noise notes volume 5 number 4

# in this issue…

# Acoustical Standards for Classroom Design Comparison of International Standards and Low Frequency Criteria

***Jack B. Evans, P.E.,***
*JEAcoustics 1705 West Koenig Lane Austin, Texas, 78756 USA*
*Evans@JEAcoustics.com*

Many countries have acoustical standards or regulations for educational facility design and construction. They are based on speaking and hearing abilities of teachers and learners. Criteria are often stipulated for reverberation decay time, sound isolation and allowable background noise. The standards may use single number A-weighted overall level descriptors (dBA), or octave band spectrum criteria (NC, RC, NR, etc.). A-weighted overall level criteria control mid- to high frequencies better than lower frequencies. Very few, if any countries specify low frequency noise standards, although limitations are implicit in spectrum criteria curves, such as (North American) Noise Criteria (NC) or Room Criteria (RC) or (European) Noise Rating (NR). Many educators focus on mid- to high-frequency effects on speech intelligibility, but low frequency noise (LFN) may cause some (upward) masking of speech with reduction of intelligibility. In addition, LFN may affect student attitudes, behaviour, performance and/or fatigue. This paper compares acoustical criteria from several countries with respect to spectrum. Frequency spans or reverberation, sound isolation and background noise are contrasted with hearing and speech characteristics of children and adult learners. Principal findings of some LFN research by others are introduced, such as annoyance, speech intelligibility and fatigue. Tabular comparisons of acoustical criteria and graphic charts of representative criteria will be presented. General recommendations are made, based on findings inferred from review and comparison of standards.

## 1. INTRODUCTION

Many countries have established acoustical standards or regulations for teaching facilities. Some are voluntary, others are mandatory, but all require the cooperation of the national or local educational systems that own classroom facilities, the architectural and engineering designers, the builders, and the facility operators. Acoustical criteria for classrooms in some countries have evolved as extrapolations of normal building acoustics standards or regulations, but in a trend of recent years that continues today, many other countries are modifying or establishing criteria to accommodate the special needs of children. Numerous behavioural studies have shown that children are more adversely affected that adults by noise and reverberation, and physiological data indicate that children's central auditory pathways are maturing well into adolescence.[1] Newer classroom acoustical standards are based on results of physiological, speech perception and other studies of young students.

## 2. CHILDREN'S LISTENING AND LEARNING ISSUES

In a review of works by others, Nelson[1] highlighted theories for adult/child differences. Issues affecting children include: 1) inefficient listening strategy, 2) inability to put together missing pieces, 3) immature weighting of acoustic information, 4) increased susceptibility to distractions, and 5) decreased ability to segregate signals from noise. Other research by Flavell, Evans etc., summarized in ANSI S12.60, Appendix A[2], has focused on speech intelligibility as a function of reverberation and correlations with signal-to-noise ratio (SNR), the essence being how loud speech is relative to the background noise. Intelligibility increases as the speech level increases, the background noise decreases, or a combination. Speech perception research has shown that individuals with hearing impairment, speech and language disorders or limited language proficiency require improved SNR[1]. Children, as a group, share these characteristics. Nelson listed four primary sources of noise in classrooms: 1) building services and utilities, including HVAC, 2) exterior noise transmitted through the classroom building envelope, 3) interior noise transmitted through partitions, floors, ceilings, ventilation ducts, etc., and 4) noise generated within the classroom by occupants and classroom equipment. Other studies can be found on classroom acoustics and characteristics of learners leading to similar results as the Nelson[6] Paper.

For practical reasons, research studies tend to focus on specific parameters (to simplify research, variables are limited). Speech perception and understanding may be evaluated based on the distance between speaker and listener, background noise, or reverberation, etc. If any single number descriptor is used, it is usually only in terms of an A-weighted sound. Since A-weighting is based on normal hearing characteristics for humans at moderate sound levels, it would seem to be ideal; however, the single-number descriptor dos not provide information about spectral or tonal characteristics. Speech intelligibility can be affected by broadband noise, including LFN, by temporal changes, (i.e. off/on or time-varying level), by tonal noise and by information-bearing content. Therefore, hidden variables relation to spectrum differences may influence some results, without researchers recognizing, acknowledging or accounting for those differences. The aggregate results of other studies tend to converge on similar findings. An in-depth review and comparison by Crandell and Smaldino[3], comparing speech recognition for normal and hearing impaired children, discussed several acoustical variables in classrooms. The study compared the variables with respect to noise effects on student and teacher performances, including background noise, SNR, speaker-to-listener distance and reverberation time. The combined effects of noise and reverberation were documented to be greater than the sum of the independent effects. Except for upward masking discussed below, the effects of low frequency noise (LFN) were largely ignored.

Continuous lower frequency noises, (i.e. heating and air conditioning system noise) can effectively create speech intelligibility interference because of the "upward spread of masking," referring to the increased masking effect on signals at higher frequencies than that of the noise. Continuous noise sources more effectively mask speech than interrupted noise sources[3]. Of the four most common primary noise sources in classrooms, identified by Nelson, above, two are (a) continuous building system noise, which is often low frequency dominant and (b) intrusive noises from the exterior which might include low frequency noise of traffic, aircraft or stationary outdoor mechanical equipment. For these reasons, LFN should be specifically considered in the design of new classroom or facility renovations.

Avoidance of teacher stress and fatigue is another reason to limit background noise and reverberation. Remarking on studies by Smith[4] and Knecht[5], Nelson[6] discusses teachers who must speak at elevated volumes and report vocal strain and health concerns. "Smearing" of speech signals by reverberation aggravates those problems. Improved SNR can be achieved with quieter voice levels when the background noise is more moderate.

Therefore, effective use of acoustically absorptive building materials can improve speech clarity, while reducing background noise incrementally, via room effect. Of course, the room effect may also attenuate teacher voice noise as well, but where the teacher-to-student distance is less than the distance from mechanical, HVAC or exterior intrusive noise sources, the student listener benefits.

The documented differences between children and adult learners provide a substantial basis for the acoustical standards and regulations that exist. As shown in the comparison tables below, most acoustical criteria in classroom standards for background noise are A-weighted. Also, sound transmission criteria, such as STC, R'w, or similar curve-fit descriptors are typically limited to frequencies between 125-4000 Hz, while reverberation decay times are generally listed for mid-frequency octaves (speech frequencies). The various classroom standards and regulations doe not specifically refer to lower frequencies, except for the occasional C-weighting for noise. This lack of LFN control limits effectiveness of standards.

*Table I: Allowable Background Noise*

| COUNTRY* | Date | Type | Descriptor | Criterion | Low Freq. |
|---|---|---|---|---|---|
| Australia and New Zealand | | Standard, AS/NZS 2107:2000 (non-mandatory) | A-wtd Leq | 35-45 (max) | |
| Belgium | 1987 | Standard | A-wtd Leq | 30-45, re: extr. | |
| Chile | | | N/A* | | |
| Denmark | 1995 | Bygningsreglement | A-wtd Leq | 35 | |
| Egypt | | | N/A* | | |
| France | 1995 | Decree | A-wtd Leq | 33, 38 | |
| Germany | 1983 | Standard | A-wtd Leq | 35-40 | |
| Italy | 1975 | Std, UNI 8199 | A-wtd Lmax | 36 | |
| Netherlands | | Guideline, NEN5077 | A-wtd Leq | 30-35-40 | |
| Poland | 2002 | Standard PN-87/B-02151/02 | A-wtd Leq | 35 (building equipment) 40 (other sources) | |
| Portugal | 2002 | Decree, 129/02 | A-wtd Leq | 43 (non continuous) 38 (continuous) [+3 dBA margin] Libraries 38/33 +3 | |
| Spain | | | N/A* | | |
| Sweden | 2001 | Standard | Leq | 26-40 | |
| Turkey | 1986 | Regulation, (New standard proposed, but not yet published as of Feb 2005) | A-wtd Leq | 45 | |
| UK | 2004 | Std, Building Bulletin 93 | A-wtd Leq, 30 min | 35 | |
| USA | 2002 | Standard, | A-wtd 1 H aug | 35-40 | dBC≤(dBA+20) |

N/A* International colleagues provided information that neither standard, nor regulation, nor enforced law exists or is used within the country.

*TABLE II. Allowable Reverberation Decay Time*

| COUNTRY | Date | Type | Descriptor | Criterion+ | Low Freq. |
|---|---|---|---|---|---|
| Australia/ New Zealand | 2000 | Standard | A-wtd Leq | 0.4-0.6 sec. | |
| Belgium | 1987 | Standard | A-wtd Leq | Varies w/size | |
| Chile | | | N/A* | | |
| Denmark | 1995 | Standard '95 | Seconds | ordinary classroom (octave bands) | 125-2000 Hz 0.9 sec ± 0,2 sec in any octave band Spec classes 0.6 sec ± 0,2 sec |
| Egypt | | | N/A* | | |
| France | 1995, 2003 | Decree | Seconds | 0.4-0.8 sec. Shops: 3dB/doubling of distance | 0.5kHz/1kHz/2 kHz Shops:250 Hz - 4kHz |
| Germany | | DIN 18041 (d)'03 | 0.3, 0.45, 0.55 | | |
| Italy | 1975 | Standard | | | |
| Netherlands | | Guideline, NEN5077 | Seconds | 0.8 sec | |
| Portugal | 2002 | Decree, 129 | Seconds (avg.:0.5k/1k/2k Hz) | 0.15*Vol^(1/3) [±25% margin] | Decree, 129/2002 |
| Sweden | 2001 | Std, SS02 5268 | Seconds | 0.5-0.6 sec. | 250 Hz-4 kHz |
| Turkey | 1986 | Regulation | | | |
| UK | 2004 | Std, BUILDING BULLETIN93 | Seconds | 0.4-0.6-0.8 sec. | |
| USA | 2002 | Standard | | 0.6-0.7 sec | 0.5k/1k/2K Hz |

N/A* International colleagues provided information that neither standard, nor regulation, nor enforced law exists or is used within the country.
± Multiple time spans are for varying conditions, age groups or room types.

## 3. REVIEW OF STANDARDS AND REGULATIONS

Many countries have established acoustical criteria for classrooms and other learning facilities. These criteria are either extrapolated from building noise regulations by adapting for speech intelligibility in classrooms or are specifically developed for the hearing and speech characteristics of students and teachers.

Public policies regarding acoustical standards are dynamic. It is difficult to acquire comprehensive and up-to-date information. The information presented above admittedly has gaps. Trends become apparent, however, with limited information. Most countries specify maximum allowable A-weighted background noise. The ANSI S12-60 in North America provides for a maximum difference between dBC and dBA as a secondary, low frequency criterion. Lower frequency reverberation criteria are unusual (re: LFN build-up). Some standards, such as the Building Bulleting 93 in UK mention low frequency reverberation for auditoria. Sound isolation criteria are based on the limited, mid-frequency spans of STC or R'w.

Background noise (Table I), Reverberation decay time (Table II), and Sound Isolation (Table III) acoustical criteria are discussed below with supplemental LFN notes. As of the later part of 2004, acoustic colleague around the world responded with the following criteria (some updates were added in the summer of 2005).

*TABLE III. Sound Isolation (Internal)*

| COUNTRY | Date | Type | Descriptor | Criterion | Low Freq. |
|---|---|---|---|---|---|
| Australia/ New Zealand | | | N/A* | | |
| Belgium | 1987 | Standard | R Dn | 25-49 | 100-3150 Hz |
| Denmark | | ISO 140 | R'w | 48 dB horizontal<br>51 dB vertical<br>(music 60 dB) | |
| Egypt | | | N/A* | | |
| France | 1995, 2003 | Decree | DnTA | 44 Room, 28 Corr. | 125 - 4000 Hz |
| Germany | 1989 | DIN 4109 | R'w | 47 | |
| Italy | 1975 | Standard | R, D | 40 | |
| Netherlands | | Guideline+, NEN5077 | $I_{lu}$+ and $I_{lukk}$ (Unique Dutch) | (Reference Value) = 0 dB | |
| Portugal | 2002 | Decree, 129 | Interior: Dn, w<br>Exterior: | 45 Room,<br>30 Corr<br>± 3 dB margin | Decree, 129/2002 |
| Sweden | 1996 | Std, SCBR94 | R'w | 48 | |
| Turkey | 1986 | Regulation | | | |
| UK | 2004 | Std, BUILDING BULLETIN93 | DnT (Tmf,max)w | Varies | source vs rcvr |
| USA | 2002 | Standard | STC | 50 | 125- 4000 Hz |

N/A* International colleagues provided information the neither standard nor regulation, nor enforced law exists or is used within the country.
+ Dutch Standard explained: Single value based on measured spectrum differences between a source room and a receiver room. The spectrum difference is compared to a reference curve. This comparison leads to a single value. A value Ilu = 0 means that the reference value is met. A $I_{lu}$ = 10 means that the isolation is about 10 dB better than the reference curve. This method is copied from ISO 717. The "k" in the index means "characteristic". This means that the isolation value is independent of the dimensions of a room. So, it doesn't matter if the room is big or small, the isolation-index will be the same.

0For standards that vary over time. Marc Asselineau (email to author, 12/28/2004) gave insight into the relation between law text for different countries and changing standard. He mentions that law text should reference the relevant standards of the time, as opposed to hard written into the law. That way when a standard is updated, then the law text needs not be updated. For example, when the new European Standardization comes out, the standard would become law instead of each country having to rewrite the law text.

## 4. LOW FREQUENCY NOISE EFFECTS ON HUMANS

Low frequency noise effects on adults have been researched and reported on by many, but LFN effects on children appear under-researched. Can findings of research on adults be applied to children? Should extrapolation of conclusions from adult studies affect public policy or implementation of classroom acoustics regulations?

An interesting study by Dockrell and Shield[7] focuses on school children's (6-7 and 10-11 years old) awareness and perception of noise at home and in school. Annoyances from various noise sources are documented, including distractions and speech interference difficulties that affect students' ability to hear and understand teachers. Other findings may illuminate the effects of low frequency noise. Interestingly, the level of noise may not be the key factor in annoyance. In the study, trains motorbikes, trucks and sirens were rated as most annoying, while wind in tree noises were least annoying. The higher the external noise recorded, the less likely children reported hearing their teachers. This study recorded exterior sound levels in A-weighted Leq and Ln, but no spectral analysis measurements were made. Therefore, comparisons among specific low-, mid- or high-frequency noises have not been made. Pulling from additional studies including Haines et al,[8] Dockrell and Shield[7] noted that of the four "worst" noises, three are low-frequency dominant, including aircraft noise. While specific conclusions were not drawn relative to similarities between adult and children's noise perceptions, the children and teachers reported hearing similar noise sources in the classrooms. With future research, could the source(s) of annoyance be correlated with tonality and temporality of noise, and perhaps, specifically with low frequency intrusions?

It is difficult to draw many conclusions about low frequency noise effects on children, because so much research is documented only with single number descriptors to represent overall noise level. Bruel[9], in 2001, presented a historical reminder of the origins and proper use of A-weighted sound levels, saying that it is wrong to use A-weighting for levels over 50-60 dBA. This is because the A-curve was developed only for low level noise. Consequently, comparison of equal loudness hearing contours and subjective testing have shown that A-weighting underestimates the lower frequencies by increasingly greater amounts as the frequency is lowered.

Studies have been done on adult subjects that show correlations among noise spectrum, annoyance, task performance, learning behaviour. Some of these studies also illustrate the inadequacy of the A-weighted measurement when considering noise effects on humans.

Persson Waye, et al., [10] carried out a study to investigate effects of low frequency noise on performance. Subjects carried out similar tasks in a controlled noise environment with relatively flat spectrum meeting NC-35 and in a low frequency dominated spectrum that was also NC-35. The second spectrum was different from the first only in the 31 - 125 Hz octaves, where the low frequencies were significantly louder. The A-weighted levels of the two spectrums were only 1 dB apart, because the A-weighting curve so deeply attenuates very low frequencies (See Fig. 1 and Fig. 2). The study showed greater annoyance, decreased performance, and longer response times on tasks in the LFN environment. There were also unconfirmed indications of fatigue effects.

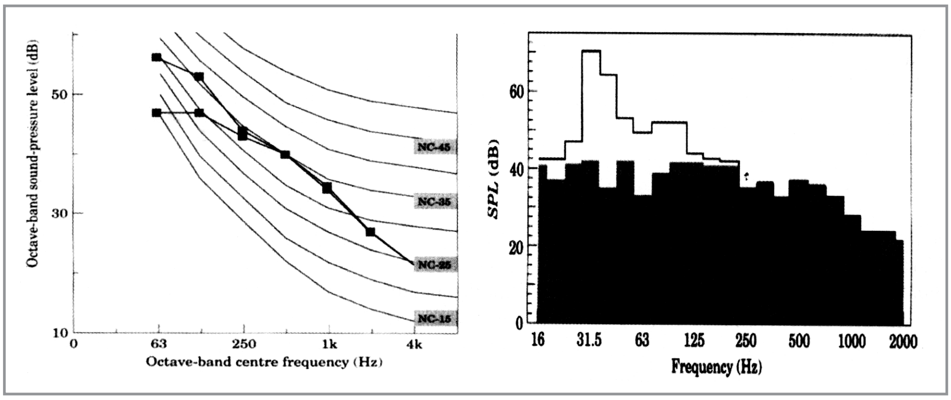


*Figure 1. and Figure 2. Octave-band (at left) and one-third Octave Band (at right) used in Persson Waye, et.al. Both figures display 45 dBA Broadband and 46 dBA Low Frequency spectra that are NC 35.*

A later study by Bengtsson, Waye, et al.[11] investigated the fatigue factor. Five different tests of performance and learning were conducted on subjects; in two environments with equivalent NC and A-weighted levels. One environment had significantly greater low frequency noise. The conclusions stated that LFN impaired performance on tasks sensitive to tiredness. Interestingly, no significant effects were found on motivation related variables.

Other studies on the effects of low frequency noise on humans can be found in the literature. The review in 2003 by Leventhall et al.[12] of published research, covers many aspects of LFN, including objective effects, annoyance, behaviour, performance, social attitudes and stress. In the research study, the difference between A-weighted and C-weighted noise as an indicator of low frequency content is discussed as a predictor of annoyance. The only study in this review specifically referring to children (Ising and Ising,[13]), dealt with sleep interference from truck noise and the resulting problems with concentration and memory. Based on $L_C$ - $L_A$ analyses, Ising and Ising concluded that A-weighting is inadequate for low frequency noise at night and that safer limits are needed. Similar studies on adults contained in the review (Persson Waye, et al., 2003) reached similar conclusions. There are indications that the LFN effects on children are similar to those on adults, but few studies specifically compare or correlate responses of children and adults, and/or determine which LFN effects are similar and which are different.

## CONCLUSIONS

Studies on adults have indicated fatigue, performance, annoyance, behavioral, speech interference and other effects due to low frequency noise. Few studies have been done to document similar effects on children, although a significant body of research has established speech and hearing characteristics of children in broadband noise environments. Children require improved signal to noise ratios to achieve listening comprehension similar to adults. Good learning environments, however may involve other facets of performance beyond listening comprehension, including annoyance, fatigue and behaviour. Research should be undertaken to correlate low frequency noise effects on children and adults.

Standards for classroom acoustics should control low frequency noise. Criteria are generally expressed in A-weighted levels for noise, which can permit excess low frequency noise. Reverberation decay time criteria are generally prescribed for 500, 1K and 2K Hz, but not lower frequency octaves, thereby allowing greater reverberant build-up of lower frequencies. Sound isolation partitions, regulated by STC and R'w criteria, do not control sound transmissions below 100 Hz. With inadequate low frequency noise criteria, LFN affects on children may limit student performance in the classroom.

Based on these findings, it would be prudent to incorporate low frequency noise criteria in classroom acoustics standards for background noise, reverberation decay time and sound isolation. Use of C-weighting as a supplemental noise criterion, or prescribing a maximum difference between C-weighted and A-weighted measurements of noise could reduce LFN. Extending reverberation time criteria to lower frequencies could reduce the build-up of noise that reinforces LFN. Requirements for low frequency noise reduction through partitions and exterior walls could reduce the intrusion of building equipment room noise-or exterior noise into classrooms. These improvements would reduce upward masking of speech form LFN and possibly maintain better learning environments that are substantially free of annoyance, fatigue and behaviour problems.

## REFERENCES


1. Nelson, P.B. Tutorial Lecture: Children's Need for Favorable Acoustics in Schools *Proceedings 146th ASA*, J. Acoust.Soc. Am, Vol.114, No. 4, Pt. 2, Oct. 2003.

2. ANSI 2002. ANSI S12.60-2002, *Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools*, American National Standards Institute, N.Y., Acoustical Society of America.

3. Crandell, C.C. and Smaldino, J.J. (2000). Classroom Acoustics for Children With Normal Hearing and With Hearing Impairment, *Language, Speech, and Hearing Services in Schools, Vol.31*, 362-370, American Speech-Language-Hearing Association.

4. Knecht, H., et al. 2002. "Structural variables and their relationship to background noise levels and reverberation times in unoccupied classrooms." *American Journal of Audiology* 11:3.

5. Smith E., et al. 1998. "Frequency of voice problems among teachers and other occupations." *Journal of Voice* 12:480-488.

6. Nelson, P.B. 2003. Sound in the Classroom - Why Children Need Quiet. *ASHRAE Journal*, February 2003, 22-25, Atlanta: ASHRAE.

7. Dockrell, J.E. and Shield, B. (2004). Children's perceptions of their acoustic environment at school and at home, *J. Acoust. Soc. Am*. Vol.115(6), 2964-2973.

8. Haines, M.M. and Stansfeld, S.A. (2001). "A follow-up study on effects of chronic aircraft noise exposure on child stress response and cognition," Int. J. Epidemiol. Vol.30, 839-845.

9. Bruel, P.V. (2001). Is A-weighting of Noise Correct? *Proc. Inter-Noise 2001. The Hague, The Netherlands*, pdf: in01_774, CD Rom Ed. By R. Boone, I-INCE and NAG, Maastricht, 2001.

10. Persson Waye, K., Rylander, R., Benton, S. and Leventhall, H.G. (1997). Effects on performance and Work Quality due to low frequency ventilation noise, *Journal of Sound and Vibration* Vol.205(4), 467-47.

11. Bengtsson, J., Persson Waye, K., Rylander, Pr. And Kjellberg, A. (2001). Effects on tirdenss/Bengtsson and motivation after low frequency noise exposure during work. *Proc. Inter-Noise 2001, The Hague, The Netherlands*, pdf: in01_299, CD Rom Ed. By R. Boone, I-INCE and NAG, Maastricht, 2001.

12. Leventhall, G. L., Pelmear, P. and Benton, S. (2003). A Review of Published Research on Low Frequency Noise and its Effects, Report for DEFRA, Dept. for Environment, Food and Rural Affairs, London.

13. Ising, H., and Ising, M. (2002): Chronic cortisol increases in the first half of the night caused by road traffic noise. *Noise and Health* Vol.4, 13-21.


## ACKNOWLEDGEMENTS


The author wishes to express his appreciation to the following people for contributions of information pertaining to the "Review of Standards and Regulations" section of this paper.

Chris Field, Arup Acoustics, Sydney, NSW and Marion Burgess, Aust Defense Force Academy, Canberra, Australia

Dr. Jorge P. Arenas and Dr. Jorge Sommerhoff, Univ. Austral de Chile, Valdivia, Chile

Ole Holst-Jensen, Minus 10dB, Beder, Denmark

Mansour El Bardisi, Ain Shams University, Cairo Egypt

Marc Asselineau, Peutz & Associes, Paris, France

Reinhard O. Neubauer VDI, Building Physics and Acoustic Consultancy, Ingolstadt, Germany

Carel Ostendorf and Sylvia Crutzen, Cauberg-Huygen R.I., Maastricht, The Netherlands

Marianna Mirowska, ITB - Building Research Institute, Acoustics Department, Warsaw, Poland

A. P. Oliveira de Carvalho, Ph.D., Dep. Eng. Civil, Univ. Porto, Portugal

Alejandro Fernández Fernández and Dr. Isabel Lopez Barrio, Instituto de Acústica, CSIC, Madrid, Spain

Patrik Andersson, Department of Applied Acoustics, Chalmers University of Technology, Göteborg, Sweden

Dr. Gulin Birlik, Dept. of Engineering Sciences, Middle East Technical University, Ankara, Turkey

Dr Geoff Leventhall, Consultant in Noise Vibration and Acoustics, Ashtead Surrey, UK.

Professor Bridget Shield, Centre for Acoustics, School of Engineering Systems and Design, South Bank University, 103 Borough Rd SE1 OAA, London, UK

**OXFORD UNIVERSITY SEEKS CITY-WIDE NOISE INJUNCTION**

A High Court judge will visit Oxford's controversial animal testing lab before he decides if campaigners' protests should be curbed. The fight over Oxford University's bid to stop protesters using megaphones, other noise amplifiers and cameras started at the High Court in London early in April, but Mr Justice Holland said he will visit the site on May 2 before deciding the scope of any future injunction. The university last month won an interim injunction limiting protests of 13 named groups or individuals, including the lab opponents Speak and the Animal Liberation Front. The existing temporary injunction bans protesters from using whistles, klaxons, sirens, megaphones and any other form of noise amplification outside the animal research laboratory in South Parks Road only. The university wants to ban noise amplification tools across the city from being used by animal rights protesters. The University's lawyer, Charles Flint said: "Witness statements show, the conduct of the defendants has actually caused real distress and alarm to many people working in departments nearby and those using them. Threatening and abusive language has been used and combined with what Speak itself describe as a barrage of noise, has affected a number of people working in the area."

**DUTCH TEAM DEVELOPS "HEARING-GLASSES"**

A Dutch company has launched a hearing aid in the form of a pair of glasses. The "hearing-glasses", like the company, are called Varibel. To capture and relay sound to the ears microphones, signal processing and miniature speakers are contained in the arms of the frames. The hearing-glasses were originally developed at Delft University of Technology in the Netherlands. Varibel developed these glasses into a consumer product in partnership with Royal Philips Electronics. Many people aged over 60 use hearing aids to try and help cope with old-age hearing loss. However, with the loss of high-frequency discrimination simple amplification is not always beneficial. Many hearing aids intensify sounds from all directions and it is not always possible to hear others well if there is surrounding noise. A frequent complaint is that hearing aids often just make confusing noise louder and more annoying. Solutions to this problem, tried with in-ear digital hearing aids, include multi-microphone systems that provide tunable directionality so that a hearing aid has a preferred direction of sensitivity, usually tuned to be forward facing. In this way the hearing aid increases the sound from a conversation ahead of the user but reduces background noises.

**NOISE POLLUTION SUFFERERS GET UP TO W1.34 MILLION**

People suffering from various kinds of noise pollution will be able to receive up to 1.34 million won ($1,400) in compensation, according to the Korean National Environmental Dispute Resolution Commission. The commission has unveiled detailed standards for compensating for environmental damage to more effectively settle disputes between polluters and victims of a wide array of environmental pollution, including noise, water and air pollution. If a person is exposed to noise levels of over 70 decibels, they will be entitled to compensation ranging from 50,000 to 510,000 won, depending on the period of exposure. Individuals will also be able to receive up to 1.34 million won, should they suffer from noise higher than 100 decibels. According to the commission, people can apply for compensation when they are exposed to more than 70 decibels generated from construction sites and 65 decibels from roads and railways. Additionally, residents of apartments can get compensation if they suffer from noise over 50 decibels from their neighbours, while those raising livestock can take noise generators to the commission for compensation if their livestock was exposed to noise over 60 decibels. Those who suffer from 80 decibels of noise from construction sites can receive between 130,000 to 840,000 won per person in compensation. When exposed to noise over 90 decibels, one could get up to 1.34 million won in compensation. Regarding noise from roads and railways, a person can ask for a maximum of 510,000 won when suffering from noise levels of 65 decibels, and 1.18 million won for more than 85 decibels. The commission estimated that about 250,000 people are suffering from various types of noise pollution across the country, who could make claims against polluters for up to 220 billion won.