.** This circuit provides a continuous, instantaneous square of the value of the electrical signal delivered from the A-weighting network.

(D) **Lag Network.** This circuit may be a first order lag (single-pole filter) used to smooth the output of the squaring circuit for delivery to subsequent circuits. The lag network provides a slow dynamic characteristic as defined for a sound level meter in ASA S1.4-1961, or latest revision thereof.

(2) **SENEL Integrator/Logger Subsystem.**

(A) **Threshold Comparator.** This device generates an output signal during the time its input exceeds a preset threshold level.

(B) **Integrator.** This circuit provides an output signal which is the definite time-integral of the input signal. The input is a slowly-varying, smooth, unipolar signal delivered from the lag network. The integrator has three operational states: integrate or run, hold, or reset. These states would be controlled by the threshold-comparator. Initially, before the integrator input signal exceeds the threshold signal, the integrator is held in reset. When the threshold is exceeded, the integrator is set in the integrate state, causing the output to be the time-integral of the input. When the input next falls below the threshold, the integrator is set into the hold state. The output of the integrator is, at hold time, the time-integral of the input while it exceeded the measurement threshold. The same signal causing hold would be used to read the output of the integrator and the true time when the hold command occurred. Following those readings, the integrator would be returned to a reset state.

(C) **Sample and Hold (Optional).** This circuit may be used to store the value of the integral at the time of integrator hold to minimize the time required for the integrator to be maintained in hold.

(D) **Clock.** This device generates true time which may be directed to a logger upon an integrator-hold command.

(E) **Logarithmic Converter.** This element is used to convert the integrated mean square sound pressure output from the integrator (or sample and hold) into an SENEL having start time and stop time defined by the threshold circuit and a reference duration equal to one second. The reference duration may be introduced as a gain (or loss) term at the input to the log-converter or as a voltage offset at the output from the logarithmic converter.

(F) **SENEL Level Comparator.** The SENEL comparator controls the actual printing/logging operation. If the signal appearing at the output of the logarithmic converter exceeds a pre-determined value, the comparator will issue a print command. If the pre-determined value is not exceeded, the event is not recorded.

(G) **Logging Element.** This element may be a printer which can concurrently or sequentially print out values of true time and SENEL.

(c) **HNL System Configuration.** An HNL system may be composed of the following elements:

(1) **Noise Level Subsystem.** The HNL noise level subsystem is identical to the SENEL noise level subsystem.

(2) **HNL Integrator/Logger Subsystem.** The HNL integrator/logger subsystem is similar to the SENEL subsystem, as noted below.

(A) **Threshold Comparator.** Similar except that the threshold level is adjustable over a different but potentially overlapping range.

(B) **Integrator.** Similar, except that the integrator is controlled in its reset, run, and hold states so that (1) it integrates for some fixed period of time, e.g., 60 seconds, (2) it "holds" only long enough to transfer out the output value for that fixed period integration, and (3) it "resets" only long enough to return the output to zero so that another "integrate" period may be initiated.

(C) **Sample and Hold (Optional).** Similar.

(D) **Clock.** This device controls the timing of the integrator and the accumulator readout.

(E) **Logarithmic Converter (Optional).** This element is used to convert the accumulated integrated noise level to a logarithmic quantity proportional to HNL.

(F) **SENEL Level Comparator.** Not required.

(G) **Logging Element.** Similar, except substitute HNL for SENEL.

(H) **Accumulator.** This device is used to store the output of the integrator for all events exceeding the threshold level within a 3600 second period. A print command signal is also provided on the hour to the logger/printer at one hour intervals.

5080.3. Performance Specifications. (a) **Overall Accuracy.** The overall accuracy of both systems shall be ±1.5 dB when measuring noise from aircraft in flight. It is the intent of the following specifications to verify this accuracy with laboratory simulation.

(b) **Noise Level Subsystem.**

(1) **Frequency Response and Microphone Characteristics.** The frequency response, and associated tolerance of the subsystem, shall be in accordance with IEC Publication 179 entitled "Precision Sound Level Meters," paragraphs 4, 5 and 8 for the A-weighting network, to be superseded by the specifications for the Type 1 precision sound level meter in the latest revision of ASA S1.4-1961, when available.

(2) **Dynamic Range.** The system output shall be proportional to the antilog of the noise level over a noise level range of 60 dB to 120 dB.

(A) For the SENEL subsystem, this range may be covered in 30 dB or greater increments through the use of attenuators. The noise level for each attenuator range shall be at least 40 dB below full scale. Full scale range shall apply to signals with a crest factor as great as 3:1.

(B) For the HNL subsystem, the internal electrical noise shall not exceed an equivalent input noise level of 50 dB, and the full scale range of 120 dB shall apply to signals with a crest factor as great as 3:1.

(3) **Linearity.** The electrical amplitude response to sine waves in the frequency range of 22.4 Hz to 11,200 Hz shall be linear within one decibel from 30 dB below each full scale range up to 7 dB above the full scale range on any given range of the instrument.

(c) **Integrator/Logger Subsystem.**

(1) **Threshold Comparator.** For SENEL, the threshold level shall be selectable in steps of no greater than 10 dB over a noise level range of at least 60 to 90 dB. For HNL, the threshold level shall be adjustable over a noise level range of at least 55 to 70 dB. In both cases, threshold triggering shall be repeatable within ±0.5 dB.

(2) **SENEL Comparator.** The maximum allowable SENEL shall be selectable over an SENEL range of 85 to

125 dB. Comparator sensing shall be repeatable within ±0.5 dB.

(3) **Clock.** The clock shall be capable of being set to the time of day within an accuracy of 10 seconds and shall not drift more than 20 seconds in a 24-hour period. For SENEL, the clock output which identifies the start or stop 'me of the single event shall be readable within one second.

(4) **End-to-End Accuracy.** The end-to-end accuracy of the integrator/logger subsystem is defined in terms of a unipolar, positive-going square wave input. The logged, integrated output of the system should fall within ±1 dB of the true value predicted for the wave of a given duration at an amplitude exceeding the measurement threshold by at least 10 dB, and at all higher amplitudes within the range. The square wave shall be applied at the input to the integrator and level comparator.

(A) **SENEL Integrator/Logger Subsystem.** For square waves defined at all frequencies between 0.025 and 1.0 Hz, the subsystem shall output the SENEL exceeding the maximum allowable SENEL and its time of occurrence to demonstrate end-to-end accuracy.

(B) **HNL Integrator/Logger Subsystem.**

1. For each hour during which no noise event exceeds the HNL system noise level threshold, the subsystem shall output the time on the hour, and indicate that the antilog of the HNL for the preceding hour is zero.

2. The end-to-end accuracy shall be determined over the range of HNL from 45 dB to 95 dB for each combination of the following conditions which gives a value in this range:

a. Square waves, as defined above, shall have durations of 1, 3, 10, 30 and 100 cycles.

b. Square waves shall be at frequencies of 0.025, 0.05, 0.10 and 0.20 Hz.

c. Square waves shall have amplitudes which are equivalent to noise levels of 70, 80, 90, 100 and 110 dB.

(d). **Overall System Accuracy Demonstration.** The overall system accuracy shall be demonstrated for several conditions within each of the following ranges, utilizing a 1000 Hz sinusoidal acoustic plane wave oriented along the preferred plane wave axis of the microphone, or an equivalent signal generated in an acoustic coupler:

(1) **SENEL Monitoring System.**

(A) The SENEL comparator shall be set at several values of interest, including at least 95, 105, 115 and 125 dB.

(B) The durations of the sinusoidal acoustic signals shall include at least 5, 10, 20 and 40 seconds.

(C) The noise levels for the acoustic inputs at each of the above durations shall be set at levels calculated to produce SENEL's of −1.5, +1.5 and +10 dB relative to the SENEL comparator setting.

(2) **HNL Monitoring System.**

(A) The noise levels for the acoustic inputs shall include at least values of 70, 80, 90 and 100 dB.

(B) The durations of the sinusoidal acoustical signals shall include at least 5, 10, 20 and 40 seconds.

(C) Each of the events defined by the above combinations shall be repeated 1, 3, 10, 30 and 100 times per one hour test to obtain the HNL resulting from such repetition. The HNL accuracy for each combination is defined as the difference between the calculated and measured value for each test. Tests are not required for those combinations which produce a calculated HNL value outside the range of 45 dB to 95 dB.

5080.4. Field Calibration. The monitoring system shall include an internal electrical means to electrically check and maintain calibration without resort to additional equipment. Provision shall also be made to enable calibration with an external acoustic coupler.

5080.5. Environmental Precautions and Requirements. (a) The field instrumentation shall be provided with suitable protection such that the system performance specified will not be degraded while the system is operating within the range of weather conditions encountered at airports within the State of California.

(b) **Humidity.** The effect of changes in relative humidity on sensitivity of field instrumentation shall be less than 0.5 decibel at any frequency between 22.4 and 11,200 Hz in the range of 5 to 100 percent relative humidity.

(c) **Vibration.** The field instrumentation shall be designed and constructed so as to minimize the effects of vibration resulting from mechanical excitation. Shock mounting of the field instrumentation shall be provided as required to preclude degradation of system performance.

(d) **Acoustic Noise.** The field instrumentation shall be designed and constructed so as to minimize effects of vibration resulting from airborne noise, and shall operate in an environment of 125 dB SPL—broadband noise over a frequency range of 22.4 to 11,200 Hz—without degradation of system performance.

(e) **Magnetic and Electrostatic.** The effects of magnetic and electrostatic fields shall be reduced to a minimum. The magnitude of such fields which would degrade the performance of the system in accordance with the specifications in Section 5080.3 shall be determined and stated.

(f) **Windscreen.** A windscreen suitable for use with the microphone shall be used at all times. The windscreen shall be designed so that for windspeeds of 20 miles per hour or less, the overall accuracy of the measurement system specified in Section 5080.3(a) is not compromised.

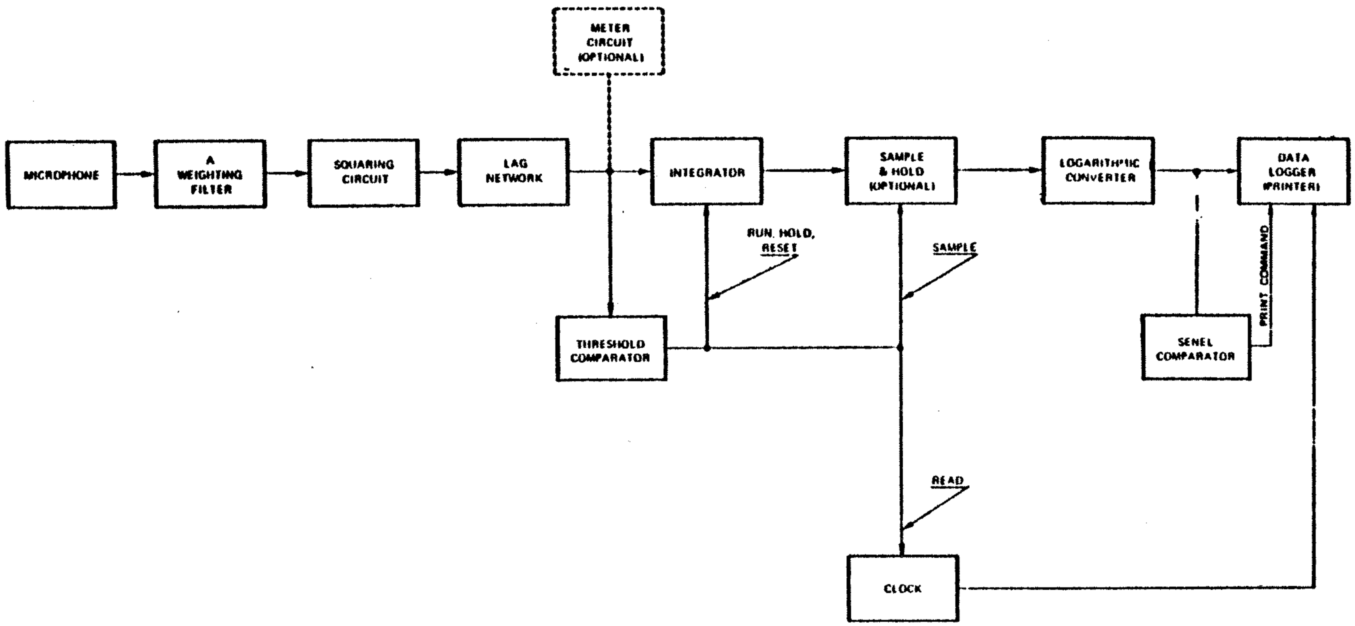


FIGURE 4. TYPICAL SINGLE EVENT NOISE EXPOSURE LEVEL (SENEL) SYSTEM

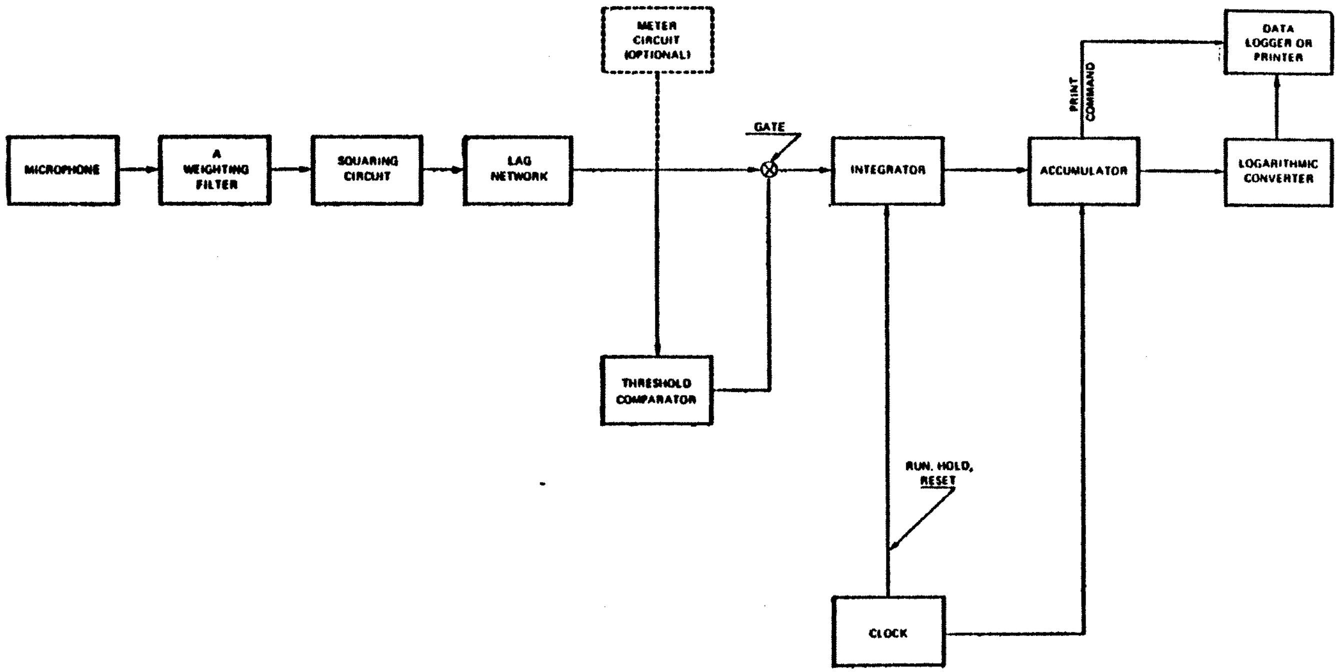


FIGURE 5. TYPICAL HOURLY NOISE LEVEL (HNL) SYSTEM

APPENDIX C

THE AUTHORIZING STATUTE

The following section is reproduced from the Public Utilities Code, Article 3, Chapter 4, Part 1, Division 9:

Noise Standards: Adoption

21669. The department shall adopt noise standards governing the operation of aircraft and aircraft engines for airports operating under a valid permit issued by the department to an extent not prohibited by federal law. The standards shall be based upon the level of noise acceptable to a reasonable person residing in the vicinity of the airport.
(Added by Stats. 1969, Ch. 1585.)

Advisory Committee

21669.1. There is hereby established an advisory committee to assist the department in the adoption of noise standards. The committee shall be composed of seven members appointed by the Governor as follows:

(a) Two members, one of whom shall be representative of homeowners concerned with aircraft noise.

(b) One member each from the Department of Public Health, the League of California Cities, the County Supervisors Association, the Department of Education, and the Air Transport Association.

The existence of the committee shall terminate on January 1, 1971.
(Added by Stats. 1969, Ch. 1585.)

Guidelines

21669.2. In its deliberations the department and the advisory committee shall be governed by the following guidelines:

(a) Statewide uniformity in standards of acceptable airport noise need not be required, and the maximum amount of local control and enforcement shall be permitted.

(b) Due consideration shall be given to the economic and technological feasibility of complying with the standards promulgated by the department.
(Added by Stats. 1969, Ch. 1585.)

Report

21669.3. The department shall submit a comprehensive report of the noise regulations adopted pursuant to Sections 21669, 21669.1, and 21669.2 to the Legislature on or prior to April 1, 1970, and the regulations shall go into effect on January 1, 1971, in the absence of legislative action adopting different standards.
(Added by Stats. 1969, Ch. 1585.)

Violation: Penalty

21669.4. (a) The violation of the noise standards by any aircraft shall be deemed a misdemeanor and the operator thereof shall be punished by a fine of one thousand dollars ($1,000) for each infraction.

(b) It shall be the function of the county wherein an airport is situated to enforce the noise regulations established by the department. To this end, the operator of an airport shall furnish to the enforcement authority designated by the county the information required by the department's regulations to permit the efficient enforcement thereof.

(c) Penalties assessed for the violation of the noise regulations shall be used first to reimburse the General Fund for the amount of any money appropriated to carry out the purposes for which the noise regulations are established, and second be used in the enforcement of the noise regulations at participating airports.

(Added by Stats. 1969, Ch. 1585.)

NOTE: Stats. 1969, Ch. 1585, also contained the following provision:

SECTION 6. There is hereby appropriated from the General Fund in the State Treasury to the Airport Assistance Revolving Fund, as a loan, the sum of fifty thousand dollars ($50,000) to be used in carrying out the purposes of Sections 21669, 21669.1 and 21669.2 of the Public Utilities Code as added by this act, and to be repaid as follows:

(a) Any penalties assessed for the violation of noise regulations pursuant to this act shall first be used to reimburse the General Fund until such loan is repaid; and

(b) If legislation is enacted to impose a tax on aircraft jet fuel, the revenues from which are to be deposited in the Airport Assistance Revolving Fund, such revenues shall first be used to reimburse the General Fund until such loan is repaid.

(c) From any federal grants that may be obtained by the department for the purpose of promulgating the standards called for by his act.

The following bill amends the foregoing section of the Public Utilities Code:

Assembly Bill No. 1040

CHAPTER 912

An act to amend Section 21669.3 of the Public Utilities Code, relating to regulation of obstructions.

[Approved by Governor September 14, 1970. Filed with Secretary of State September 14, 1970.]

The people of the State of California do enact as follows:

SECTION 1. Section 21669.3 of the Public Utilities Code is amended to read:

21669.3. The department shall submit a comprehensive report of the noise regulations adopted pursuant to Sections 21669, 21669.1 and 21669.2 to the Legislature on or prior to December 31, 1970, and the regulations shall go into effect on December 1, 1971, in the absence of legislative action adopting different standards.

APPENDIX D

SINGLE EVENT NOISE EXPOSURE LEVELS AND COMPARISON OF NOISE EXPOSURE SCALES

This appendix provides the baseline data used for establishing the limits for single event noise exposure levels (SENEL) for jet aircraft. Approximate expressions for specifying the single event and community noise scales utilized in the standard are given, along with comparable expressions for the other community noise scales referred to in Section 4.2.3. Finally, a procedure is given for estimating the maximum extent (or position of the closure point under the flight track) of the noise impact boundary for a given value of the community noise equivalent level (CNEL).

D.1 Average Values for SENEL Under Flight Path

The expected average values for SENEL directly underneath the flight track are shown in Figure D-1 for take-off and Figure D-2 for landing. For take-off, the values are based on estimated flight profiles for maximum gross weight conditions specified in References D-1 and D-2. The average SENEL values are based on the most probable values obtained from direct measurements (Reference D-8) or computed by applying the correction factors given in Table D-1 to published values of effective perceived noise level (EPNL) (References D-1 through D-7). The estimated accuracy of the final values for SENEL shown in Figures D-1 and D-2 is ±5 dB.

Table D-1

APPROXIMATE CORRECTION FACTORS TO CONVERT EPNL* TO SENEL FOR VARIOUS TYPES OF JET AIRCRAFT

Aircraft Type	EPNL -SENEL Take-off	EPNL -SENEL Approach
4 Engine Turbojet, Turbofan	4	7
4 Engine Jumbo Fan	5	4
3 Engine Airbus	2	4.5
2,3 Engine Fan	4	6.5
Executive Jets	2	2.5

*As defined in Reference D-9.

Curve	Aircraft Class	
A	4	Engine Turbojet Turbofan (e.g., 707, 720, DC-8)
B	4	Engine "Jumbo" Turbofan* (e.g., 747)
C	3	Engine Turbofan and Airbus* (e.g., 727, DC-10, L-1011)
D	2	Engine Turbofan (e.g., DC-9, 737)
E	2	Engine Business Jet
E + 3 dB	4	Engine Business Jet

* High Bypass Ratio Engine

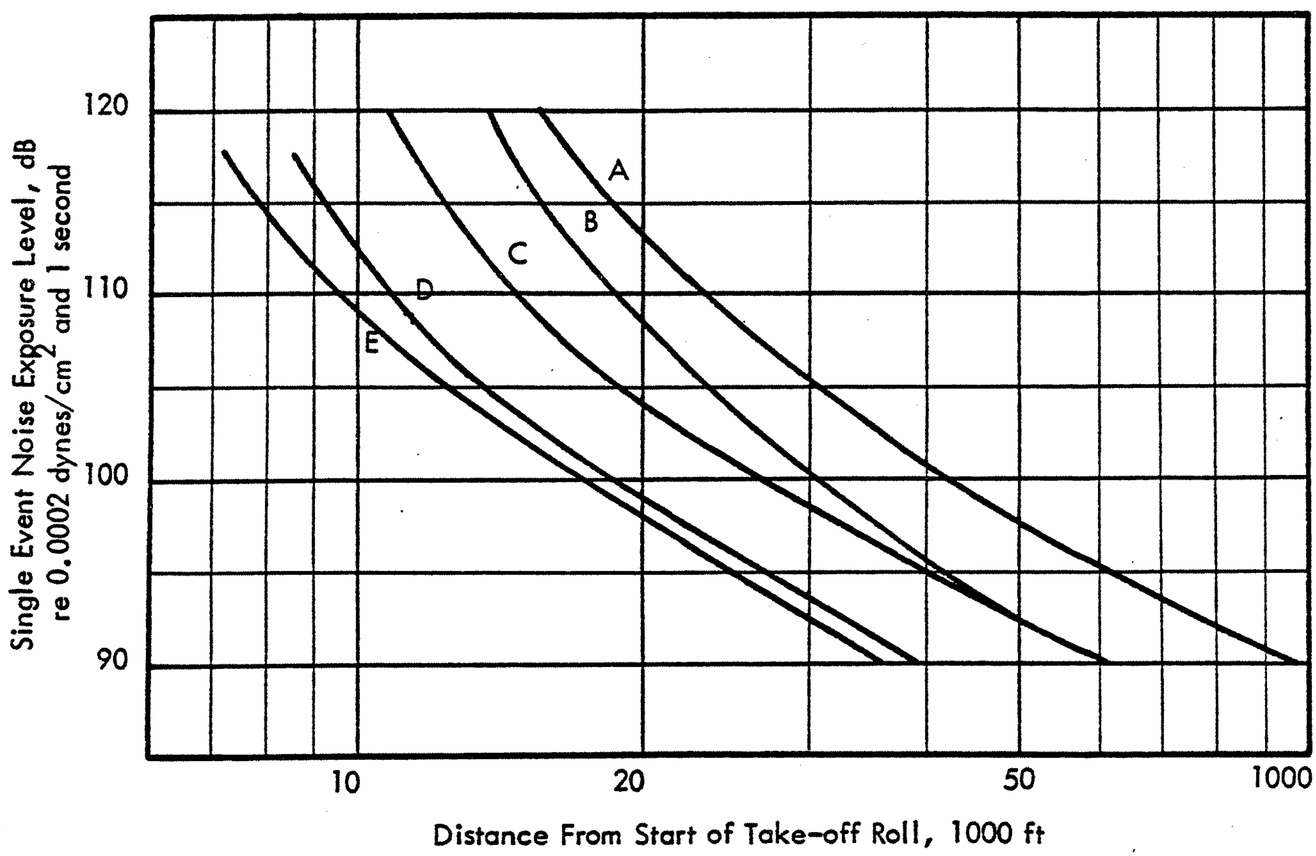


Figure D-1. VARIATION IN SINGLE EVENT NOISE EXPOSURE LEVEL ALONG THE TAKE-OFF PATH

Curve	Aircraft Class	
Z	4	Engine Turbojet and Turbofan (e.g., 707, 720, DC-8)
Y	2,3	Engine Turbofan (e.g., 727, 737, DC-9)
X	4	Engine "Jumbo" Turbofan* (e.g., 747)
W	3	Engine Airbus Turbofan* (e.g., DC-10, L-1011)
V	2	Engine Business Jet
V + 3 dB	4	Engine Business Jet

* High Bypass Ratio Engine

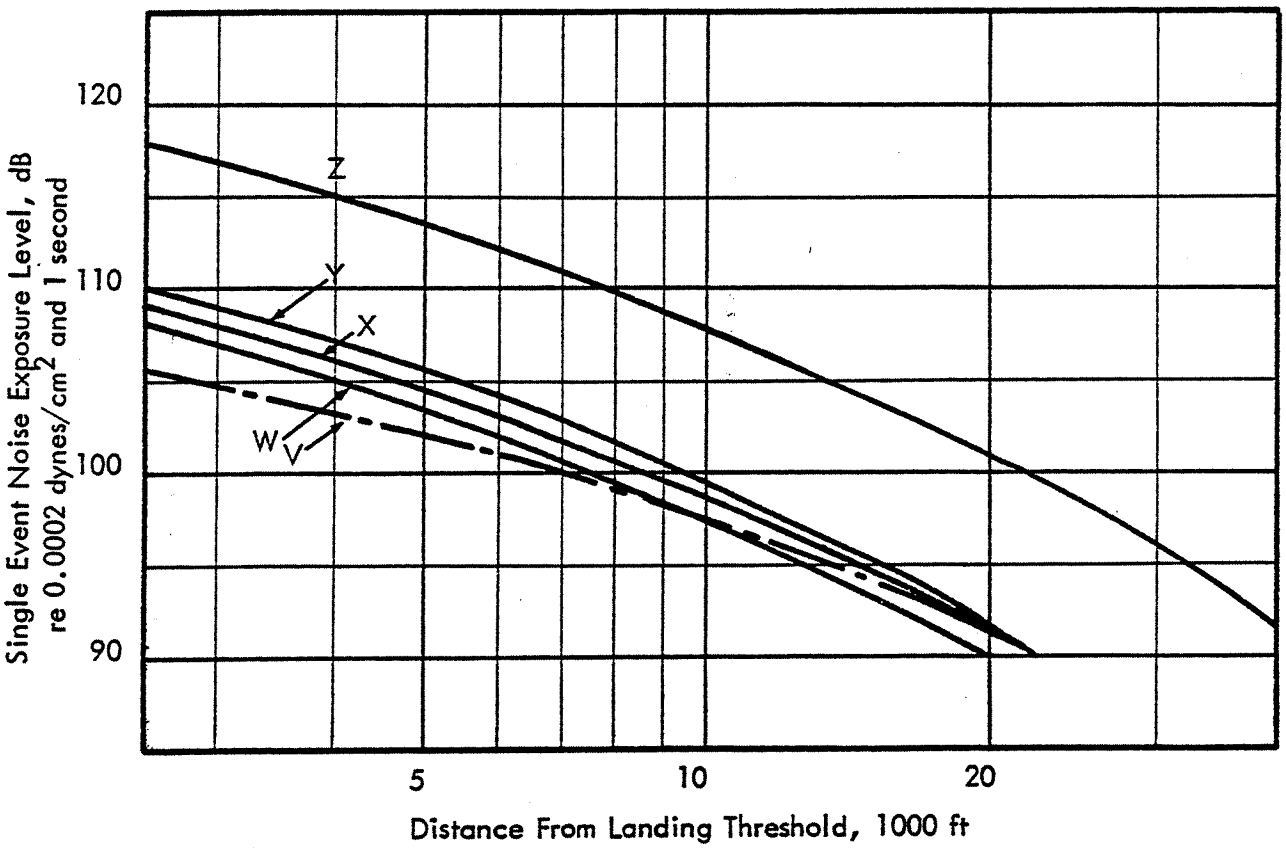


Figure D-2. VARIATION IN SINGLE EVENT NOISE EXPOSURE LEVEL ALONG THE LANDING PATH

D.2 COMPARISON OF NOISE EXPOSURE AND NOISE LEVEL SCALES

"Noise exposure is the integrated effect, over a given period of time, of a number of different events of equal or different noise levels and durations." (Reference D-10). The integration may include weighting factors for the number of events during certain time periods in which people are more annoyed by noise (e.g., sleep interference by noise at night).

A "noise level" is the weighted measure of the amplitude of a single noise event. The weighting emphasizes the spectral content of the noise in the frequency range where persons are more annoyed.

The various scales for noise exposure or noise level in use throughout the world differ according to the particular method of integration or summation, time period weighting factors, or frequency weightings.

The following summarizes the essential features of and correlation between the noise scales currently used in the United States and in Europe including the scales employed in the noise standard. The correlations are necessarily approximate, but are considered valid for interrelating evaluations of aircraft noise exposure at major airports served by current commercial jet aircraft. The definitions used herein are not always the same as those formally given in the source references. In all cases, however, the simplified form given here is an exact equivalent or valid approximation thereto.

D.2.1 SCALES FOR THE NOISE STANDARD FOR CALIFORNIA AIRPORTS

The following simplified expressions are derived from the exact definitions in the noise standard. They can be used to estimate values of CNEL where one type of aircraft and one flight path dominate the noise exposure level.

Single Event Noise

This is specified by the single event noise exposure level (SENEL) in dB and can be closely approximated by:

$$SENEL = NL_{max} + 10 \log_{10} t_{ea}, \text{ dB} \qquad (1)$$

where

NL_{max} = maximum noise level as observed on the A scale of a standard sound level meter, and

t_{ea} = effective time duration of the noise level (on A scale) in seconds

The effective duration is equal to the "energy" of the integrated noise level (NL), above a specified threshold noise level divided by the maximum noise level, NL_{max}, when both are expressed in terms of antilogs. It is approximately 1/2 of the 10 dB down duration, which is the duration for which the noise level is within 10 dB of NL_{max}.

A measure of the average integrated noise level over one hour is also utilized in the proposed standard. This is the hourly noise level (in dB), defined as:

$$HNL \simeq \overline{SENEL} + 10 \log n - 35.6, \text{ dB} \quad (2)$$

where

$\overline{SENEL}$ = arithmetic mean value of SENEL for each single event,

and

n = number of flights per hour.

It is assumed for this approximation that the difference between the maximum and minimum values of SENEL for the hour, divided by n, is less than about 1.5 dB. When this is not the case, the exact integration method specified in the noise standard should be used.

Community Noise Exposure

The total noise exposure for a day is specified by the community noise equivalent level (CNEL) in dB, and may be expressed as:

$$CNEL = \overline{SENEL} + 10 \log N_c - 49.4, \text{ dB} \quad (3)$$

where

$$N_c = (N_d + 3N_e + 10N_n)$$

or

$$= (12\bar{n}_d + 9\bar{n}_e + 90\bar{n}_n)$$

N_d, $\bar{n}_d$ = total number and average number per hour, respectively, of flights during the period 0700 to 1900,

N_e, $\bar{n}_e$ = total number and average number per hour, respectively, of flights during the period 1900 to 2200,

and

N_n, $\bar{n}_n$ = total number and average number per hour, respectively, of flights during the period 2200 to 0700.

D.2.2 NOISE EXPOSURE FORECASTS FOR LAND USE PLANNING

A method currently in wide use for making noise exposure forecasts utilized a perceived noise level scale with additional corrections for the presence of pure tones. In addition, only two time periods are used to weight the number of flights (Reference D-12).

Single Event Noise

For this scale, the single event noise level is defined by the quantity effective perceived noise level (EPNL) which can be specified approximately by:

$$EPNL \doteq PNL_{max} + 10 \log \frac{t_{10}}{20} + F, \text{ EPNdB} \qquad (4)$$

where

PNL_{max} = maximum perceived noise level during flyover, in PNdB,

t_{10} = 10 dB down duration of the perceived noise level time history, in seconds,

and F = pure tone correction to be applied as specified in Reference D-13. Typically, $F \simeq +3$ dB.

Community Noise Exposure

This is specified by the quantity, noise exposure forecast (NEF). For a given runway and one or two dominant aircraft types, the total NEF for both daytime and nighttime operations can be expressed as:

$$NEF = \overline{EPNL} + 10 \log N_f - 88.0 \qquad (5)$$

where

$\overline{EPNL}$ = arithmetic mean value of EPNL for each single event at the point in question. It is assumed that the range of EPNL divided by N_f is less than about 1.5 EPNdB. When this is not true, then the NEF value must be computed for each aircraft type separately and the total value determined by a logarithmic sum

$$N_f = (N'_d + 16.7 N_n) \quad \text{or}$$

$$= (15 \bar{n}'_d + 150 \bar{n}_n)$$

N'_d, $\bar{n}_d$ = total number and average number per hour, respectively, of flights during the day period 0700 to 2200. (Note: This is not the same day period as for CNEL.)

N_n, $\bar{n}_n$ = the total number and average number per hour, respectively, of flights during the night period 2200 to 0700, as for CNEL.

The constant (-88.0) dB includes an arbitrary -75 scale-changing constant and a reference number of daytime flights of 20. The constant 16.7 accounts for the 10-to-1 weighting factor for flights during the 9-hour night period.

D.2.3 COMPOSITE NOISE RATING METHOD

The original method for evaluating land use around airports was based on the composite noise rating (CNR) concept. It is still in wide use by the Federal Aviation Administration and the Department of Defense for evaluating land use around airfields, Reference D-11. This noise exposure scale may be expressed as follows.

Single Event Noise

The single event noise level is expressed (without a duration or tone correction) as simply the maximum perceived noise level (PNL_{max}) in PNdB.

Community Noise Exposure

The noise exposure in a community is specified in terms of the composite noise rating (CNR), which can be expressed as follows.

$$CNR = \overline{PNL}_{max} + 10 \log N_f - 12 \qquad (6)$$

where

$\overline{PNL}_{max}$	=	arithmetic mean maximum perceived noise level (PNL) at a given point. As before, it is assumed that the range in PNL_{max} is relatively small.
N_f	=	Same as defined for Equation (5). The actual method employed in Reference D-11 for accounting for the number of flights and time periods uses discrete interval correction factors. These have been approximated by the use of the equivalent continuous weighted number of flights, N_f.

D.2.4 COMPARISON OF COMPOSITE RATING SCALES FOR SPECIFYING COMMUNITY NOISE EXPOSURE

The basic expressions defined above for specifying community noise exposure are summarized below, along with corresponding approximate expressions for the other composite rating scales listed in Table 6 of Section 4.2.3 (Reference D-12).

Title	Equation
Community Noise Equivalent Level	$CNEL = SENEL + 10 \log N_c - 49.4$, dB
Noise Exposure Forecast	$NEF = EPNL + 10 \log N_f - 88$, dB
Composite Noise Rating	$CNR = PNL_{max} + 10 \log N_f - 12$, dB
Noise and Number Index	$NNI = PNL_{max} + 15 \log N - 80$, dB

Störindex	Q	$= NL_{max} + 13.3 \log N - 40.3$, dB
Noisiness Index	NI	$= NL_{max} + 10 \log N - 39.4$, dB
Annoyance Index	AI	$= PNL_{max} + 10 \log N$

where

SENEL	=	single event noise exposure level, dB (see Equation 1)
EPNL	=	effective perceived noise level (see Equation 4 and Table D-1 for relationship to SENEL)
NL_{max}	=	maximum A-weighted sound level, dB
PNL_{max}	=	maximum perceived noise level, PNdB
	=	NL_{max} + 12 dB
N_c	=	weighted number of flights per day for 3 time periods (see Equation 3)
N_f	=	weighted number of flights per day for two time periods (see Equation 5)
N	=	total number of daytime flights (unweighted) averaged over 24-hour period.

For the "Q" and Noisiness (NI) Indices, an effective duration of 10 seconds has been assumed in deriving the above expressions.

D.3 MAXIMUM EXTENT OF CNEL CONTOUR UNDER FLIGHT PATH

The maximum extent of a CNEL contour under the flight path is called the closure point. It is the farthest extent of a given CNEL contour from the runway along the flight track and occurs where the contour crosses the flight track. Its computation is illustrated by an example. The closure point for the CNEL = 65 dB contour is computed on one take-off path with the following schedule of maximum gross weight aircraft departures.

Aircraft Type	Number of Departures 0700-1900	1900-2200	2200-0700
2 Engine Turbofan	17	6	2

The example is illustrated by the following step-by-step procedure.

Step 1 Compute the weighted number of departures (N_c), see Equation 3.

$$N_c = 17 + (3)(6) + (10)(2) = 55$$

Step 2 Compute $10 \log N_c = 10 \log 55 = 17.4$ dB

Step 3 Compute $\overline{SENEL}$ from Equation (3).

$$\overline{SENEL} = CNEL - 10 \log N_c + 49.4$$
$$= 65 - 17.4 + 49.4 = 97.0 \text{ dB}$$

Step 4 Enter Figure D-1 to find the distance from brake release for SENEL = 97.0 for two-engine turbofan aircraft. This yields a distance of 22,600 ft. Thus, the CNEL = 65 dB contour closes on, or crosses over, the take-off flight track at 22,600 ft from the brake release point.

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