ACOUSTICS AND NOISE CONTROL IN CANADA

L'ACOUSTIQUE ET LA LUTTE ANTIBRUIT AU CANADA

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Articles in English or French are welcome, and should be addressed to any editor.
Vous êtes invités à soumettre des articles en anglais ou en francais. Prière de les envoyer à un des rédacteurs.

NOTICE OF MEETING

The next annual meeting of the Canadian Acoustical Association will take place in Windsor, Ontario on October 25-26, 1979. The meeting convenor is Dr. Z. Reif, Department of Mechanical Engineering at the University of Windsor. His telephone number is (519) 253-4232 extension 550. More details on the program will appear in the next issue, together with a call for papers.

As in past years, the week of the annual meeting will also be devoted to other matters of interest to acousticians and the public, including meetings of the Canadian Standards Association committee on Acoustics and Noise Control and its subcommittees.

The tentative timetable is:

October 22	-	CSA subcommittees meet
23	-	CSA main committee meets
24	-	Education day, CSA standards
	-	CAA registration and reception (Eve.)
25	-	CAA technical meeting commences
	-	CAA annual meeting (Eve.)
26	-	CAA technical meeting (Morning)
	-	Windsor area plant tours (Afternoon)

AVIS DE REUNION

La prochaine réunion de l'Association Canadienne de l'Acoustique aura lieu le 25-26 octobre, 1979 à Windsor, Ontario. Monsieur Z. Rief, Département de Génie Mécanique, Université de Windsor, convoquera la réunion. Son numéro de téléphone est: (519) 253-4232 local 550. Des renseignements sur le programme seront publiés dans la prochaire issue, ainsi qu'une invitation à présenter des articles.

Comme des années passées, pendant la semaine de la réunion annuelle autres activités auront lieu, elles seront consacrées aux intérêts divers des acousticiens et des membres du public y inclus les réunions de l'Association Canadienne de Normalisation sur l'Acoustique et la Lutte Antibruit et ses souscomités.

L'agenda proposé est le suivant:

22 octobre	-	*Réunions des souscomités de l'ACN*
23	-	*Réunion du comité principal de l'ACN*
24	-	*Jour d'éducation, Normes de l'ACN*
	-	*Inscription et réception (soir) de l'ACA*
25	-	*Commencement de la réunion technique de l'ACA*
	-	*Réunion annuelle de l'ACA (soir)*
26	-	*Réunion technique de l'ACA (matin)*
	-	*Tour des usines de Windsor (après-midi)*

JOBS AVAILABLE
ACOUSTICAL SPECIALISTS

Several positions are open in the Edmonton, Alberta office of this progressive western-Canada based professional consulting acoustical engineering firm. Experience in architectural acoustics, building services, industrial noise and vibration analysis and control, etc. is required. Familiarity with the usual complement of test equipment as well as PDP-8 mini-computers would be an asset. Your duties will include conceiving and implementing field measurement programs, data reduction and analysis by computer, preparation of written reports, and working closely with clients and other consultants on project design teams.

If you want an opportunity for personal and professional growth, we believe you will find it in this expanding firm.

Contact: Kenneth E. Barron, P. Eng, Principal
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JOBS WANTED

VICTOR SCHROTER is looking for a position in the field of acoustics and vibration. He has an M.Sc. in Sound and Vibration from the I.S.V.R., University of Southampton: the specialization was in acoustic barriers. He is at present completing industrially sponsored Ph.D. research at the same establishment, concerned with the dynamic response of nuclear reactor structures to acoustic excitation. He has also been recently involved with the development and evaluation of an acoustic intensity meter, an instrument capable of sound power and source identification measurements. The applicant would consider consultancy, industrial, or research work. Please contact applicant directly at 12 Bassett Gardens, Southampton S01 7EA, England.

NAHUM GOLDMANN, expert in noise and vibration control and acoustical measurements. Particular experience in research and design of silencers; noise and vibration control of mechanical devices and in building acoustics, including design of reverberant and anechoic rooms; and industrial hygiene. Diploma in Electroacoustics and Ultrasound Engineering (equivalent M.A.) from Electrotechnical University (LETI), Leningrad, U.S.S.R. Numerous publications. Interested in job in any aspect of acoustics. Please contact applicant directly at 6030 Bathurst St., Apt. 806, Willowdale, Ontario M2R 1Z9, Telephone (416) 636-3103.

THE PHYSIOLOGICAL EFFECTS OF NOISE EXPOSURE ON MAN

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No one would argue the point that modern technology has introduced rapid growth and advancement throughout the world within the last few decades. While achievements are countless, one detrimental adversity which has been, until recently, an unknown consequence, is the effect of noise on man. Specifically, noise has introduced irreversible hair cell damage to the cochlea reducing man's potential for normal hearing sensitivity. Noise induced hearing loss (NIHL) may be caused by either long term exposure above the damage risk criteria, or instantaneous exposure. In any event, hair cell damage to the cochlea is the end result. Depending on man's exposure to noise, either temporary threshold shifts (TTS) or permanent threshold shifts (PTS) will ensue. The intent of this paper is to present current research in the area of noise exposure as it affects physiological changes within the auditory system. In addition, concomitant changes that face man due to a reduction in hearing sensitivity are discussed. Finally, current research by the present author in the area of noise exposure, ototoxicity and the additive effects on high risk infants are presented.

While intense noise exposure in excess of 160 dB SPL may produce structural damage to the middle ear system such as rupturing of the tympanic membrane or fracturing of the ossicular chain, the primary damaging mechanism seems to be metabolic stress on the stimulated sensory hair cells. Most vulnerable to acoustic trauma is the region of the organ of corti approximately eight to ten millimeters from the basilar end of the cochlea, an area which corresponds to the 4000 Hz sensitivity region. This frequency region will produce the largest threshold shifts regardless of the stimulus frequency, and is most probably due to the auditory system which acts as a built-in filter whose band pass somewhat limits the frequency of sounds which are hazardous to the organ of corti. A contributing factor to this filter system is the contraction of the middle ear muscles which attenuate transmission of sound in the lower frequencies. The acoustic middle ear contraction magnitude increases with increased SPL up to about 30 dB above the reflex threshold, thereby altering the ear's sensitivity due to the efficiency of the middle ear.

Other factors related to the maximum threshold shift seen at the 4000 Hz region may be attributed to the physiological and anatomical differences of the basilar membrane, the direction and pattern of the travelling wave within the cochlea, and the resonance characteristics of the external auditory canal.

Physiologically, two basic alterations occur to the auditory system due to noise exposure and are reflected in the degree of hearing sensitivity loss and its method of measurement. These are adaptation and fatigue. Adaptation deals with low intensity stimulation between 20 and 90 dB SPL and is measured as a change in the perception or threshold while the stimulus is present. Adaptation is basically a neural phenomenon and results in a decreased rate of neural firing or action potential. Adaptation occurs in a normal, healthy ear and produces no permanent damage to the cochlea. Fatigue, on the other hand, deals with high intensity stimulation, usually greater than 80 dB SPL and is measured approximately 3 minutes after the cessation of the stimulus. The temporary threshold shift measured is due to fatigue, basically a cochlear phenomenon. Physiological changes which result from fatigue include alterations in both the cochlear and action potentials, a substantial reduction in the vascular supply thereby diminishing oxygen to the auditory system, distortion of the basilar membrane and organ of corti; all resulting in tissue damage to the sensory receptor hair cells in the cochlea.

The most common index of auditory fatigue is the temporary threshold shift and is measured by determining the ear's threshold, exposing the ear to fatigue, measuring the exposed threshold and the differences between them; that is, the pre and post thresholds are considered the degree of threshold shift. It is presumed that anytime you have induced a TTS of more than 40 dB, you have induced actual damage. As long as the TTS has not exceeded this dB value, recovery time all tends to meet at approximately 1000 minutes or 16 hours.

The consequence of reduction in hearing will not only reduce the ear's auditory sensitivity to tonal stimulus, but will also reduce the system's ability to discriminate speech, man's obvious means of communication. Because consonant phonemes are high frequency, low intensity in nature and provide meaningfulness to speech, a concomitant reduction in hearing sensitivity will reduce the high frequency resolution capabilities of the auditory system while introducing a masking effect by the stronger low frequency vowel phonemes. Taking this into consideration, as well as the low frequency noise in our environment, it is no wonder the major complaint of individuals with sensori-neural hearing losses is that, while speech is usually loud enough to hear, the discrimination of the speech signal is unintelligible.

Recently, I have done some extensive work in the area of noise measurement as it relates to potential hearing loss in premature infants who have spent, in some cases, the first three to six months of their lives in incubators. The results of my investigation are consistent with other research in the literature. Using B & K equipment and measuring noise intensity on dBA and linear settings, we found that the frequency distribution of incubator noise produced peak levels between 31.5 and 250 Hz with approximately 90% of all sound level energy below 500 Hz. Depending upon the incubator measured, mean intensity values ranged between 62 and 67 dBA and 70 to 77 unweighted. Interestingly, and consistent with Dr. Mencher's work at the Izaak Walton Killam Children's Hospital in Halifax, the most intense noise measured was attributed to the closing of the incubator door, introducing impact measurements as much as 115 dB.

According to well established damage-risk criteria, the maximum sound intensity an adult may safely tolerate is 80 dBA regardless of the duration. Thus, according to our measurements, incubator noise should not be considered a potential risk; however, a number of factors must be taken into consideration before accepting this conclusion. First, damage-risk criteria are established on adult subjects and based on intermittent noise during an eight hour per day exposure. Research has revealed that continuous noise is more damaging than intermittent. In addition, animal evidence has shown that hair cell damage following noise exposure with associated ototoxic antibiotics appear to affect the auditory system more than just additively. It should be noted that the large numbers of premature infants concomitantly receive antibiotics such as gentamycin, which may have ototoxic effects on the auditory system. While conclusive evidence has not been formulated, longitudinal studies are in order to determine any potential hazards that may exist.

This paper was presented at the Annual Meeting of the CAA, Halifax, Nova Scotia, November 1978.

CORRECTION

In "The Ford Auditorium" (October 1978 issue, page 16), "Lewis M. Dimenco" was named as design architect when Lewis M. Dickens was in fact responsible. We apologise to Mr. Dickens and Mr. Dimenco.

INTENSITIES DIFFERENCE IN

DICHOTIC LISTENING TASKS

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INTRODUCTION

A wealth of previous studies have continuously demonstrated that when consonant-vowel (CV) nonsense syllables are simultaneously presented to normal hearing subjects in a dichotic listening task, a significant hemispheric asymmetry will be reflected from reported scores. That is when speech is used as a dichotic stimuli, a right ear advantage (REA) results. While functional hemispheric asymmetry has received supporting evidence from electrophysiological animal study as well as anatomical and physiological evidence in man, the actual size of the right ear advantage has varied from study to study.

One parameter of dichotic listening tasks which have produced inconsistent differences between right and left ear scores as well as overall performance, may be attributed to changes in the intensity presentation level. Depending on the intensity level used, a wide variance in ear score differences have been observed. A review of literature has revealed significant REA differences which range from 2.1% to 27%. Thompson and Hughes presented CV's at 6 intensity levels, 30, 40, 50, 60, 70 and 80 dB SPL to twelve adult listeners. Although a REA was obtained at all intensity levels, the magnitude of the ear advantage decreased above 50 dB SPL. Right ear advantages ranged between 4 and 13 percent depending upon the intensity level.

To date, presentation intensities have been based on absolute sound pressure levels (SPL). As an alternative to this procedure, the use of the most comfortable loudness levels (MCL) have been suggested. Recently, data have provided results which indicated that MCL is clinically feasible, statistically reliable and provides the intensity presentation level that would produce maximum speech discrimination.

To date, incorporation of MCL as a presentation level in dichotic listening studies has not been explored. Due to the variance in ear scores derived under different levels of stimulus presentation, it was the purpose of this study to determine if the use of MCL as a presentation intensity could be demonstrated to be a viable alternative to absolute intensity levels in dichotic listening tasks.

METHOD

Subjects

A total of 30 right-handed normal hearing adult subjects was chosen for this study. Subjects met the following criteria: 1) hearing sensitivity as measured by audiometric pure-tone air conduction testing had to be 15 dB HTL or better at octave frequencies 250 to 4000 Hz (re: ANSI, 1969); 2) speech reception thresholds were at least 15 dB HTL; 3) speech discrimination scores were 90% or better as measured by recorded phonetically balanced word lists (CID-W22).

Test Stimuli

The CV syllables used in this study consisted of six English stop consonants, /b,d,g,p,t,k/ paired with the vowel /a/. Dichotic presentations consisted of independently paired syllables presented simultaneously to each ear. Each presentation was followed by a six second (± 0.5) silent period. Four individual lists, consisting of thirty dichotic pairs each, were constructed in such a way that each consonant was presented equally with no competition occurring between identical CV syllables. Stimulus duration for all CV syllables was exactly 270 ms., with a signal-to-noise ratio of plus 30 dB SPL or better. The stimulus tapes were constructed by using a special computer program at the Kresge Research Laboratory South by Dr. Charles Berlin.

Instrumentation

All the monaural and dichotic listening tasks were performed in a sound treated booth (IAC-1200). CV syllables were presented on an Akai-4000 stereo tape recorder operated at 7½ ips. The signal was fed via a Madsen OB-70 Clinical Audiometer coupled to Telephonic TDH-39 earphones with MX-41/AR cushions. The acoustic outputs of the earphones were calibrated using a Brüel and Kjaer (Type 2209) sound pressure level meter and an artificial ear (Type 4105), prior to the testing of each subject.

Procedures

Five individual test lists consisting of 30 CV nonsense syllables were used as stimuli in the present study. Intensity levels and list presentations were counter-balanced to assure the elimination of any possible order or learning effect. In addition, all subjects received 30 monaural CV syllables at MCL using equal loudness as the criterion. All responses for CV syllables were on an answer sheet provided and subjects were instructed to use a two-forced choice recall method of response.

RESULTS

Thirty normal hearing adult subjects received dichotic stimuli at five presentation intensity levels, 50,60,70,80 dB SPL and MCL based on equal loudness levels. Mean MCL values were 76.3 and 76.7 dB SPL for the right and left ears respectively. Further analysis revealed that the bracketing method used did not produce intensity differences within subjects which exceeded 3 dB between right and left ears. Results of a *t* test indicated that differences between right and left ear presentation levels were nonsignificant.

Ear Asymmetry: Monaural

Ear asymmetry for monaural scores was determined using absolute right minus left differences for ear advantage. The scores were computed by averaging the sum obtained from the right ear scores minus the sum of the left ear scores. Mean correct raw scores were 28.9 (96.3%) for the right and 29.0 (96.6%) for the left. When raw score data were statistically analyzed, no significant ear differences were obtained for monaural CV syllables. The lack of statistical difference for monaural scores indicates the similar perception capability for each subject's auditory pathway under normal conditions.

Ear Asymmetry: Dichotic

In the present study, the percentage of error (POE) index was used as a measure of the relative degree of lateralization without variations due to accuracy, the amount of guessing, level of presentation or the method of subject response.

Based on POE scores, a two-way analysis of variance with repeated observations was performed on the results. Although the analysis of overall dichotic performance as a function of intensity proved significant differences between ears, intensity/subject interactions were nonsignificant. In essence, no intensity level was significantly different than any other within the present dichotic paradigm. Subsequent *t* scores were computed in order to analyze between-ear differences for the five individual intensity presentation levels. Results produced significant individual right ear advantages for each of the 5 presentation levels. REA's ranged between 5.9% at 80 dB SPL to 12.2% at MCL.

Mean POE scores at the 5 intensity presentation levels were obtained. The direction and degree of lateralization are represented by the POE scores contributed by the left ear. A percentage of greater than 50% indicates right ear/left hemisphere dominance.

DISCUSSION

Although the results of a two-way analysis of variance revealed nonsignificant differences between the five intensity presentation levels, individual REA differences were seen. These results are consistent with previous studies which also show a variance in the REA based on several intensity presentation levels. A maximum REA of 12.2% was obtained at MCL. The other absolute intensity levels used in the present study produced REA's which ranged from a minimum of 5.9% obtained at 80 dB SPL to 11.4% at 60 dB SPL. To date, no firm conclusions can be drawn from the range in percentage differences (6.3%). When taking into consideration, however, the degree of descussation between the two auditory pathways and the multitude of neural innervation occurring in both the primary and secondary projection centres of the auditory cortex, it is little wonder that the effects of intensity can only be speculative.

One advantage in using MCL, however, as a presentation level of choice may be the balancing of potential differences between the individual auditory pathways. According to recent research, dichotic laterality may be affected by physiological interaural differences such as loudness and the level of test presentation because of small asymmetries in the peripheral auditory system.

The utilization of MCL as an intensity level has also been found to have applicability for the study of pathological hearing impaired subjects when dichotic listening tasks were employed. Recently, Jacobson presented a series of dichotic CV syllables at equal loudness levels using MCL as the loudness criteria to a group of 30 moderate bilateral symmetrical sensorineural subjects and 10 normal hearing adults in order to determine interaural intensity differences between ears. In every case, a significant ear advantage was observed and interaural intensity differences were proven to be a nonsignificant influencing factor in ear laterality. Jacobson concluded that MCL would compensate for possible physiological loudness differences in sensorineural patients who suffer from recruitment.

CONCLUSIONS

The intent of this study was to determine the effect different intensity levels had on REA scores in a CV dichotic listening paradigm. To accomplish this task, five different intensity levels (50,60,70,80 dB SPL and MCL) were utilized in presenting a dichotic listening task to 30 normal hearing subjects. Although MCL produced the largest REA, the ANOVA data analysis revealed non-significant differences between the five presentation levels. Results of the study would suggest that the use of MCL as a presentation level in dichotic listening paradigms is a visible and acceptable procedure and may have direct applicability when investigating a population with known peripheral asymmetries.

This paper was presented at the Annual Meeting of the CAA, Halifax, Nova Scotia, November 1978.

TONE PIP ELICITED BER'S

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Since the initial work of Jewett and Williston in 1971, a remarkable degree of quantification and confirmation of brainstem evoked response data has been published. The consensus of findings has led to the clinical acceptance of BER as an intricate test in the diagnostic assessment of both normal and pathological subjects. BER studies continue to demonstrate that the BER technique does provide an objective means for assessing hearing, especially among infants and difficult-to-test patients.

The principle underlying BER is the same as that used for any evoked potential study. Basically, EEG changes resulting from auditory stimuli are recorded by scalp electrodes. These auditory evoked EEG changes are usually too small to be observable in the ongoing EEG and in order to extract these minute potentials, amplification and signal averaging must be used. It is necessary that the auditory stimulus be repeated a number of times. The electrical responses as recorded by the scalp electrodes are time-locked to stimulus onset. With the use of a signal averaging computer, any random background EEG activity that is not associated with the brain's response to auditory stimuli averages to zero, while the EEG responses to the auditory stimuli summate.

The subject's EEG is obtained via electrodes attached to specific portions of scalp, usually the vertex and both mastoids. The signal which is picked up is amplified by a preamplifier prior to its transmission to the signal averager. The EEG signals are amplified a minimum of 20,000 times for BER studies. The result is a specific wave form which may be recorded and the latency of each wave peak can be accurately measured.

All in all, there are seven different wave peaks that are available to use as measurement points, some more stable than others, each reflecting different areas of neural activity in the auditory pathways through the brainstem.

The individual peaks reflect changes in the auditory pathway that occur within the first 10 msec after the onset of the auditory stimulus. Each of the seven different waves has its own Roman numeral designator and anatomical location. Wave I is thought to be generated by the cochlea and auditory nerve, Wave II by the cochlear nuclei, Wave III by the superior olivary complex, Wave IV by the nuclei of the lateral lemniscus, Wave V by the area around inferior colliculi, and Wave VI and Wave VII by the medial geniculate and auditory cortex areas. In brainstem evoked response audiometry, Wave V has been found to be the most diagnostically useful waveform. Accurate estimates of thresholds have been made from the curves described by the latency values of the Wave V's of BER's elicited by click stimuli. These thresholds refer to intensity only and lack the frequency specificity required for audiological assessment. Speculation exists that other stimuli, especially more frequency-specific stimuli, might provide additional frequency-specific information. Research continues in studies using BER technique.

While a number of different types of frequency-specific stimuli have been tested, the tone pip stimulus appears to be the most clinically useful frequency-specific stimulus to date. It can be shaped to a specific time and contain little or no plateau. The onset of the pip can be nearly instantaneous as is the click. The stimulus duration of the tone pip can be held to within the time constraints of the BER. The effect of frequency-specific tone pip stimuli on the Wave V component has not been studied to the extent that the click stimulus has. Only three studies to date have specifically investigated intensity, latency functions from selected tone pip stimuli. All three have demonstrated that a definite latency-intensity frequency function exists for BER elicited by frequency-specific tone pips.

The data in our study clearly illustrate such a latency-intensity function. The latency values of Wave V increased systematically as intensity decreased. For example, in a BER trace elicited by a 1000 Hz tone pip, the latency of Wave V at a 70 dB intensity level is shorter than the latency at any of the lower intensity levels.

Comparison across different frequencies illustrates a definite relationship among frequency-specific tone pips at the same intensity level.

The results also show that the latency of Wave V as elicited by a 4000 Hz tone pip is shorter than the latency of the Wave V component for either the 2000 Hz, 1000 Hz or 500 Hz tone pips. This type of a relationship was found in all the studies done with tone pip stimuli. Some differences in actual times did exist between studies, but I will refer to this more specifically later in the discussion.

Past tone pip studies clearly indicate that Wave V latency values elicited by tone pips consistently describe a curve in a manner similar to clicks. However, much research needs to be done in order to determine the optimum acoustic envelope for selected tone pip stimuli used in BER. In that all current research and diagnostic use of BER depends upon specific waveform parameters, it appears that additional study is needed to develop a clinical procedure which would result in a stable replicable BER technique for selected tone pip stimuli. Thus the purposes of our study were 1) to obtain Wave V latency curves for selected tone pip frequencies; 2) to compare the frequency-specific curves with previously obtained tone pip curves from other studies; and 3) to determine, if possible, the clinical utility of the selected procedure.

METHOD

Subjects

Ten normal hearing adults, five females and five males, ranging in age from 22 through 47 years of age (mean age 31 years) volunteered to be subjects. Each S had hearing thresholds better than 10 dB re: ANSI 1969 for the frequencies tested.

Stimulus Parameters

The decision was made to test 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. All of these frequencies had been tested in one or more of the previous studies but no two studies had all these frequencies in common. In addition, these frequencies have clinical diagnostic value because of their importance in the reception and perception of speech and language.

The stimulus envelope which we used was diamond shaped with a 5 msec rise/fall time. Four intensity levels were considered sufficient to permit observation of a latency shift. Levels of 70 dB, 50 dB, 30 dB and 10 dB were selected. A presentation rate of 33.3/sec was used. This meant that each subject heard 33 tone pips each second. A large number of samples is required to elicit the BER and by presenting at a rate of 33.3/sec, the latency of Wave V was not appreciably affected but it did decrease the time required for testing as compared to a presentation rate of 10/sec, which was used in one of the studies previously referred to.

Procedure

Three silver-silver chloride electrodes were attached to the scalp with the active electrodes placed on the vertex (Cz, 10-20 system) and the reference electrode placed on the mastoid ipsilateral to the ear being stimulated. A ground electrode was attached to the opposite mastoid during all testing procedures. The subjects rested on a cot in a double-walled electrically shielded booth. Shielded earphones were placed over the ears so as not to occlude the external auditory canal.

Each tone pip stimulus was delivered through shielded TDH-39 earphones to the test ear. The EEG signal was amplified by a physiological amplifier (Nicolet AGA-1000) with a gain of 10^4. The signal was routed through a band-pass filter set between 150-3000 Hz and fed to a clinical averager (Nicolet CA-1000). The time base was 20 msec and 2000 repetitions were used for each BER. Each BER was replicated to judge repeatability.

Responses were plotted using an X-Y plotter (Hewlett-Packard 7010A). Whenever possible, the Wave V component was identified and latency measures were recorded. The traces were labelled for later blind analysis.

Three qualified observers, trained in BER analysis, independently judged all BER traces to determine the presence or absence of the Wave V component. Agreement among all three observers was required for acceptance of the existence of Wave V. The Wave V component is identified by the characteristic sharp negative deflection, the latency of which varied in our study between 6.5 msec and 13.5 msec.

RESULTS AND DISCUSSION

The mean latency values and standard deviations for all four tone pip frequencies at tested intensity levels were derived along with normative click latencies for the same intensity levels. At a 70 dB intensity level the Wave V component was well defined for all frequencies. However the probability of unanimous agreement in the identification of Wave V by the judges decreased as intensity level decreased.

These latency values were the means of the number of subjects who produced BER's with recognizable Wave V components for each frequency and intensity. Wave V latency intensity curves for the specific tone pips presented at four intensity levels were virtually parallel except at the lower intensity levels.

While the frequency-specific latency values compare favourably with the previously mentioned studies, there are differences which may be attributed to variations in methodology, particularly rise/fall time and presentation rates, none of which were consistent across studies. The specific procedure which we used in our study proved practical for the collection of BER data elicited by tone pip stimuli. The traces produced by the normal subjects permitted a better than 85% agreement among the observers in respect to identification of the Wave V component. This particular procedure, however, did not result in clear resolution of Wave V at intensity levels below 30 dB for some of the subjects. Tone pip frequencies with shorter rise/fall times might permit better synchrony of the auditory nerve resulting in a more conclusive Wave V component at the lower intensity levels. But more study is needed to confirm or reject this hypothesis. Evaluating the BER traces collected by the procedure used in our study, we have been able to establish systematic Wave V latency values for each of the four frequencies tested.

These values compare with previous studies and do appear to indicate reasonably accurate values for estimating normal frequency-specific thresholds.

The norms which were established in our study are currently being used in our clinic at Dalhousie University to assess thresholds with clinical patients.

This paper was presented at the Annual Meeting of the CAA, Halifax, Nova Scotia, November 1978.

Helicopter Noise Propagation Studies for Air Installation Compatible Use Zoning.

Philip Dickinson
Bickerdike, Allen, Partners.

With the helicopter, noise undoubtedly is the environmental pollutant which causes the greatest concern from the point of view of the general public and social acceptability (1). The noise radiated from a helicopter is very complex, composed of sound produced by several different sources, each of which generates acoustic energy by more than one mechanism. These include noise from engines, tail rotor and 'Blade Slap'. The former is adequately described in terms of dBA. Certainly the other two are not.

Externally, the noise is controlled largely by the noise component from the rotors, although high frequency compressor 'whine' is subjectively significant at relatively short distances from the helicopter. From subjective considerations, the two most important sources are the blade-slap and tail rotor noise. Blade-slap is a loud impact noise which occurs at the blade passing frequency - typically 15 to 20 Hz - and when it occurs it can cause extreme annoyance. It is usually associated with tandem rotor helicopters and those helicopters with a two blade single rotor, although it can be generated to some extent on practically all helicopters (1). Opinions differ as to the exact cause, but the most likely hypothesis (2) is that it is caused by a blade/vortex interaction mechanism.

The methodology for predicting helicopter noise in the far field is similarly very complex also; the initial process being one of pseudo-convection with the directivity of the advancing blade, resulting in many cases in an epicentric curling of vortices predominantly along one side of the flight track. In the mid-field, often these ride over on-coming low level wind; producing increased noise levels upwind, i.e., the converse of noise from conventional take-off and land aircraft, with the exception sometimes of some turbo-propeller varieties - as discovered by researchers during the design considerations for the Schiphol and

Saltholm Airports in the Netherlands (3). This lasts until the individual vortices expend all their energy as sound and heat, at which point the pulse propagates in a more conventional manner. But this too is complicated by the nature of the pulse and the directivity it has gained by the air movement. Hence the pulse itself - basically one of a narrow band signal in the 250 Hz range, on a carrier wave of about 20 Hz - is not exactly conventional and the polar spread, air attenuation and ground absorption properties differ considerably from conventional aircraft spectra.

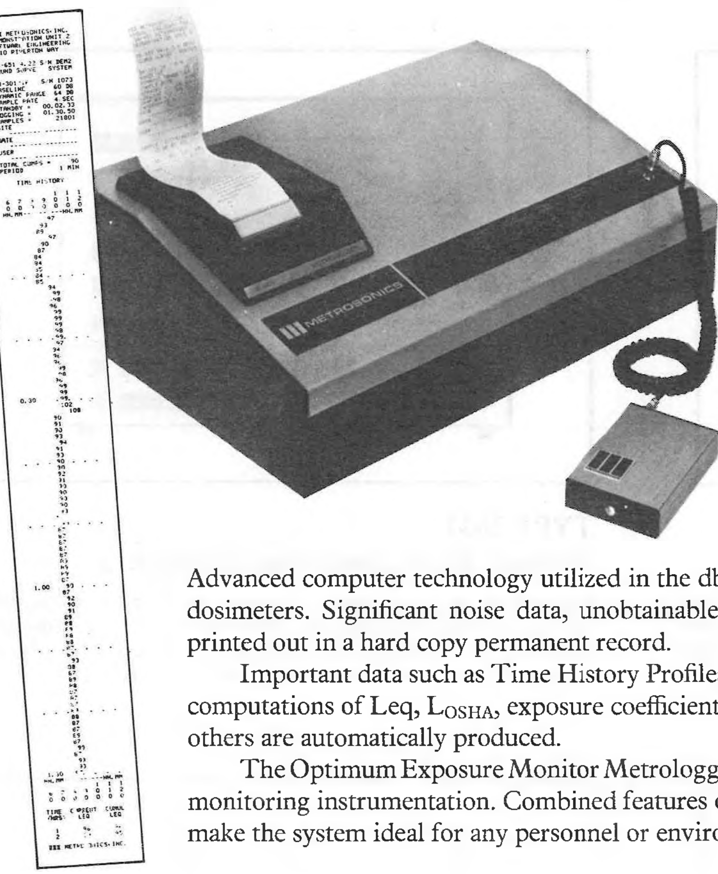
One of the greatest problems is in determining the lateral propagation, i.e., the noise propagation at right angles to the helicopter track. Noise levels in the mid-field - up to 2000 feet or so - do not continuously decrease with distance. Nor is the noise from a single event symmetrical about the flight track, except for a few helicopters at fairly high altitude. The shape of the noise footprint also differs from one helicopter variant to another of the same model. Such considerations make the computation process very difficult and time consuming.

The effect of the topography and general climate of the area under consideration is critical and, in all helicopter noise prediction work, raw base data, within the particular geographical confines of the area under consideration, must be obtained. The noise exposure contours for a certain group of helicopters in, say, Nova Scotia will be quite different from the noise exposure contours for the same helicopters doing exactly the same operations in, say, Alberta or even another part of Nova Scotia!

Subjective Considerations

Subjectively, blade-slap is perhaps the most important noise source on helicopters in certain flight regions. It is fairly clear that conventional use of PNL or dBA rating methods do not adequately account for the subjective effects or intrusiveness of helicopter noise when it is dominated by blade-slap. This has been shown clearly by a number of

MICROCOMPUTERIZED NOISE DOSIMETRY...



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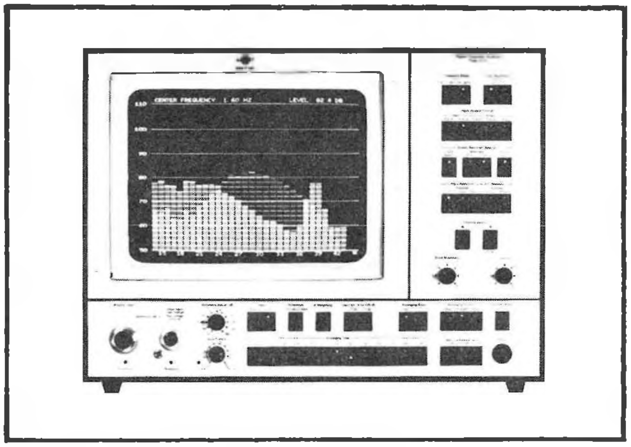

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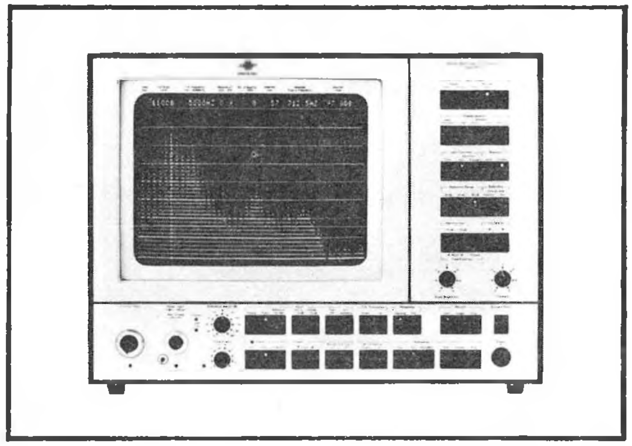

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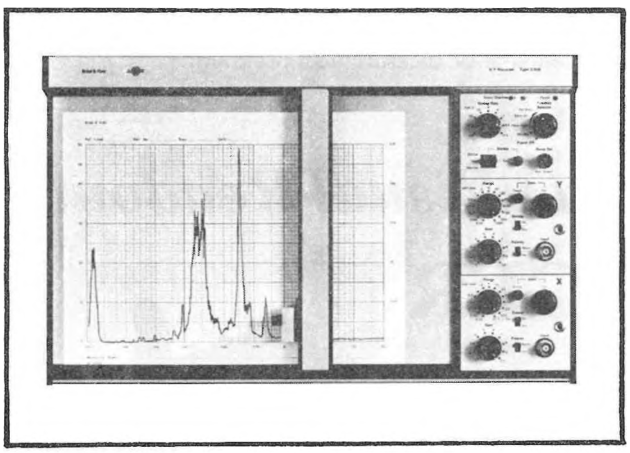

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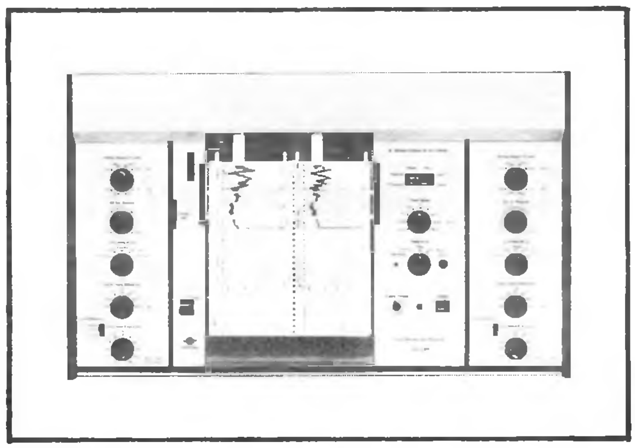

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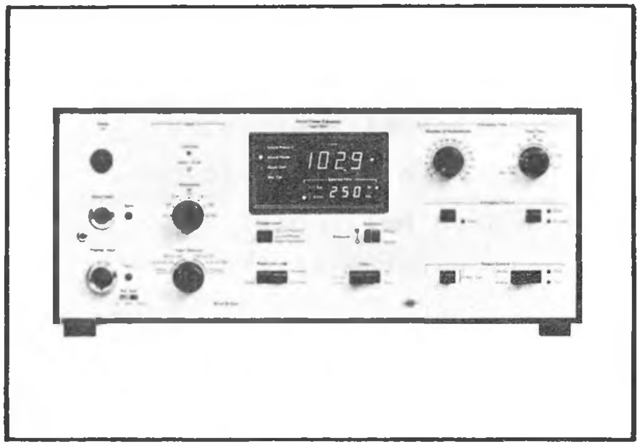

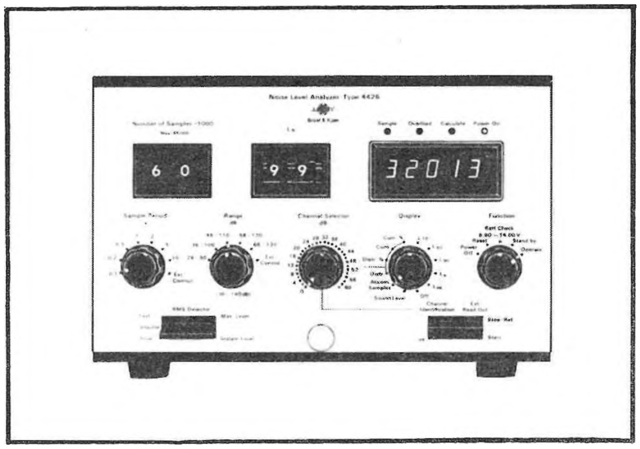

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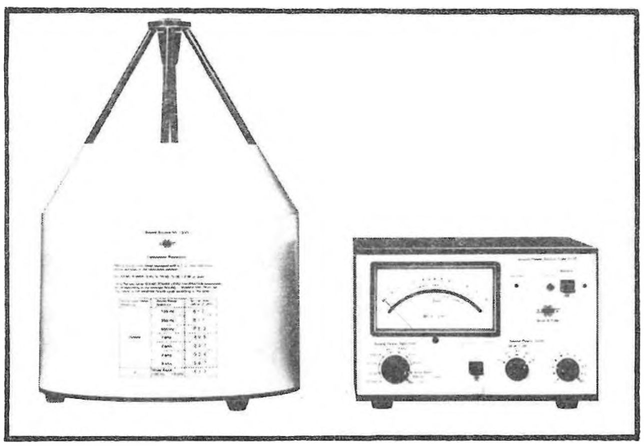

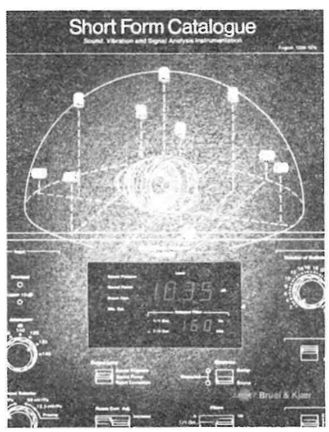

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investigations (4, 5). However, few studies have been carried out to develop a suitable method for differentiating between slapping and non-slapping helicopters or to determine the subjective penalty.

The most comprehensive study has been by John Leverton - considered the world authority on helicopter noise - and his acoustics group at Westland Helicopters (6). From a comprehensive series of subjective tests of noise from slapping and non-slapping helicopters, they found that a simple add-on type of correction for impulsive helicopter noise was possible, the correction factor being directly related to the Crest Factor of the noise in the 250 Hz octave band i.e., (Peak Linear - Slow Response) in the frequency range from about 200 to 400 Hz.

Munch and King of Sikorsky Helicopters (7) undertook a study for N.A.S.A. on the Community Acceptance of Helicopters and came to a very similar conclusion. Figure 1 shows the findings in graph form (8). Considering the two studies had no inter-relationship and were separated by some thousands of miles and subjects were of different types, the results are remarkably alike. When suitable instrumentation is not available, the F.A.A. has suggested (9) a +7 dB correction to meter readings when blade-slap is present, i.e., as a rough guide, impulsive helicopter noise is subjectively the same as that from a jet aircraft that is 7 dB noisier.

The helicopters we find most common in military circles are derivatives of the Bell model 209 (AH1), the Bell model 204 (UH1), the Boeing Vertol model 107 (CH46) and the Sikorsky S61 (CH53). On the occasions that blade-slap occurs, the envelope of propagation is in the forward direction only. The blade-slap for small single rotor helicopters, such as the AH1J and the UH1N, we believe follows that of a cone of half angle 10° centred about the forward axis of flight. Measurements on the twin rotor CH46 lead us to believe that the blade-slap, although still in a forward direction only, is not symmetrical but follows that of a skewed cone where on the left hand side of the craft the half angle is about 10° but on the right hand side the half angle approaches 44°, with a sharp transition on the flight track, if there is no wind. This angle is very difficult to measure and we are by no means certain that the figures we have used are precise. But, with all the environmental factors present, a few degrees error is not significant.

As the propagation is in the forward direction only, the subjective correction for blade-slap can be applied only on the rise of the time-history (as shown in Figure 2). The net effect is more an increase in duration and not a straight addition to the peak level as in other attempts to qualify the subjective effects. The correction is applied at half-second intervals. To bring this computation within bounds, this was applied to the interval between the initial 10 dB down point and the peak level of the time history, and the curve extrapolated back to the point where the A weighted sound pressure level + the subjective correction was 10 dB below the peak level.

We believe this Westland impulsive correction to be the most appropriate extant for this type of noise. It is understood that this correction procedure is now under deliberation by the International Standards Organisation for a standard on helicopter noise - to be issued shortly.

It must be stressed that by using a subjective correction of any sort to a noise descriptor, one changes the nature of that descriptor and should therefore change the name as well. Internationally, the use of a noise equivalent level is gaining acceptance. In the United States, a night weighted equivalent level - the Day/Night Level L_{DN} - is in general use. For our studies of helicopter noise impact in the United States, based on this unit with a subjective correction, rather than to completely change the name of the noise descriptor we have, to save confusion, used the term Impact Weighted Day/Night Level IL_{DN}.

In an Air Installation Compatible Use Zoning study (AICUZ) usually the aircraft noise assessment employs only a few spot checks of noise level; the contours being predicted solely by the use of a computer program.

This incorporates a comprehensive file of source-noise reference data on the usual aircraft types - by category only - that are encountered at military airfields. Rarely are more than 9 categories used, often considerably less. Also, this reference data is exclusively for fixed wing aircraft, there being really no comparable noise data for rotorcraft. Indeed few programs can include rotorcraft except by assuming conventional propagation applies. With only one or, maybe, two exceptions, the programs cannot accomplish predictions in, and are not intended for, cases where helicopters form a significant part of the total traffic.

Bickerdike, Allen was, a short while ago, commissioned by the U.S. Navy to produce noise contours for bases where helicopters predominate. Of course, in order to get a true idea of the base data, a four season measurement study should be undertaken. But, all programmes - particularly for the Military - have time limitations and so measurements have to be confined to a short period only. Inevitably this has, in the past, become April or May, when it has been supposed that reasonably average sort of conditions for the year occur. One such study was for the Marine Corps Air Station (Helicopter) at New River North Carolina, and its outlying fields of Oak Grove and Camp Davis.

The Marine Corps Air Station is located in the designated West Base Planning Zone in the northwest area of Camp Lejeune. The air station occupies about 4700 acres to the south and east of the city of Jacksonville, North Carolina, with two outlying fields in the nearby "Boondocks" - a word actually originating in Camp Lejeune from marine operations in the Philippines.

For data acquisition at various locations, our main measuring systems consisted of a pair of Genrad 1933 Precision Sound Level Meters each feeding one channel of a Uher CR134 stereo recorder, and, in the dc mode, an Esterline Angus Miniservorecorder. One of the sound level meters was in the slow mode recording in 'A' weighted deciBels, the other in the impact mode was specially converted to accept a 50 micro-second rise time held to a 50 milli-second decay time operating in the 250 Hz octave band. The Uher recorder was also specially prepared so that with Maxell UD tape it was capable of capturing a 70 micro-second rise time in the frequency range 18 to 15,000 Hz. This type of system enabled an immediate determination to be made of the crest factor for each event at that location, related to dBA slow response, as well as providing recorded material for later analysis. Hindsight, however, showed that if a system is working the benefits of immediate 'viewing' are marginal - except of course to show that the system is working. A system comprising a Castle CS 192B Precision Sound Level Meter feeding the Uher recorder was found much more convenient and probably more accurate. Calibration was carefully maintained, of course, and a continual check of compatibility between the several systems used made by recording some events at each location with a Bruel and Kjaer 2209 and Nagra 4S recorder, and comparing the results in the slow mode - the Nagra and its Ampex tape had not been specially prepared to accept the 70 micro-second rise time.

In addition to noise recording, meteorological conditions at each location were measured - wind, temperature, humidity etc., - and this data used in conjunction with the macro data from the local meteorological station. Polaroid photography was used to determine the altitude of each helicopter, and radio contact maintained for details of speed and power setting. Also for future use, rough estimates of the ground impedance were made by the 'Free Field Method' (11).

In the laboratory, real time analysis was not possible, and the data analysis was accomplished using Bruel and Kjaer 2120, 2113 and 2209 + 1616 frequency analysing systems recording on B & K type 2305 level recorders. An oscillograph was used to check the crest factor determinations.

The primary aim of the measurement programme was to accumulate sufficient noise data on each of the various types of aircraft under each operational mode sequence, to allow typical noise event levels to be predicted within a reasonable confidence level at any position for any operational activity. For maximum accuracy and sensitivity the majority of recordings were made in relatively close proximity to the source aircraft, and this meant most were in the air base confines. A second purpose was to measure actual events encountered in adjacent areas and on cross-country routes to act as corroborative tests of the levels predicted for such areas.

Since it was quite impracticable to obtain data on all the types of aircraft in use at these bases, the 4 main types comprising 84% of all helicopter movements were selected. Lateral and longitudinal traverses were made of the initial part of the flight envelope, as well as a complete traverse of the base itself to obtain the effects of engine testing and maintenance operations and to delimit the effects of the various barrier buildings and obstacles on base. A large number of measurements were made in the nearby city, but at no time was the helicopter noise in the same order as that from the surface transportation.

Observations.

The directionality of the impulsive blade-slap and the overall strange propagation was very noticeable. In particular, this region has many small drainage ditches and inevitably the noise recorded on the far side would be greater than that on the near side. We can give no explanation for this. Also, on base for low altitudes of rotorcraft (50 feet or so) noise levels at 800 feet laterally were often well in excess of those at 200 feet and 400 feet. This can perhaps be explained by the directionality of the pulse and the effects of fuselage shielding. With a helicopter bearing towards, but a few degrees off, the wind direction the main noise event may be completely to one side of the track. However, with no wind, by taking into account the directionality of pulse and the shielding, it has been found that a reasonable prediction can be made. A derivative of the British Noise Model has been adapted to utilise this data and performs well provided the wind can be assumed zero. Just a little wind and things are not so good at all.

The contours produced for New River and shown in Figures 3 and 4 being the true L_{DN} and the Impact corrected L_{DN} respectively. Where barriers occurred on the base, much weight was given to interpolation of measured values rather than predictions for no satisfactory theory for the passage of such a noise over a barrier has yet been devised (we believe).

Figure 5 shows the contour for Camp Davis. It is interesting to note that at one point this contour is actually outside the track. This is due to the large majority of flights by the CH46, which in a bank produces an extremely lop-sided impact noise footprint.

A selection of some of the data recorded is given in tables 1-1 to 1-4.

This work was supported by the United States Navy Southern Division under contract No. N62467-76-C-0860. Their permission to present this paper is acknowledged.

This paper was presented at the Annual Meeting of the CAA, Halifax, Nova Scotia, November 1978.

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BLADE-SLAP IMPULSE CORRECTION

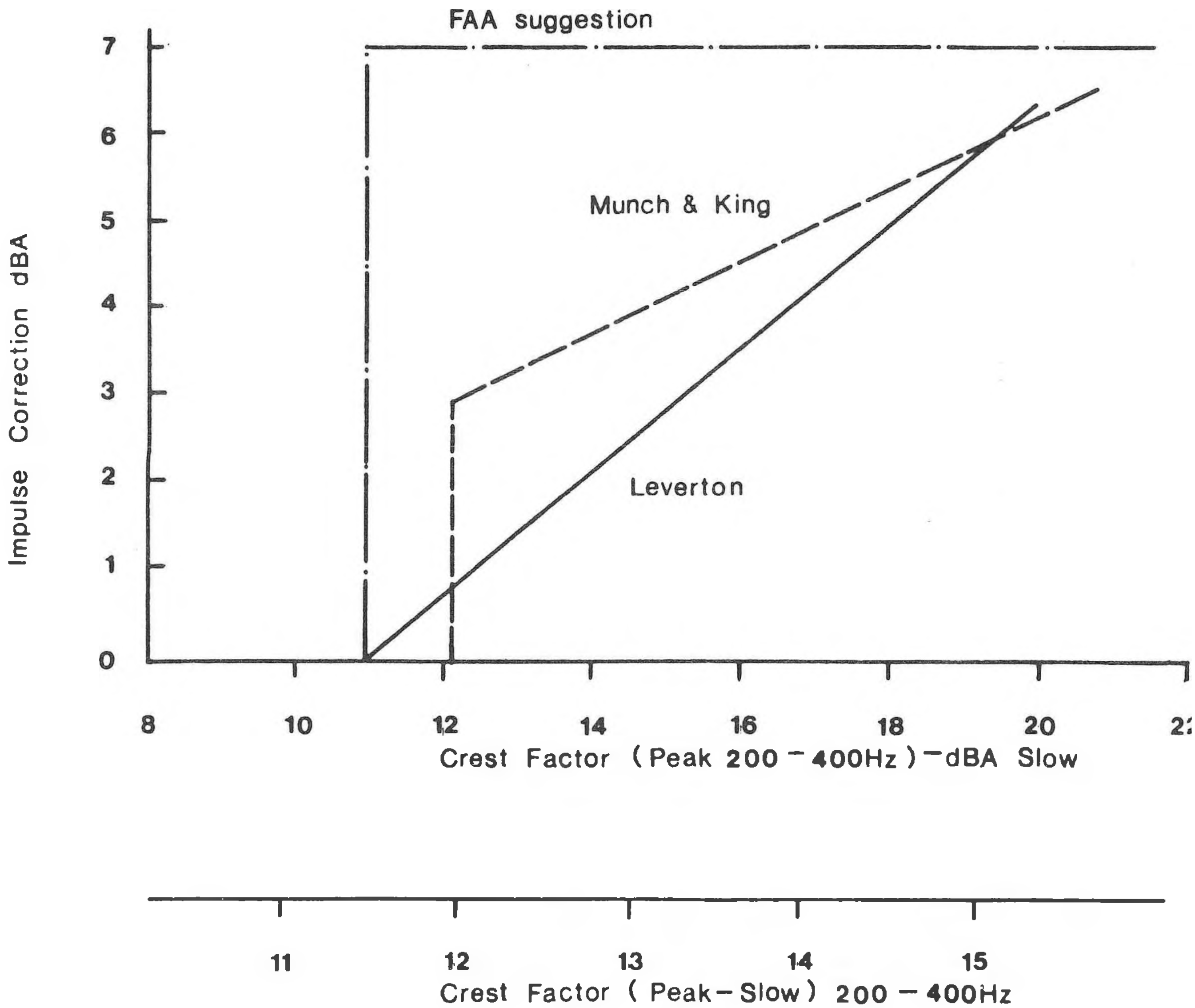


FIGURE 1

EXAMPLE OF IMPACT CORRECTED dBA TIME HISTORY FOR A HELICOPTER OVERFLIGHT

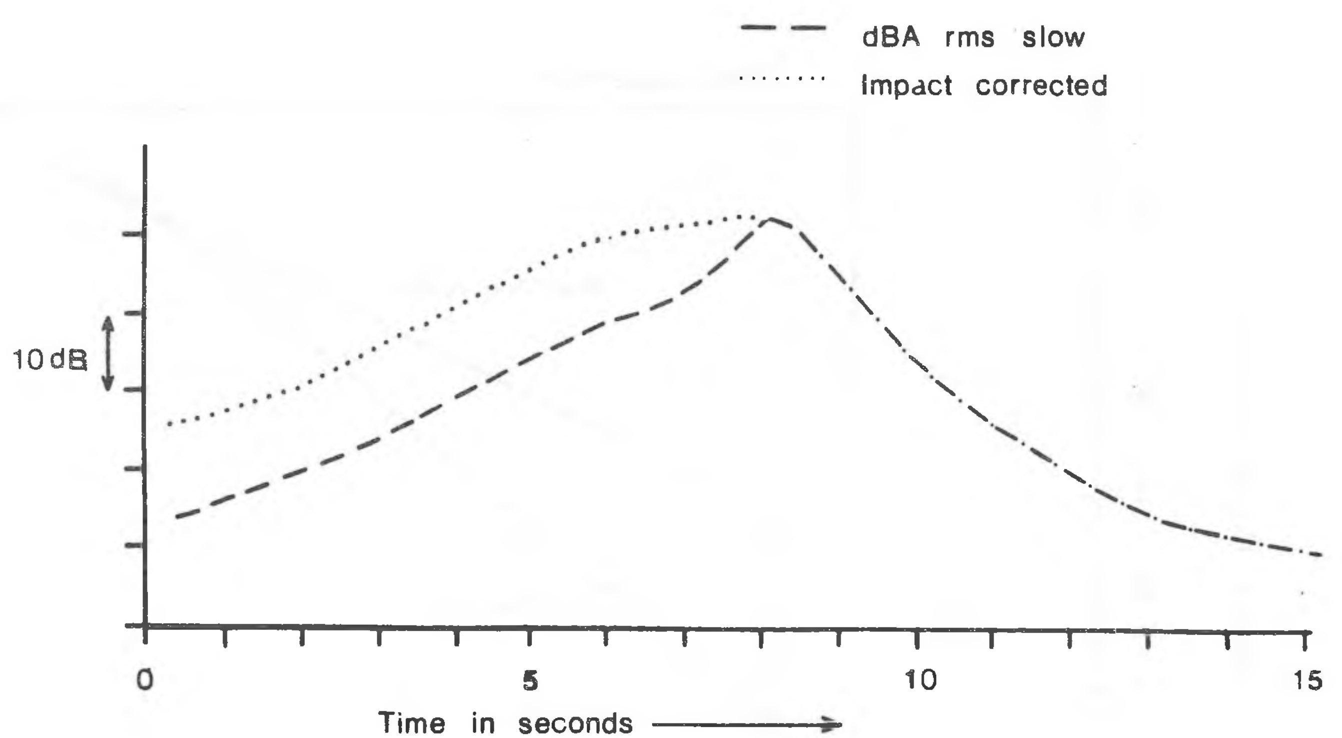
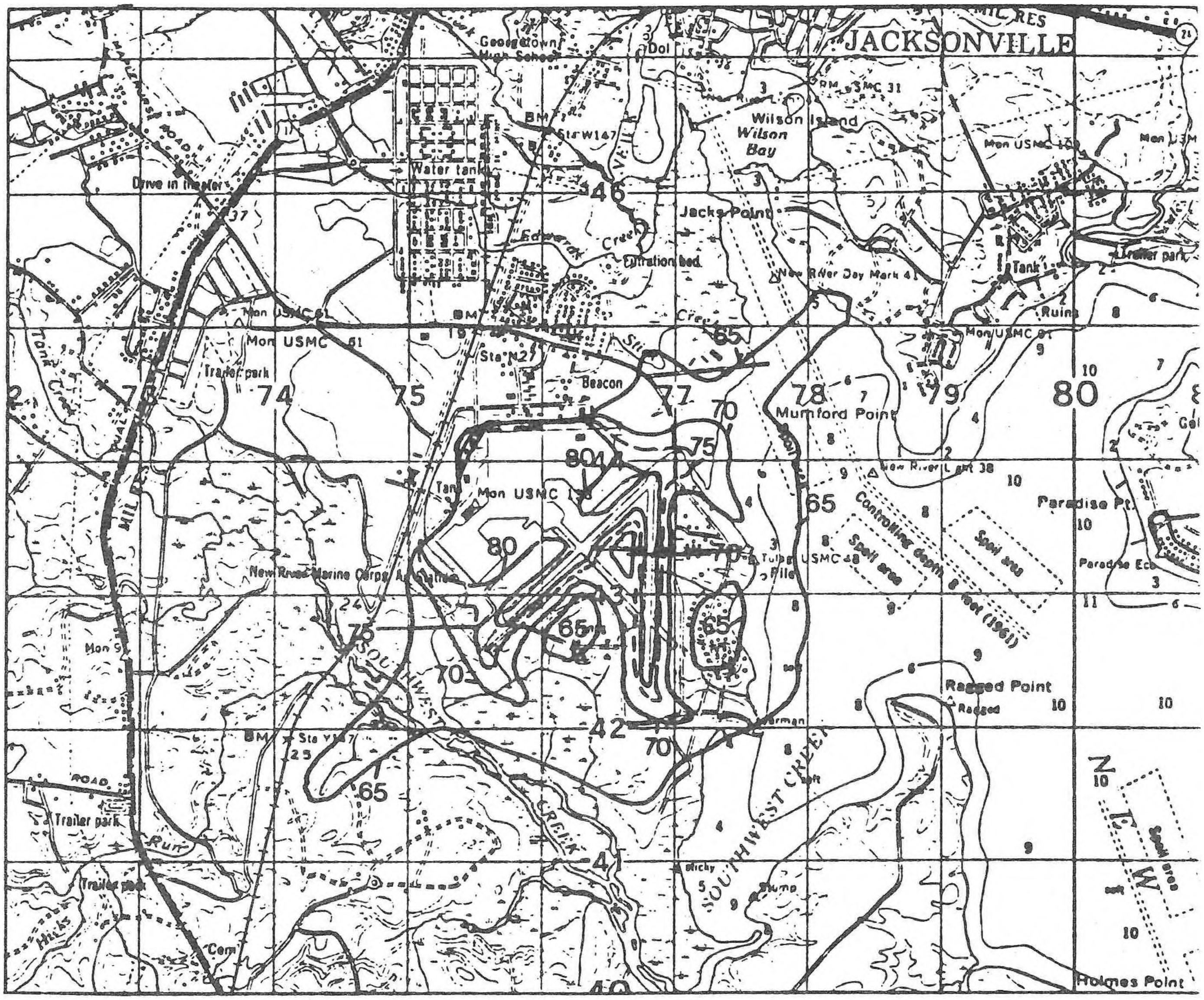


FIGURE 2

New River Marine Corps Air Station.

True L_{DN} 1977



Scale 1:50,000

Figure 3

New River Marine Corps Air Station (Helicopter)

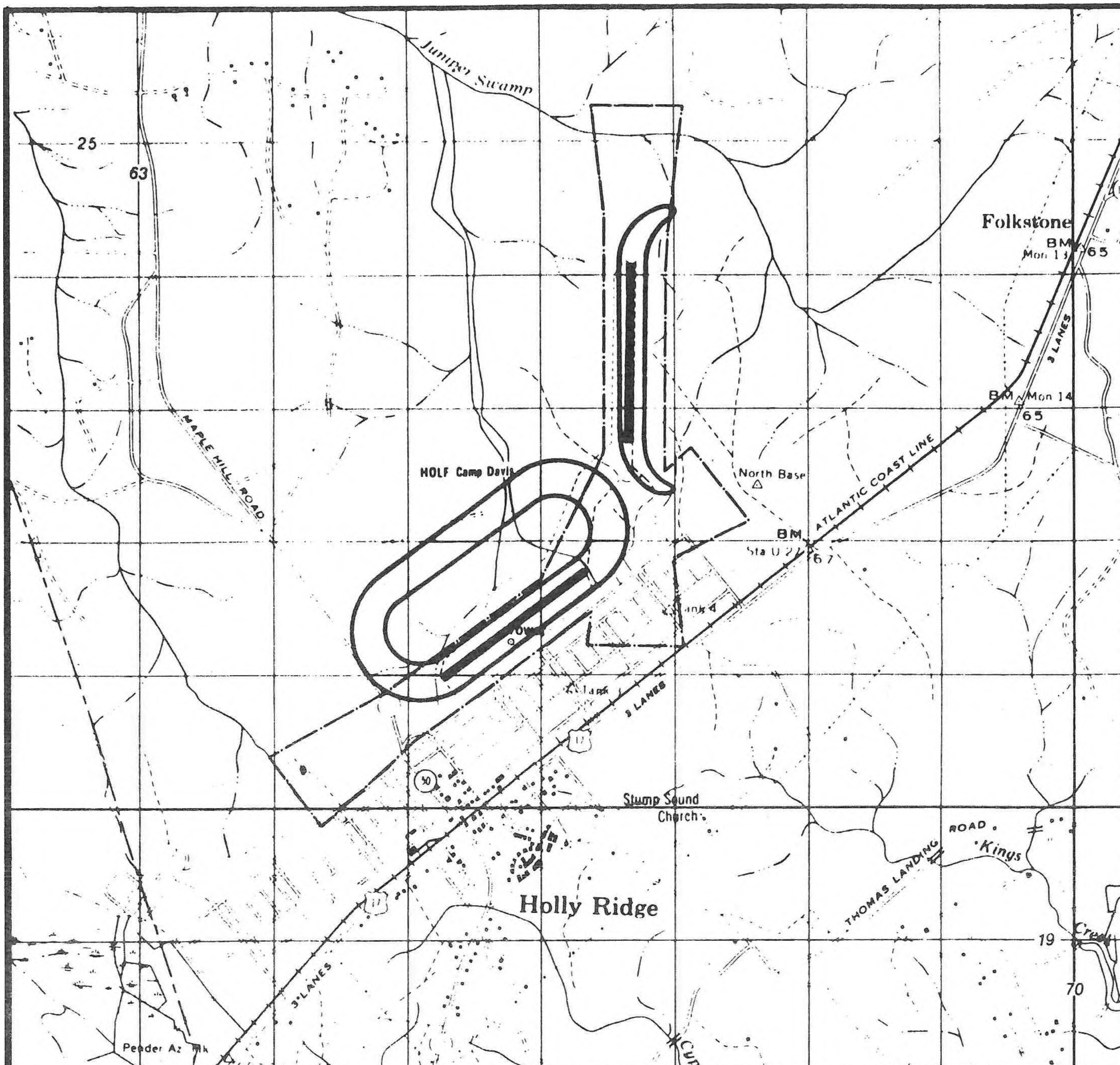
Impact weighted L_{DN} at 4'6"   1977

Scale 1:50 000

0 1 2 3 4 5 6 7 8 9 10

thousands of feet

Figure 4



Noise Contour Map

Impact Weighted L_{DN} 1977

Zone 2 (65-75 L_{DN})

Station Boundary

0 2,000 4,000 FEET

Figure 5

Exhibit 9B

HOLF CAMP DAVIS, NC

Table 1-1 Representative Single Event Noise Levels. dBA

Maneuver: Level Flight

Temperature °F		R.H.	Wind		Ground Imped. estim. 3 - 9i			
ground	500ft				Roughness length estim. .005m			
77	66	55%	Not signif		Skies: Clear			
Aircraft	Hor.dist	Slant ht	Track	Bearing	Speed	Crest	SEL	SEL_{Imp}
CH46	0	500	230	-	240	20+	94.6	98.8
	800	950	230	320	ft/s	20+	90.9	95.4
	1600	1690	230	320	240	20+	85.4	90.5
	0	1000	230	-	240	20+	90.6	95.2
	800	1300	230	320	240	20+	89.2	94.2
	1600	1900	230	320	240	20+	86.9	92.2
CH53	400	640	230	140	250	11-	92.3	92.3
	800	950	230	320	250	11-	89.6	89.6
	1600	1700	230	320	250	11-	83.4	83.4
	400	1080	230	140	250	11-	88.7	88.7
	1600	1900	230	320	250	11-	84.8	84.8
UH1N	0	500	230	-	180	20+	95.6	100.4
	800	940	230	320	180	20+	92.7	97.8
	1600	1670	230	320	180	20+	87.8	93.1
AH1J	400	570	230	140	300	20+	93.0	97.7
	800	895	230	140	300	20+	90.3	95.6
	800	940	230	320	300	20+	89.9	95.2
	3200	3240	230	320	300	20+	78.1	83.5
OV10	0	500	180	-	290		92.0	92.0
	800	950	180	090	290		88.5	88.5
	1600	1680	180	090	290		82.3	82.3
	0	1000	180	090	290		87.8	87.8
	800	1280	180	090	290		85.6	85.6
	1600	1890	180	090	290		81.8	81.8

Hor.dist: feet

Slant ht: feet

Crest: At 10dB down

Table 1-2 Representative Single Event Noise Levels. dBA.

Maneuver: Level Flight

Temperature °F		R.H.	Wind	Ground Imped. estim. 4 - 11i
ground	500ft			Roughness length estim. .00005m
80	66	58%	Not signif	Skies: Clear

Aircraft	Hor. dist	Slant ht	Track	Bearing	Speed	Crest	SEL	SEL_{Imp}
CH46	0	490	270	-	240	20+	97.4	101.5
	400	630	270	360	ft/s	20+	95.8	100.1
	800	930	270	360	240	20+	93.6	98.1
CH53	0	500	270	-	250	11-	96.5	96.5
	400	640	270	360	250	11-	94.8	94.8
	800	940	270	360	250	11-	92.1	92.1
AH1J	0	490	270	-	300	20+	96.2	100.3
	400	650	270	360	300	20+	94.7	99.5
	800	950	270	360	300	20+	92.3	97.7
CH46	400	640	090	360	240	20+	95.3	99.7
	800	940	090	360	240	20+	93.0	97.6
	400	1100	090	360	240	20+	92.7	97.5
	800	1300	090	360	240	20+	91.8	96.9
CH53	400	1100	090	360	250	11-	91.5	91.5
	800	1300	090	360	250	11-	90.2	90.2

Hor. dist: feet

Slant ht: feet

Crest: At 10dB down

Table 1-3 Representative Single Event Noise Levels. dBA.

Maneuver: Climbing turn

Temperature °F		R.H.	Wind	Ground Imped.estim. 3 - 9i
ground	500ft	55%		Roughness length estim. .005m
77	66	55%	Not signif	Skies: Clear

Aircraft	Hor.dist	Slant ht	Track	Bearing	Speed	Crest	SEL	SEL_{Imp}
CH46	0	300	left	-	Not assessed	20+	97.6	102.6
	400	510	turn	inside		20+	95.6	100.5
	800	850		turn		20+	91.4	96.4
	400	490		outside		20+	94.6	99.5
	800	850		turn		20+	90.0	95.2
	800	900		inside		20+	92.0	97.3
	800	900		outside		20+	90.8	95.9
	800	850	right	inside		20+	93.0	98.7
	800	850	turn	outside		20+	90.4	95.3
CH53	0	300	left	-		11-	97.6	97.6
	400	500	turn	inside		11-	95.0	95.0
	800	850		"		11-	90.2	90.2
	400	500		outside		11-	94.0	94.0
	800	850		"		11-	88.8	88.8
	800	900		inside		11-	90.8	90.8
	800	900		outside		11-	89.7	89.7
UH1N	0	290	left	-		11-	97.9	97.9
	400	500	turn	inside		11-	96.2	96.2
	800	850		"		11-	93.0	93.0
	400	500		outside		11-	95.6	95.6
	800	850		"		11-	91.7	91.7
	800	900		inside		11-	93.8	93.8
	800	900		outside		11-	92.6	92.6
AH1J	0	300	left	-		11-	96.8	96.8
	400	490	turn	inside		11-	94.7	94.7
	800	850		"		11-	90.4	90.4
	400	510		outside		11-	93.7	93.7
	800	850		"		11-	89.4	89.4
	800	900		inside		11-	91.1	91.1
	800	900		outside		11-	90.0	90.0
	800	850	right	inside		11-	89.9	89.9
	800	850	turn	outside		11-	89.1	89.1
	feet	feet				At 10dB down		

Table 1-4 Representative Single Event Noise Levels. dBA

Maneuver: Approach

Temperature °F		R.H.	Wind		Ground Imped.estim. 3 - 91			
ground 77	500ft 66	55%	Not signif		Roughness length estim. .005m Skies: Clear			
Aircraft	Hor.dist	Slant ht	Track	Bearing	Speed	Crest	SEL	SEL_{Imp}
CH46	0	400	050	-	Not assessed	20+	95.9	101.1
	400	570	050	140		20+	93.9	99.6
	1600	1650	050	140		20+	85.0	91.0
	400	570	050	320		20+	93.8	99.7
	1600	1650	050	320		20+	85.1	91.4
	0	200	050	-		20+	100.0	105.0
	400	450	050	140		20+	95.3	100.8
	800	825	050	140		20+	90.0	95.8
	400	450	050	320		20+	95.1	100.8
	800	825	050	320		20+	90.0	96.0
CH53	0	400	050	-		11-	95.6	95.6
	400	570	050	140		11-	93.2	93.2
	1600	1650	050	320		11-	83.1	83.1
	0	200	050	140		11-	100.4	100.4
	400	450	050	140		11-	94.8	94.8
	1600	1610	050	320		11-	82.2	82.2
UH1N	0	400	050	-		13	96.1	97.6
	400	560	050	140		14	95.0	96.8
	800	890	050	320		14	92.9	94.9
	0	200	050	-		16	99.7	103.3
	400	450	050	140		17	96.1	100.0
	800	820	050	320		17	91.6	95.8
AH1J	0	400	050	-		13	94.4	96.2
	400	570	050	140		14	93.0	95.0
	800	900	050	320		15	90.3	92.5
	0	200	050	-		16	99.2	103.0
	400	450	050	140		18	94.4	98.5
	800	820	050	320		18	89.0	93.3
OV10	0	400	180	-			92.0	92.0
	800	890	180	270			86.3	86.3
	0	200	180	-			97.8	97.8
	800	820	180	270			87.0	87.0
	↑ feet	↑ feet				↑ At 10dB down		

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