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contents

The Institute of Acoustics was formed in 1974 through the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society and is the premier organisation in the United Kingdom concerned with acoustics. The present membership is in excess of one thousand seven hundred and since 1977 it has been a fully professional Institute. The Institute has representation in many major research, educational, planning and industrial establishments covering all aspects of acoustics including aerodynamic noise, environmental, industrial and architectural acoustics, audiology, building acoustics, hearing, electroacoustics, infrasonics, ultrasonics, noise, physical acoustics, speech, transportation noise, underwater acoustics and vibration.

President's Letter

Dear Fellow Member

This is the first issue designed and produced entirely in the Institute's Office and so benefitting from the economies of computer-based typesetting technology.

You will recall that it is intended to publish six issues per year and to use this greater frequency to simplify the way in which information on the Institute's activities reaches the membership. The opportunity has been taken to revise the way in which the material is organised so it should now be easier for readers to find their way around.

It is envisaged that each issue will carry an invited review article offering an authoritative overview of the state of knowledge in a topic of general interest. It is also planned that the section entitled Technical Contributions will attract papers of good quality which will be subject to referees comments in the normal way.

Material for future issues can most conveniently be submitted as an ASCII or text file on a PC or Macintosh floppy disk, or else as typewritten text that can be electronically scanned.

I am pleased to bring to your attention the fact that the Institute, through its Underwater Acoustics Group in collaboration with the University of Bath, has published its first hard-back book. I am referring to Dr Stansfield's book on Underwater Electroacoustic Transducers for which the publication date was 1st February and sales are already very encouraging.

Acoustics '91, the 1991 Spring Conference and Exhibition incorporating the Institute's Annual Dinner and AGM is nearly upon us. This year there is a special session devoted to the memory of our Founding President, the late Dr R W B Stephens. I hope to see a high level of support for what is clearly an interesting and stimulating programme.

Best Wishes

Mike Auker.

Does Engineering as a Profession Exist in Europe ?

Marcel Guerin, Secretary General of FEANI*

Ingenieur, engineer, ingegnere, engenheiro... the root of the word engineer occurs in all European languages and, for that matter, in nearly all the languages spoken in the world. The word conjures up the image of a profession practised in all countries, and is associated with modern technological development. The query in the present article's heading, therefore, is unusual if not provocative.

Yet the question does arise: the profession's branches of activity in Europe are not exactly the same from one country to another. As for engineers themselves, defining their *profile* is a difficult task, so great are the differences in the training that makes up their backgrounds. Nevertheless, there is a need for cohesion: the strong support given to FEANI by its Member organisations, forty years after it was founded, proves the fact. Will this need be sufficient to sweep away the obstacles to unity?

Causes of division

The first difficulty to crop up when one conducts a study of the engineering profession is the definition of the engineer as a notion.

Countless formulas have been suggested. None is universally recognised. There is agreement, at least, on the statement that the engineer practises his calling in the field of applied science, and that to do so he must possess a knowledge of the basic scientific disciplines and of his own speciality, as well as some elements of general knowledge.

Divergences appear as soon as it comes to defining what is meant by *field of applied science*, and the nature as well as the range of knowledge required.

While all countries are willing to consider that Civil Engineering, Mechanics, Electronics... belong to the engineer's field of activity, the same can not be said of — for instance — Agronomy, Cartography, Meteorology, Biotechnics, Biochemistry. A list of such *atypical* domains is not easy to draw up.

We have here, therefore, obstacles to cohesion. Others spring from regulations governing the practice of the profession in several countries where the performance of certain acts is restricted by law to holders of specific diplomas.

Cleavages result, too, from the diversity of educational systems. The title of *engineer*, recognised by national legislations, bears witness to levels of higher education that are comparable among themselves neither by the conditions of access thereto, nor by their duration or content.

* *European Federation of National Engineering Assemblies*

This situation is due in part to the fact that many countries, wishing to respond to increasing offers of employment, have created, alongside with the traditional university route, a path oriented rather towards the acquisition of practice. Of these paths one of the most telling examples is that of the German Fachhochschulen. The distinction between the two systems, however, is not always clear, the law awarding to each a *university level* in many countries where both routes exist. Just as the term *engineer* and its national versions do not have the same meaning in European countries, so the term *university level* apply to courses whose nature may differ considerably.

Moreover, there often exist means of access other than the normal ones to the title of engineer.

It should be bome in mind also that European educational systems vary as regards the importance attached to experience. In certain countries, the sole condition for obtaining the title of engineer is the possession of a diploma, and no professional experience is necessary. In other countries, such as Great Britain and Ireland, the title cannot be obtained without completion of a training course and/or probationary period in industry. Thus we find, within the profession, academic titles and professional titles, not easily comparable.

To sum up, the engineering profession in Europe presents a fragmentary picture with hazy outlines, for three essential reasons: - the branches of activity in which it is practised, and the corresponding specialisations, are not the same in every country, - the profession is governed by regulations in some countries only, - educational systems within a country, and between countries, differ so widely that it does not seem possible to arrive at a profile to fit all members of the profession.

Under such conditions, can one speak of a *European Engineering profession*?

The dynamics of unity

In the face of the divisive factors just mentioned, the dynamics of unity does exist. This unity stems, in the first place, from the fact that all engineers, whatever their initial training, speak the same technical language, have an identical mental attitude towards nature's laws, shape their thoughts according to the same logic, and consequently understand each other when they talk shop. It springs, too, from the consciousness shared by all engineers that they participate in a common task, in this great movement towards technological development that is a feature of modern civilisation. And, finally, from a code of ethics they have in common. Today this momentum is encouraged by the construction of Europe.

In the presence of these realities, how much do divergences on the definition of branches of activity weigh? Are not the evolution of science and technique and the ever-growing demand for multi-disciplinary proficiency a cause of frailty affecting even the frontiers that separate traditional specialities? Can one, in fact, harbour the thought that the engineer's sphere of activity is a world-wide problem whose solution, to be found in evolution, will be dictated by practical necessities?

With respect now to the obstacles inherent in the different categories within the education systems, opposite arguments are presented.

Nobody would deny the fact that prolonged university education on a high scientific level confers on him who receives it a particular qualification, acquired at the cost of sustained effort in youth. But such a qualification, of intellectual order more than anything, is accessible only to a necessarily restricted number of persons destined, in principle, to work on the conception of comprehensive projects and research and to occupy senior positions: it remains to fill the other jobs indispensable to the functioning of industry, the self-same jobs for which engineers are trained in a cycle oriented towards practical applications. Is this theoretical distribution of tasks between the two types of education strictly observed in actual fact?

The scientific and technical education acquired in the early stage of a career does not confer all the qualifications required for the immediate exercise of important responsibilities. As for research, its chief concern is the industrial applications of new scientific discoveries, with innovation as a goal. Here again experience is called for, and basic education is not enough. The weight of experience in the exercise of the engineering profession is the subject of debate. Those engineers whose education has been practice oriented invoke it to support their contention that, after a certain length of time, professional experience can offset a basic education that has not been pursued to the highest level.

Advocates of the long cycle naturally dispute this thesis, arguing that high level fundamental theoretical learning cannot be achieved by experience alone: the *gangways* linking the two types of education imperatively call for the acquisition of fresh knowledge in basic areas. The two theses clash and cleavage is still possible.

The imperative necessity for continuous education which, in the eyes of engineers of all origins, appears ever more unavoidable in the years to come, shall perhaps be of help in moderating this conflict.

Be that as it may, some established facts remain:
- industry needs at one and the same time engineers with a high-level theoretical education and extensive general knowledge, and engineers more particularly trained for practical applications, - different types of education must therefore, be available to permit recruitment of the entire range of indispensable personnel, - experience as well as complementary, continuous education are a necessity for all engineers to make them capable of assuming high-level responsibilities in the course of their career.

The above are generally accepted. It is interesting to see that engineers with all types of education now meet and converse under the aegis of FEANI. The National Associations represented in that Organisation have mustered more than one million engineers from all backgrounds: the concept of unity within the profession therefore still has chance of winning through.

It is true that the profession has not been able up to now to come to an agreement in the matter of obtaining from the ECC a special directive concerning engineers. The profession is at present included among those, whose number is hard to determine, which are to be governed as from January 1991 by the general directive of December 21, 1988 fixing B + 3 as the mandatory threshold for education. The complex text of the document in question has already given rise to divergent interpretations.

But the FEANI Register, active since 1987, offers a structure open to all European engineers and technicians. Its aim is to confer upon those who appear in its pages a label of professional competence that respects precise criteria. The label in question is attested by the professional Title of European Engineers: EUR ING, for which engineers with different types of education are eligible. For the sake of unity no hierachy was introduced among the types of education, but the concerned one is indicated on each document of attribution. So, the FEANI Register does not serve to mix the different existing types of engineering education and does not establish any equivalences among them. It only provides an assessment of professional competence, being admitted that every engineer, without disguising his basic education may acquire a good professional qualification and then be recognized as *a good engineer*. The assessment given by FEANI is of interest for potential employers but, of course, cannot override the legal regulations which govern in some countries, the work of engineers.

Prospects

It is certain that the engineering profession in Europe is currently in a state of evolution. History, traditions, the language barriers still make their considerable weight felt. But scientific and technical progress, the constraints of competition, the modern organisation of production and its growing concentration, new methods of tuition, the development of continuous education, all these are factors that make changes unavoidable.

Classification and assessment methods will likely have to be adapted to new situations and new needs. It would be good that engineers whatever their basic formation, stand sufficiently close together, before entering this new period.

This article is published at the request of the British National Committee for International Engineering Affairs and first appeared in the September issue of SEFI News.

The views are strictly personal and do not commit FEANI. The Editor would welcome comments from members. ❖

Biology of Hearing and Noise-induced Hearing Loss

David R Moore and David McAlpine

Introduction

In Thomas Kuhn's [1] book "The Structure of Scientific Revolutions" science is seen as developing in a step-wise function, where the step risers correspond to periods of immense development brought about by a fundamental and widely agreed re-assessment of the way scientists think about their subject. Most people working in hearing research would agree that their subject has passed through two such revolutions during the last 40 years. The first of these was the discovery during the '50s by von Békésy [2] that sound coding in the inner ear, the cochlea, is achieved by a "place principle". Sound waves striking the ear drum produce maximum displacement of the basilar membrane at different distances along the length of the cochlea (Figs. 1 & 2). The position of maximum displacement depends on sound frequency, with high frequencies represented at the base of the cochlea and low frequencies represented at the apex. The second revolution, and the one on which we concentrate in this paper, has occurred during the last 15 years, and has been the result of discoveries in several laboratories. These discoveries (collectively called "active processes", see ref. [3]) have demonstrated that the cochlea does not act as a simple, passive receiver. Rather, a specialised cell type within the cochlea, the outer hair cell (OHC), feeds energy into the cochlea to sharpen dramatically the frequency tuning of the mechanical response discovered by Békésy.

The discovery of active processes in the cochlea has led to a re-evaluation of the mechanisms underlying noise-induced hearing loss and the properties of stimuli that can induce a loss. Our own interest in this subject derived partly from basic research on cochlear trauma, and partly from a concern that the "Noise at Work" regulations of the Health and Safety Executive (HSE;[4]) were being applied somewhat indiscriminately to stimulus situations other than those on which the research underlying the regulations was originally based. In this paper we outline the biology of noise- induced hearing loss and go on to consider the implications of that research for human exposure to a novel, but prevalent form of noise, reproduced music delivered via personal stereos.

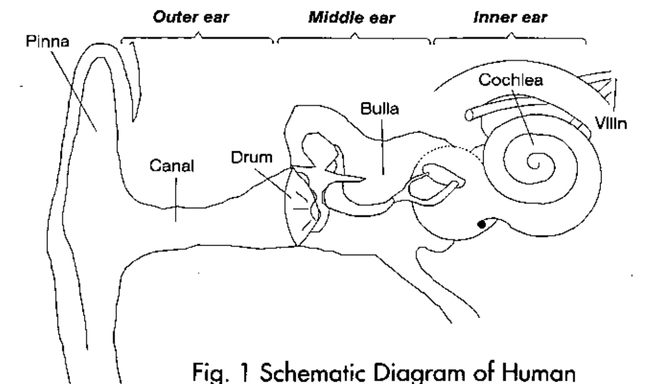

Fig. 1 Schematic Diagram of Human Peripheral Auditory Structures.

Active Processes

An early problem recognised from Békésy's work was the apparent mismatch between the mechanical response of the basilar membrane and the exquisite ability of humans to discriminate pure tones. Under optimal conditions we can detect a change of less than 3Hz in a 1,000Hz pure tone [5]. In contrast, Békésy's travelling wave envelopes had a half-power bandwidth of about one octave. Békésy suggested that a sharpening of tuning occurred through neural processing, but the finding that auditory nerve fibres were sharply tuned cast doubt on this notion. If any neural sharpening occurred it would have to take place in the hair cells. Nevertheless, the idea of neural processing acting as a "second filter" gained favour, and for almost 20 years this was accepted doctrine.

In the early '70s, Russell and Sellick [6] performed the seemingly impossible task of recording the electrical activity inside hair cells in a living animal. The technical

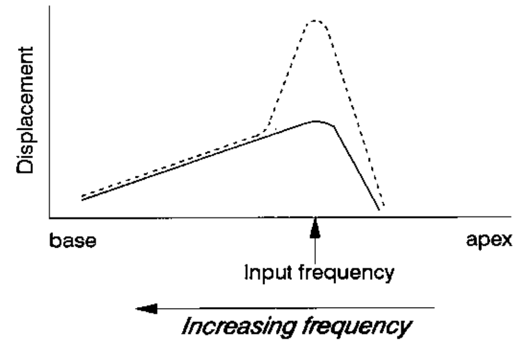

Fig. 2 Passive (solid) and Active (dotted) Travelling Wave Envelopes on the Basilar Membrane of the Cochlea.

difficulty of this procedure may be appreciated by considering that the temporal bone, housing the cochlea, is the hardest bone in the body, and that the whole cochlea is about the size of a pea and has over a million essential moving parts [7]. Perhaps the most important result of Russell and Sellick's work was the finding that the tuning of inner hair cells (Fig. 3) was as sharp as that of auditory nerve fibres. This finding destroyed the notion of neurally-mediated sharpening, since the receptor potential is the very first stage of neural processing. The final death knell of the second filter hypothesis came in the early '80s when two groups · independently demonstrated (see ref. [3]) that, using heroic tissue preservation techniques, the mechanical tuning of the basilar membrane could be as sharp as that of the nerve fibres and the hair cells (Fig. 3).

One of the main interests of recent studies of cochlear mechanics is not the occasional demonstration of sharp tuning, but the more common finding of broad tuning. Békésy's measurements were made in cadavers (an obvious necessity in the case of his human studies!), but it gradually became clear that the physiological condition of the preparation was all-important in determining the sharpness of tuning. In particular, measurements made in the one subject before and after oxygen deprivation or death showed a broadening of mechanical tuning that was related to general pathology. These findings therefore suggested that the mechanics of the cochlea were somehow dependent on active physiological processes.

It is, of course, also possible that the differences observed between living and dead preparations were simply the result of post-mortem changes in tissue stiffness or some other passive property of the cochlea. However, in 1978, Kemp [8] showed that active processes must occur in the cochlea. By sealing a miniature microphone in the ear canal, together with a sound delivery system, it was found that sound stimuli were followed by an acoustic signal that emanated from the ear. Although these otoacoustic emissions (OAEs) were originally called cochlear echoes, they were not true echoes since they had larger than predicted latency variability from case to case, their waveform did not reflect that of the signal and, as shown in subsequent studies [9], they were physiologically vulnerable. Moreover, about 25-40% of normal human ears produce spontaneous (S)OAEs in the absence of stimulation. While the existence of SOAEs remains the most powerful and direct evidence for active processes in the cochlea, it does not in itself provide any indication of the site or nature of the energy input.

The transduction of mechanical into electrical energy in the inner ear has long been thought to involve a gating of currents into hair cells by modulation of a variable resistance between the positively charged scala media and the negatively charged interior of the hair cells (Fig. 3). The question remained, however, of the separate role played by the inner (IHC) and outer hair cells. The OHCs were known to be more vulnerable to trauma (eg. through noise, see below) than the IHCs, and combined anatomical and physiological experiments showed that damage to or loss of the OHCs was associated with a 30-40dB threshold increase and a broadening in frequency tuning of auditory nerve fibres. Thus, deliberate cochlear trauma, resulting in a selective lesioning of the OHCs, mimicked in auditory nerve responses the effects of inadvertent trauma seen in the mechanical response of the basilar membrane. These correlations raised the possibility that the OHCs might be critical in determining the mechanical response of the cochlea.

Another indirect line of evidence for this proposal came from purely anatomical studies of the cochlea. Each IHC was known to make contact with many auditory nerve fibres, whereas a single auditory nerve fibre contacted many OHCs. It therefore seemed that IHCs were especially important in the delivery of information to the brain. Conversely, the efferent fibres (those coming from the brain) were known primarily to contact the OHCs. This segregation of innervation suggested a

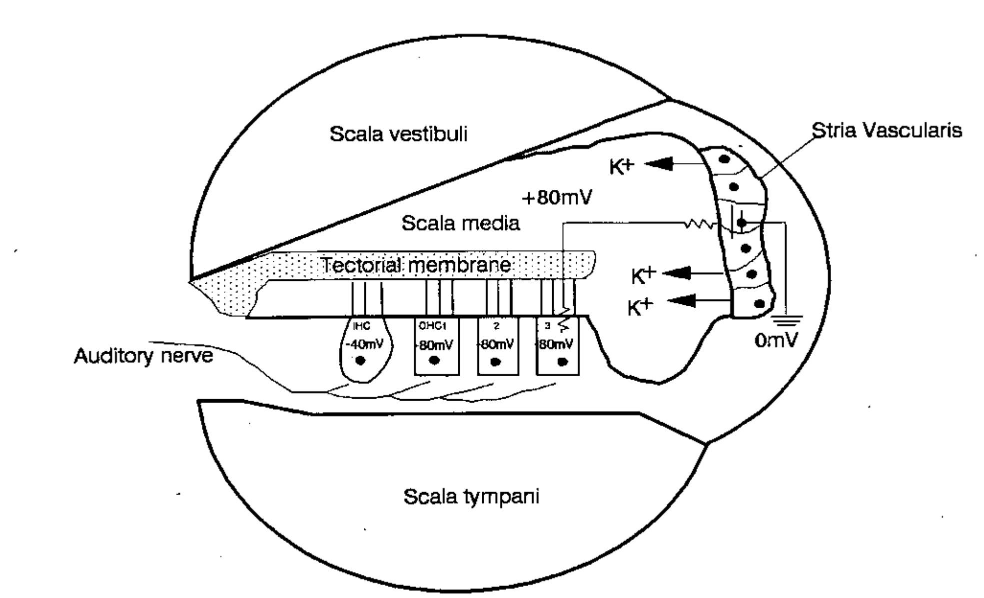

Fig. 3 Cross Section of a Single Turn of the Mammalian Cochlea.

segregation of function. The IHCs were seen as the true, sensory receptors, whereas the OHCs were effector cells, responsible for modulating the output of the IHCs.

The precise way in which the OHC modulation might be achieved is still a matter of conjecture. However, another major discovery of the last decade was that, in tissue culture, OHCs can be induced to move [10]. In this procedure, cells were dissociated by enzymatic digestion of connective tissue. The cells could then be kept in culture for some hours.

A microelectrode applied to the cell membrane was used to inject current. OHCs could be induced either to elongate or contract (by up to 5%, ref. [11]), according to the polarity of the injected current. In the living animal, the stimulus current for the contractions could be supplied by the modulation of the variable resistance across the OHC membrane, resulting in a bi-directional transduction (see above and Fig. 3). The contractions are thus seen as a means by which the OHCs could modulate the mechanical response of the cochlea to produce sharp tuning.

Hearing Loss

Noise-induced hearing loss has usually been divided into temporary and permanent threshold shifts (TTS and PTS). As the names imply, TTS is a reversible phenomenon, whereas PTS is used in cases of indefinitely prolonged impairment. Since it is unclear to us that there is a qualitative difference between these phenomena we will refer to both simply as hearing loss, at least in this section dealing with the biological consequences of noise exposure in animals. The stimuli used to induce hearing loss have usually been relatively short (up to a few hours) periods of very high intensity, spectrally simple signals, such as pure tones or broad- band noise. The techniques used to study the effects of the loss have predominantly been light and electron microscopy, and physiological recording of cochlear potentials or auditory nerve fibre responses.

Structural cochlear changes after noise exposure have recently been discussed by Ade Pye [12]. The index of change used in these anatomical studies has traditionally been the number of hair cells, but more recent reports have used ultrastructural (ie. electron microscopic) indices, sometimes in conjunction with physiological measurements. Probably the most surprising aspect of this work has been the extreme variability between individual ears of the damage produced by noise, even when the stimulus conditions have been strictly controlled. Nevertheless, the mean degree and extent of damage increases with stimulus level, and several fairly distinct types of structural damage have been consistently reported. These include loss of hair cells, loss or damage of stereocilia, and swelling of the nerve endings underlying the base of the hair cells. OHCs are generally more severely affected than IHCs, and the first row of OHCs (OHC1, those closest to the IHCs; Fig. 3) are the most affected of all. Another surprising finding is that the region of the cochlea in which maximal damage occurs to the stereocilia is about 0.5 octaves higher than the frequency of the traumatizing tone. While most of the changes are observed immediately after presentation of the traumatizing stimulus, some only develop following a latent period of 10-30 minutes [12]. Finally, there is evidence of some recovery, particularly following damage that is limited to the stereocilia, after a further period of days or weeks. In certain non-mammalian animal species (eg. birds) regeneration of lost hair cells and recovery of function has recently been shown, but this has not been found in mammals.

Functional changes following acoustic trauma are also extremely variable. Unlike the structural changes discussed above, it is possible to follow the time-course of compound action potential (CAP) audiograms (reflecting neural activity in the auditory nerve), or auditory brainstem responses in one animal before, during and after exposure to the traumatizing stimulus. Physiological studies invariably show a recovery of function that is related to the level and duration of the stimulus. Early hearing loss ("TTS") occurs at all frequencies higher than that of the stimulus, whereas long-term loss ("PTS") is greatest at, or slightly above the stimulus frequency.

As outlined above, a powerful approach has been the combined use of ultrastructure and physiological recording in the same animals. This approach has shown that structural and functional aspects of hearing loss are quite well correlated in individuals, despite the inter-animal variability of both measures. In one study [13] it was found that a CAP threshold decrement was always accompanied by stereocilia damage in OHC1. However, in some cases, stereocilia damage was not accompanied by a threshold loss. An important point that arises from these observations is that the indices used to monitor hearing loss can never give a complete picture of the full extent of the loss. In this case, structural damage was not accompanied by a threshold decrement, but it is entirely possible that some other functional measure (eg. frequency resolution, see below and [14]) may have been affected by the damaged stereocilia.

Recent studies of the biology of hearing loss have concentrated on the cellular mechanisms underlying the loss. In the most recent of those studies [15], a reduction in the AC current (the "cochlear microphonic" or CM) across the variable resistance of the OHCs (Fig. 3) was observed after overstimulation of the ear with a pure tone. Normally, the amplitude of the CM increases with increasing sound level until it saturates. This saturation is due to the finite number of receptor channels in the apex of the OHCs through which current can flow. Following the traumatizing stimulus, the amplitude of the CM response at all sound levels was reduced and the response saturated at a lower amplitude. The effect of acoustic overstimulation was thus to block transduction channels in the apex of the OHCs. This in turn reduced the electro-mechanical coupling between the basilar membrane and the OHCs (the bi-directional transduction). The end result was a reduction in the sharp tuning of the cochlea and the elevation of auditory nerve fibre thresholds for the frequencies affected by the traumatizing tone.

Personal Stereos

In a recent article in "Which?", the consumer magazine, it was claimed that personal stereos can damage your hearing [16]. The evidence cited for this claim was based on the HSE's Noise at Work regulations [4]. Those regulations specify the maximum permissable exposure to sound in working environments, and are themselves based on research mainly carried out in the '50s and '60s. Some of that research (eg. Baughn [17]) attempted to assess the prevalence of hearing loss in humans working in various, 'typical' environments. Unfortunately, the research is questionable for a number of reasons, including the uncontrolled nature of the noise exposure, the assumptions made regarding the relation between TTS and PTS and the selection of the control (normal) population.

The HSE regulations invoke the "equal energy hypothesis" (EEH) to deal with noise durations shorter than 8 hours. The EEH allows for a halving of noise exposure time for every 3dB increase in sound level. Although the EEH has received some support from animal research, recent studies suggest that various forms of intermittent noise incorporating intense peak levels produce a significantly lesser or greater degree of hearing loss than that produced by continuous sounds of the same total energy. These recent studies raise two problems. First, they question the use of short duration sampling times for application of the HSE regulations. Second, they suggest the need for separate research dealing with the effects of different noise types.

Given the prevalence of personal stereo use and, indeed, of exposure to all modes of recorded sound, it now seems timely to conduct some research specifically directed at the effects of that form of sound on the auditory system. Our feeling is that the methodological and ethical problems of studies in humans suggest the need for more animal research. In terms of stimulus control and assessment of the consequences of the stimulation, animals offer obvious advantages. The disadvantages that can be readily identified include possible differences between human and animal susceptibility to hearing loss, and the relative difficulty of assessing behavioural responses to sound in animals. Regarding the first of these points, it may be possible to apply filtering functions (such as the human 'A' weighting function) in order to present test sounds within the appropriate frequency range for the animal under test. Alternatively, we may choose an animal species having a frequency range similar to that of humans. Regarding behavioural testing, parallel physiological and audiometric tests on several animal species have confirmed the similarity between CAP and behavioural audiograms. However, these considerations raise again the question of the appropriateness of any form of audiometry as a test procedure. West and Evans [14] have recently shown that frequency resolution provides an earlier sign of the harmful effects of amplified music than simple thresholds, and that high resolution audiometry provides earlier evidence than standard audiometry. We suggest that, although relatively simple audiometric tests should be applied initially to sort out the parametric aspects of the noise exposure, there will be a future need for more detailed and wider ranging test procedures, probably on a smaller sample of subjects.

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This review article is based on an invited paper presented at Reproduced Sound 6, Windermere, November 1990

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An Examination of the Relationship Between Vehicle Noise Measures and Perceived Noisiness

Greg Watts, Nigel Godfrey and Bernard Berry MIOA

Introduction

In a number of countries including the UK the noise emitted by road vehicles is controlled by vehicle type approval noise tests which set limit values for various vehicle classes. These limit values are specified in terms of the maximum permissible weighted sound pressure level achieved during full acceleration under specified conditions. The specification has used the maximum A-weighted sound pressure level for many years now, but as more stringent requirements are stipulated there is an increasing need to ensure that there are commensurate improvements in the perceived noisiness of these vehicles. It is possible that there are other physical scales of noise that are better correlated to people's perception of noisiness and should therefore be considered as measures to test noise emission.

This paper describes a jury experiment where subjects were instructed to rate the noisiness of a range of vehicles as they were driven past a measurement site under different operating conditions. The experiment aimed to extend the original tests held about 30 years ago which led to the use of the dB(A) scale for vehicle noise [1,2,3]. In the present trials, listeners were positioned both inside a listening room and in the open air, whereas in the original trials ratings were only made in the open air. A variety of noise measures were examined including A-, B-, and C-weighted levels and measures of loudness based on the Zwicker method of computation. The vehicles performed a variety of operations; passes at steady speed, acceleration from rest and from low speed, and steady tickover.

The initial analysis of this study involved the measurement of A- and C-weighted sound levels only and that has been reported elsewhere [4]. This further analysis concentrated on loudness descriptors and B-weighted levels and comparisons with the former measures.

Method

The current trials were held at the TRRL test track. In order to examine the response of people exposed to noise indoors, a single storey building containing a listening room was constructed alongside the test track (Fig. 1).

A broad range of vehicle types were chosen and categorized into the following groups.

(i) Heavy vehicles - articulated vehicles with a gross vehicle weight between 16 and 38 tonnes.
(ii) Medium vehicles - vehicles with a gross weight between 7.5 and 16 tonnes.
(iii) Light vehicles - cars and vans up to 3.5 tonnes.
(iv) Mixed vehicles - a selection of vehicles from the preceding groups.

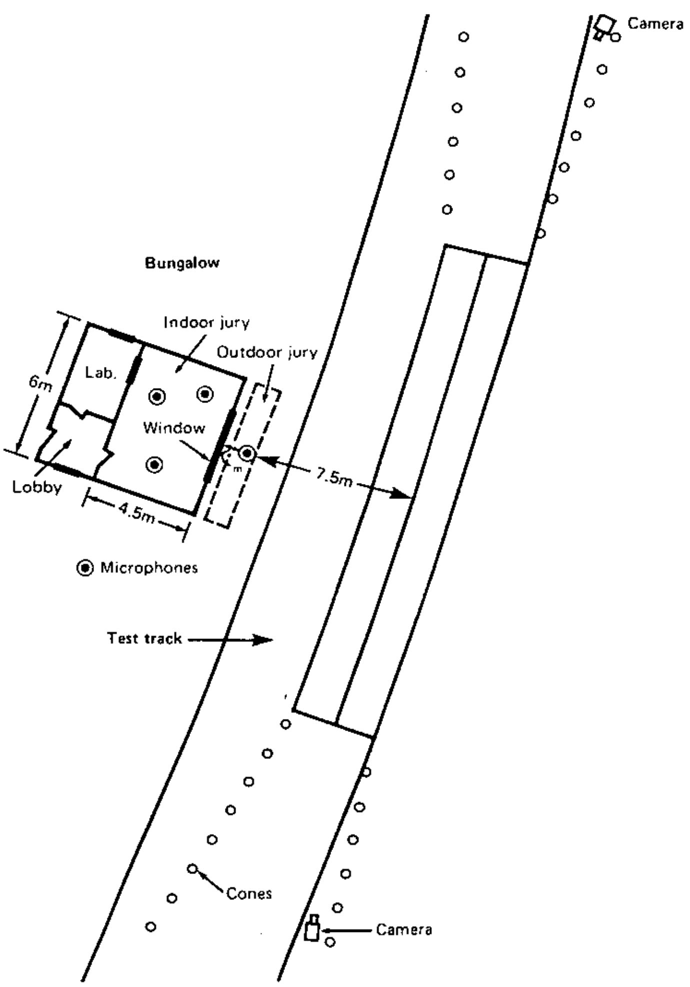

Fig. 1 Plan of Test Track and Listening Room Facility.

During each test day, all vehicles within the selected group were driven past the building in convoy with approximately 30s separation between vehicles to allow time for marking. The first convoy of any block had mixed vehicle operations to demonstrate to the juries the range of noise to be rated. In each subsequent convoy all vehicle operations were similar, but different between convoys. In this way each vehicle was tested under six operating conditions: low medium and high steady speeds; maximum acceleration from a standard entry speed; and an idling condition followed by a maximum acceleration pull-away. Each operation was repeated for uphill and downhill directions. After one block of convoys in a particular direction the two groups of jurors changed places and a further block of convoys was presented with vehicles running in the same direction. In this way separate indoor and outdoor ratings of essentially the same pass-by event were made by each listener. There were two test days for each vehicle group with the second day being operated in reverse order to the first day in order to balance out residual effects.

Each listener was instructed to give an assessment of the relative noisiness of each vehicle event using a 0-9 scale labelled 'increasing noisiness'. There was a minimum attendance of 20 per day ie a minimum of 10 in each group of listeners. There were approximately 2,250 individual vehicle pass-bys and approximately 70,000 individual noisiness ratings taken during the course of the trials.

All pass-bys were recorded using calibrated 2-channel digital audio tape recorders. There were three microphones positioned in the listening room and one in the middle of the outside listening area. The recordings were analysed at TRRL using a four channel computer-based sound level meter system and at the National Physical Laboratory using a version of the Zwicker Loudness meter. The loudness meter printed out the maximum loudness in sones and various statistical measures such as N20, the sone level exceeded for 20 percent of the event duration. Maximum loudness in sones (S) was converted to maximum loudness level in phons (P) using the relationship: $P=40+33.21\log S$. Mean subjective scores were computed for each vehicle pass-by for each listening condition (indoors or outdoors).

Results

Correlation analysis was used to investigate the relationship between average noisiness scores and the various physical measures of noise in order to gauge their usefulness for predicting disturbance. Table 1 below lists the correlations for the outdoor noise measures with mean subjective scores for outdoor and indoor listening conditions. In this paper only results for the moving acceleration operation are given since these most closely correspond to test conditions for noise emission. For maximum level measures the loudness level in phons was generally the best correlated measure, the coefficients ranging from 0.533 to 0.872 with an average value of 0.735. The maximum loudness in sones and A-weighted level were slightly less well correlated although the differences were not statistically significant. The correlations for B- and C-weighted levels were substantially lower than the best correlated measures.

The single-event level (SEL) is a measure of the average noise level during the event and is therefore sensitive to both the maximum level and duration of the

	Heavy (n=32)*		Medium (n=64)		Light (n=64)		Mixed (n=61, 63, 64)	
Noise measures	outside scores	inside scores	outside scores	inside scores	outside scores	inside scores	outside scores	inside scores
Max levels								
Phon	0.790	0.533	0.738	0.598	0.786	0.756	0.872	0.810
Sone	0.722	0.515	0.743	0.607	0.777	0.758	0.831	0.779
dB(A)	0.780	0.510	0.738	0.690	0.727	0.700	0.866	0.792
dB(B)	0.695	0.442	-	-	-	-	-	-
dB(C)	0.682	0.454	0.479	0.449	0.580	0.514	0.749	0.674
Others								
20% Sone	- 0.122	0.452	0.298	0.161	0.563	0.514	0.491	0.385
SEL dB(A)	0.790	0.452	0.786	0.694	0.788	0.719	0.908	0.804
SEL dB(B)	0.729	0.439	-	-	-	-	-	-
SEL dB(C)	0.710	0.395	0.479	0.383	0.688	0.556	0.824	0.743

** n is the number of pass-by events for which the correlation coefficient is computed. Because of equipment faults, results for only one day of testing are presented for the heavy vehicle group*

Table 1. Correlation coefficients (r) for outside noise measures with outside and inside ratings for accelerating vehicles by group

event. The SEL dB(A) was consistently better correlated than SEL dB(B) and dB(C) and the 20 percent sone value and was similar in performance to the maximum loudness level. Results for the other operating conditions are in broad agreement with the results presented here for the acceleration pass-by events.

Discussion and Conclusions

The correlations for the A-weighted levels were relatively good although clearly there remains a substantial amount of variance in subjects' ratings unexplained by this physical measure. These results are in agreement with a much earlier study involving the rating of the noisiness of passing vehicles on a public highway [1,3]. This showed that the maximum A-weighted level was superior to maximum B-weighted level and that maximum loudness was better than both. No tests of the statistical significance of the results are reported in this former study. In the present study the correlation coefficients for these measures are not significantly different. For the SEL measures the A-weighted was better correlated than the other measures and the level of association was similar to that for maximum loudness level. The results are sufficiently encouraging to consider further the use of loudness and SEL measures for assessing vehicle noise nuisance. It is planned to carry out laboratory studies of noise nuisance using high quality recording and replay equipment to ensure realistic listening conditions. Statistical precision will be improved by measuring noise levels at the listener's head position and by using experimental designs involving repeat ratings of the noise events. In addition the duration and timing of events will be tightly controlled in order to ensure easier and more valid judgements of noise nuisance. In this way a noise measure, or combination of measures, might be identified which will be more suitable than the maximum A-weighted level for assessing noise emissions.

Acknowledgements

The study formed part of the programme of research of the Transport and Road Research Laboratory and the paper is published by permission of the Director. The original experiment involved the efforts of many including Dr I H Flindell and Professor C G Rice of ISVR and Dr P Nelson, J Tyler and J Abbott of TRRL and their contribution is gratefully acknowledged.

The co-operation of the National Physical Laboratory in carrying out the loudness measurements is also acknowledged.

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This contribution is based on a paper presented at Internoise 90 in Gothenburg.

Greg Watts and Nigel Godfrey are at the Transport and Road Research Laboratory and Bernard Berry MIOA is at the National Physical Laboratory.

Acoustics Bulletin

Offers of technical contributions, letters to the editor or news likely to be of interest to members or others in the acoustics community should be sent to the Editor:

John Tyler FIOA,
11 Colwyn Close,
Yately, Camberley,
Surrey GU17 7QH

Information on new products should be forwarded directly to:

John Sargent MIOA,
Building Research Establishment,
Garston, Watford WD2 7JR


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George Saunders' "Treatise on Theatres" of 1790 and Optimum Acoustic Profiles

Michael Barron MIOA

Introduction

We now refer to the eighteenth century as the 'Age of Reason'. Perhaps it should come as no surprise to find enterprising attempts from the period at logical development of auditorium forms. For instance, Pierre Patte in 1782 [1] proposes the elliptical plan form for a theatre because:

"the elliptical curve ..... possesses the unique ability of preserving from all directions the useful reflections of the voice. ..... Consequently such a theatre could not fail of being perfect."

Patte's concept of acoustic reflection seems sound enough. But it now seems amazing that he was unconcerned by the extreme focusing behaviour from which his preferred form suffers.

The human voice is obviously a directional sound source, which could form the basis of a design profile. Christopher Wren made a now famous statement regarding the implications of its directional nature in churches:

"Concerning the placing of the pulpit, I shall observe - a moderate voice may be heard 50 feet distant before the preacher, 30 feet on each side and 20 behind the pulpit; and not unless the pronunciation be distinct and equal, without losing the voice at the last word of the sentence, which is commonly emphatical, and if obscured spoils the whole sense."

George Saunders' contribution to the arguments of this period deserves more than passing attention, even though his acoustic understanding is generally quaint, and frequently wrong.

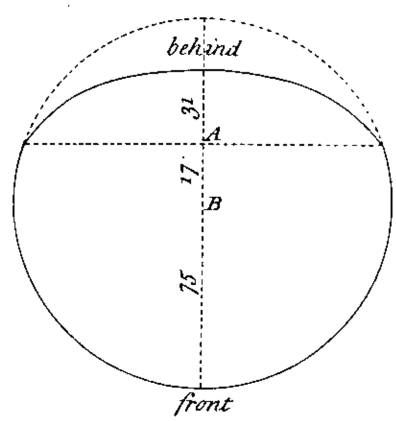

Fig. 1 Saunders' Profile for Limiting Distances of Intelligible Speech. The Speaker is at A Facing B.

George Saunders' "A Treatise on Theatres"

George Saunders (1762-1839) was an architect who became Surveyor to the County of Middlesex. (He also apparently wrote an interesting paper on Gothic vaults.) The reason for his interest in theatres is not clear, nor does it seem as if he ever built a theatre himself. His 'Treatise on theatres' [2] was written in 1790 soon after Patte's 'Essai', when Saunders was only 28 years old. The Treatise contains a discussion of "optics and phonics, as they relate to Theatres", accounts of experiments on the voice and development of ideas for good theatre design, stage design etc. The longest chapter in the Treatise contains discussion of 17 theatre designs existing at the time (as well as ridicule for Patte's design!). The final chapter proposes designs for an ideal theatre and opera house.

It may seem somewhat surprising to us now, but both Vitruvius in the first century B.C. [3] and Saunders pay more attention to acoustics than vision. Saunders conducted his own experiment on speech propagation "on a calm day chosen for the purpose and (over) an open plane":

"EXP1. Having traced a circle of 100 feet in diameter, I placed the speaker in the centre; the distance, therefore, was the radius of 50 feet every way. The hearer moving on the circumference of this circle heard most distinctly when in front of the speaker, not much less so on each side, but scarce at all behind.

EXP2. In the same circle, I placed the speaker at 25 feet from the centre, which was 3-4ths of the diameter or 75 feet to the front, and 25 feet behind. He was heard best at the sides and indifferently in front and behind.

EXP3. On repeating these experiments, and changing the situation of the speaker, I found the voice reached the circumference most equally when he was placed at 17 feet from the centre. I then, without regarding the circle, traced the extreme distance at which the voice could be distinctly heard every way. The line it formed was that described in Figure 1 (this paper); the situation of the speaker was at A, from which point, at the distance of 17 feet in front, B will be the centre part of the circle which it formed: the extent from speaker to hearer will be 92 feet in front, 75 feet on each side, and 31 feet behind.

The difference of the form made by the voice, and that made by fixed sound, is evidently occasioned by the voice's being pushed forward from the mouth; and this difference will always be in proportion to the exertion of the speaker, and subject to very little variation."

Saunders here exposes an obvious prejudice for the circle, but we find that his comment "without regarding the circle" in EXP3 may be accurate.

His view of sound behaviour at room boundaries is less impressive. Influenced presumably by the experience of the whispering gallery, he considered that sound after reflection travelled along the surface. His interpretation of his result in Figure 1 was also compromised by his decision that "sound expands equally in every way", based presumably on observations of circular waves on water. He reconciled this with his experimental observations on the voice by concluding that it was "occasioned by the voice's (form) being pushed forward from the mouth". He had measured this distance as 17 feet and considered it relevant to theatre design. Beyond 17 feet the voice is assumed to expand "equally", hence the circular profile.

Contemporary measurement of voice directivity

The most extensive measurements to date of the polar characteristics of the human speaker are due to Moreno and Pretzschner [4], who made measurements at third octaves in an anechoic chamber with several speakers. To obtain a single directional pattern, some frequency weighting has to be applied. It has been decided here to take the average of 1/3rd octave responses at 500, 1000 and 2000 Hz. If this data is replotted in terms of a constant sound level profile, Figure 2 is the result. For comparison with Wren's statement above, the maximum forward distance has been labelled 50. Agreement with Wren's values is good. In reality the profile only truly applies to open air situations without reflections preferential to particular directions or distances. In the case of a church however the reverberant sound level is likely to be constant and significant early reflections are unlikely, which leaves the free-space profile as appropriate for the church as well.

Turning to comparison of Figure 2 with Saunders'

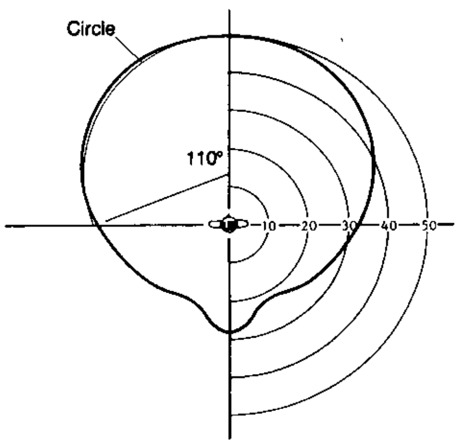

Fig. 2 Constant Sound Level Profile for a Human Speaker Derived from Measurements of Moreno and Pfretzschner [4].

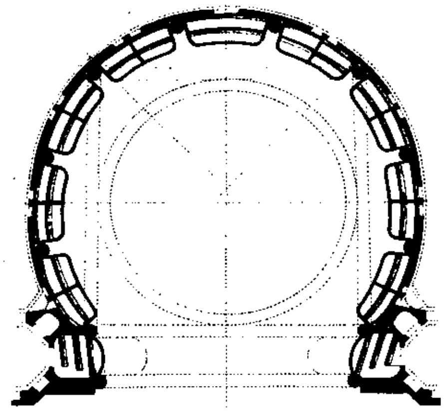

Fig. 3 Plan of the Grand Theatre, Bordeaux.

result, we do indeed find that the profile in front of the speaker corresponds closely to a segment of a circle. Interpreted in contemporary terms, we know it is the form which is constant, not a specific distance in front of the speaker. The angle at the centre of the segment in Figure 2 is 220°, which can be compared with 205° for Saunders' profile (Figure 1). Saunders' data was thus quite accurate though we have to assume that his actual distance values were influenced by incidental noise at his measurement site. Knudsen [5] measured a maximum speech propagation distance of 42m in front of a speaker in quiet conditions in the Mohave desert.

Grand Theatre, Bordeaux

In the section of Saunders' Treatise where he discusses the virtues of various contemporary theatres, he reserves particular enthusiasm for the Grand Theatre in Bordeaux:

"All persons acquainted with the theatre at Bordeaux are unanimous in its favour. They all agree that the voice of the actor spreads more equally in this than in any other theatre. The figure, reckoning at the front of the amphitheatre is nearly equal to its whole circle; but the wall is cut off at about one fifth of the diameter for the stage opening."

The Grand Theatre by Victor Louis [6] was completed in 1780 and still stands. The auditorium has indeed a segment of a circle as its plan (Figure 3), which incidentally is constructed of timber. The angle at the centre of the circular segment described by the auditorium is 260° in this theatre. The auditorium is however relatively small so that at stalls level the actor only has to project a maximum of 16m.

Saunders' ideal theatre

Saunders considered "that the direct force of the voice only can be depended on in a theatre". He thus used his speech profile as the basis of his theatre design, whose plan therefore became a segment of a circle [Figure 4].

"It is clear from the experiments that at 17 feet from the front of the speaker will be the centre to the part of the circle formed by the expansion of the voice; and that in every part thereof the hearers will equally participate in

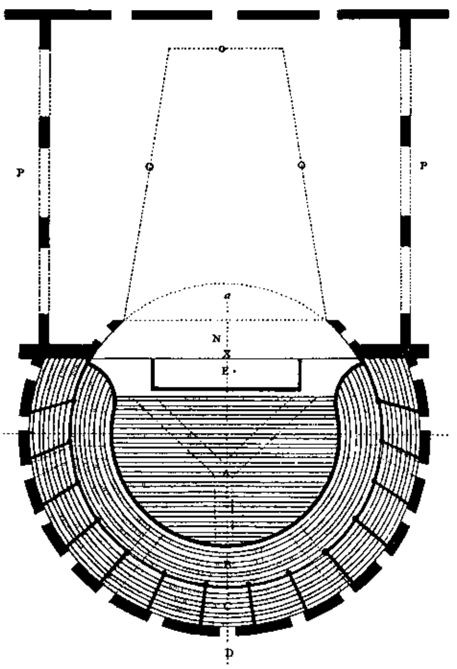

Fig. 4 Plan of Saunders' Ideal Theatre.

the advantages."

Having described the shape of his profile, it appears that the size of the theatre was developed from the proscenium width. The distance from the stage front to the rear wall of the stalls was 16.8m, but the design stepped back for the two balcony levels with a maximum distance for audience from the stage front of 22.6m. The design held an amazing 2817 people. The angle in plan at the centre of the circular segment described by the auditorium was 230°.

Theatre Royal, Drury Lane, London

Between 1660 and 1843 Drury Lane theatre was one of only two establishments in London permitted to put on plays. (The other one after 1732 was Covent Garden). Being in a monopoly situation meant frequent rebuilding of the theatre, helped predictably by a few fires. In this case the previous Drury Lane theatre had been totally gutted by fire in 1809. For his rebuilding Benjamin Wyatt [7] was strongly influenced by Saunders' ideas and he therefore followed the circular plan form, with in fact a similar size plan to Saunders' ideal. The theatre had five balcony levels with a total capacity of over 3100 [8]. The foyer areas of Wyatt's theatre remain to this day but the auditorium was not a success for sightline and acoustic reasons. The auditorium was replaced in 1822 by a horseshoe form designed by Beazley. Beazley's auditorium survived for 82 years, until changes were required in order to conform to new fire regulations.

It is easy to appreciate the visual disadvantages of the circular plan form. The viewing angle from seats in the front half of the auditorium but furthest from the centre line will be especially high. This implies that these spectators will be unable to see a substantial area of the stage behind the proscenium. Sightlines with the horseshoe plan are already bad, with a truncated circle they are even worse. From a social point of view, at a time when being seen was often more important than seeing the performance, the horseshoe plan is also more satisfactory.

There are two possible acoustic criticisms of Wyatt's design: focusing and excessive reverberation. Focusing is obviously more likely in a circular plan than a horseshoe, but in reality it may not have been of much concern. Only audience in the stalls (then 'the pit') might have perceived it and that was not the 'refined' section of the audience! The height of the auditorium was 14.6m. Due to the large distance between gallery fronts there was a substantial reverberant room volume which may have resulted in an excessive reverberation time. Whether Beazley's reconstruction would have significantly reduced the reverberation time is not obvious. Since he used the same ceiling the change was probably small. In fact the evidence that Beazley's design offered valuable acoustic advantages is not clear from the historical record.

Fallacies in Saunders' argument

There are several obvious fallacies in the logical argument which Saunders used to derive his ideal theatre plan:

1 The profile is for direct sound alone but reflections in rooms strongly influence intelligibility. For example, at the back of a large theatre, the direct sound may only be 10% of the received total sound energy.

2. The profile represents a maximum limiting distance. The same form does not have to be followed rigidly for smaller theatres.

3. The profile is for audience positions and need not determine the location of walls in a theatre. In a modern design curved seating rows are perfectly acceptable but walls would generally be made of plane sections to avoid focusing.

The first point constitutes the major criticism. Amazingly the same error was perpetrated by Izenour [9], when he superimposed onto auditorium plans the speech profile measured by Knudsen [5] in the Mohave desert. Experience of large church spaces indicates immediately that speech intelligibility is affected by room reflections. Unfortunately, in order to derive a design profile, more variables need to be included.

An optimum theatre profile ?

To derive a theatre profile, we require a measure of speech intelligibility and a theory for sound behaviour in theatres suitable for prediction purposes. The 50ms early energy fraction or 'Deutlichkeit' is a good predictor of speech intelligibility in quiet environments. Seats with an early energy fraction greater than 50% tend to have adequate intelligibility. (Our experience in theatres suggests that signal-to-noise problems are much less common than impulse response problems.) It proves to be a reasonable assumption that the number of early reflections in a theatre is approximately constant. In other words if we take the directionality of the voice into account, the early sound energy within 50ms is

SECRETARIAT NOTE

This is the first issue of the re-structured Bulletin, designed, typeset and produced in the Institute office. I hope you feel the new style encourages you to consider submitting a review paper or a technical contribution to the Editor for consideration.

May I remind you that Calls for Papers and one-day Meeting Notices will now *only* appear in the IOA News section although additional arrangements will be made for collaborating societies.

Council is aware that finances are likely to become a bit more problematical towards the end of 1991 but there is a determination that services to members will not be adversely affected by such economies as may be considered essential. This is the reason for proceeding with the publication of the 1991 Register of Members which, providing printing schedules allow, should be dispatched with this issue. I expect the Register will be a useful document, and if this is generally held to be the case I would anticipate a 1992 issue at this time next year. A form for amendments and additions will be printed on the back of the1992 Membership Subscription notice.

At its February meeting, Council endorsed a Meetings Committee recommendation to introduce Colloquia into the meetings programme. These will be half-day or one-day meetings treating the sort of minority topic which would be expected to attract perhaps 20 delegates or less. A low-cost venue would be used and published proceedings would not normally be available at the time of the meeting. I think this move could be of particular benefit to those out of the mainstream of acoustics.

May I ask members who attend non-IOA Conferences to send the Bulletin Editor a report on the proceedings, including attendance statistics where possible.

Cathy Mackenzie

INSTITUTE MEETINGS

May 1
Speech Group Meeting
SPEECH IN THE HUMAN-COMPUTER INTERFACE
Hatfield Polytechnic

May 20 - 22
Underwater Group International Conference
RECENT ADVANCES IN UNDERWATER ACOUSTICS
Weymouth
Programme published

May 22
Eastern Branch Meeting
Visit to CEL at Hitchin

June 19
London Branch Meeting
EC NOISE LEGISLATION FOR CONSTRUCTION EQUIPMENT AND MACHINERY

September 24 - 25
Physical Acoustics Group
ANNUAL REVIEW OF PROGRESS IN PHYSICAL ACOUSTICS AND ULTRA-SONICS
University of Leeds

October 16
Eastern Branch Meeting
Dr Roy Patterson, lecture

October 31 - November 3
REPRODUCED SOUND 7
In collaboration with AES, SCIF, ABTT and APRS
Hydro Hotel, Windermere
Call for Papers published: offers of contributions by June 30

November 13
Eastern Branch Meeting and AGM

November 21 - 24
AUTUMN CONFERENCE, NOISE IN THE NINETIES - A QUIETER BRITAIN?
Hydro Hotel, Windermere
Call for Papers published: offers of contributions by June 3

1992
September 14 - 18
International Conference
EURONOISE 92
Imperial College London
First Call for Papers published

COUNCIL & COMMITTEES

MEMBERSHIP COMMITTEE

New Elections

Council approved the following new elections to membership and upgradings on 28 February 1991

MEMBER
Cheung, K M
Cockcroft, P W
Davies, P L C
Denton, D
Hollier, M P
Nedwell, J
Roberts, M
Saunders, B H
Steel, G A
Steel, J A
Turnbull, A J
Woodward, M C A

ASSOCIATE MEMBER
Chiu, F C K
Etchells, I
Friel, B E
Heald, G J
Higson, W D
Jackson, P T
Norman, A B G
Proudfoot, N
Robinson, P
Singh, B
Watts, D L
West, R L
Windle, R M

ASSOCIATE
Cook, S M
Hall, G A
Hampson, F D
Marshall, D R

Next Committee Meeting

May 23; Closing date for sub-mission of applications is Friday 17 May 1991

With regret the Institute has been informed of the sudden death of Simon John Lovell, Associate.

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CALLS FOR PAPERS - WINDERMERE

Seventh Annual Conference

REPRODUCED SOUND 7

Hydro Hotel, Bowness on Windermere 3l October - 3 November 1991

(Organised in collaboration with Sound and Communication Industries Federation, Audio Engineering Society, Association of British Theatre Technicians, Association of Professional Recording Studios)

Even with careful planning, parallel sessions can leave some delegates regretting their inability to be in two rooms at the same time so there are two main changes this year. Firstly the conference will open at 2pm on Thursday instead of Friday morning and close with lunch on Sunday; this extends the total time available. The second change is the introduction of **poster sessions***.

With this in mind the Programme Committee invite offers of contributions on **any aspect of REPRODUCED SOUND**. Particularly it is intended that the following topics will be given some prominence.

- Computer Aided Design of Sound Systems: a continuation of last year's vigorous session.
- Broadcasting and Motion Picture Sound Developments.
- Listening versus Measurement - Exploring the Mythology.
- Electromagnetic Compatability and the 1992 Regulations.
- Transducer Developments at Both Ends of the Sound Reproduction Chain.
- Advances in the Technology and Practical Applications of Digital Sound.

Contributions of sufficient technical merit presented in both types of session will be published in Volume 13 of the Proceedings of the Institute of Acoustics (1991), a copy of which will be available to delegates on arrival. A 100-word abstract, indicating which form of presentation the author considers more appropriate (the Programme Committee may find reason on reading the abstract to vary this suggestion), should be sent to the **Programme Committee Chairman** before 30 June. Completed papers are required by 20th September at the latest. In order to protect the Institute's status and the spirit of the Reproduced Sound conferences, papers will be scrutinised for overt advertising material.

Programme Committee Chairman:
Dr Malcolm Hawksford FIOA, Department of Electronic Systems Engineering, University of Essex, Wyvenhoe Park, Colchester CO4 5SQ
Programme Committee :
James Angus, Ken Dibble, Mike Snalam, Hiro Negishi, Ian Flindell, Roy Lawrence, Andy Mackenzie, Julian Wright
Conference Organiser:
Dr R Lawrence FIOA, Oscar Faber Acoustics, Upper Marlborough Road, St Albans, AL1 3UT

*For those unfamiliar with this form of procedure, contributors are allocated, along with as many as twenty others presenting related topics, to one of the special sixty-minute sessions in the programme. Contributors pin up on a 6' x 4' board provided in one of the lecture spaces a selection of visual display material. This, plus any additional audio material, serves as the basis for discussion with other delegates circulating around the displays. This method is especially suited to some types of contribution, for example where a project shows interesting early results but is insufficiently complete for a formal oral presentation. Equally this would suit contributions of an intrinsically discursive nature and some contributors may personally find the relaxed atmosphere and the interactive situation more congenial to their needs. Guidance will be offered on what makes a satisfactory display.

1991 Autumn Conference

NOISE IN THE NINETIES - A QUIETER BRITAIN?

Hydro Hotel, Bowness on Windermere 21 - 24 November 1991

(organised jointly by the Industrial Noise and Building Acoustics Groups)

Many procedures for controlling noise in the environment were developed in the 1960s and 1970s out of the Wilson Report, and are now under review. Recently the Government has published the **White Paper on the Environment**, the **Batho Report**, and the **Mitchell Report** on railway noise. **BS 4142** has been revised and the **Building Regulations** and **DOE Circular 10/73** on Noise and Planning are in the process of revision. In Europe **EC Directives** have been issued on Construction Products and Machinery Noise.

This year's Conference offers an opportunity, at an important time, to discuss and exchange views about recent changes and future developments. Offers of contributions are invited on **any aspect of environmental noise affecting people in and around buildings**; suggested topics include:

- issues arising from the Batho report
- entertainment and neighbourhood noise
- criteria for the assessment of environmental noise (eg inaudibility re-visited?)
- revision of BS 4142 (comparisons, case studies)
- sound insulation in buildings (Building Regulations, construction techniques, test methods)
- EC Directives on machinery noise, and techniques for controlling noise
- transportation noise (including railway noise and the Mitchell Report)
- problem areas (eg background noise measurements, low frequency and impulsive noise)
- new techniques for predicting, monitoring and controlling environmental noise.

Last year's Autumn Conference showed the value of poster sessions in providing an interactive environment that could be a more appropriate one for the presentation of some types of contribution. This year's Organising Committee wish to retain this feature and intending contributors should therefore indicate whether, in their view, the proposed material is likely to be more suitable for a poster or a formal oral session. The Programme Committee will take note of the expressed views but reserve the right to make a final decision after refereeing abstracts.

Papers of sufficient technical merit, whether presented in the formal or poster sessions, will be published in Volume 13 of the Proceedings of the Institute of Acoustics (1991), available at registration. Guidance will be offered to anyone unfamiliar with poster presentations, particularly in respect of the preparation and presentation of material.

Abstracts of not more than 100 words should be sent to the Conference Organiser by Monday 3rd June and completed papers are required by 18th October.

Conference Organiser:
Jeff G Charles FIOA, Bickerdike Allen Partners, 121 Salusbury Road ,London NW6 6RG
Programme Committee Chairmen:
Dr L Fothergill MIOA (Building Acoustics Group)
Dr R J Peters FIOA (Industrial Noise Group)

NOMINATIONS FOR IOA HONOURS AND AWARDS

The Institute of Acoustics annually honours people whose contributions to acoustics have been particularly noteworthy.
The awards under consideration for 1992 are the Rayleigh, Tyndall and A B Wood Medals and Honorary Fellowships all of which will be awarded to acousticians from the UK.
Nominations for these honours are now sought from the membership and should be sent in the first instance to the President at the Institute office marked "Medal Nomination: Confidential". Information on these awards follows below.

Rayleigh Medal
John William Strutt, Third Baron Rayleigh (1842-1919) is remembered as a most versatile physicist, both as an experimentalist and as a theoretician.
A graduate, fellow and finally Chancellor of Cambridge University, he was early elected to Fellowship of the Royal Society of which he was President from 1905 to 1908. He received the Nobel Prize for physics in 1904.
Rayleigh's work covered practically every branch of physics and he was the co-discoverer of the rare gas argon. In acoustics, he published over 100 articles and his book The Theory of Sound remains a land mark in the development of the subject.
The Rayleigh Medal, of gold-plated silver and bearing the portrait of Lord Rayleigh, is awarded without regard to age to persons of undoubted renown for outstanding contributions to acoustics.
The award is normally made to a United Kingdom acoustician in even numbered years.
The Institute is pleased to have honoured these acousticians with the Rayleigh Medal:

P H Parkin UK 1975
L M Brekhovskikh USSR 1977
E G S Paige UK 1978
E A G Shaw Canada 1979
P E Doak UK 1980
K U Ingard USA/Sweden 1981
G B Warburton UK 1982
E J Skudrzyk USA/Austria 1983
J E Ffowcs-Williams UK 1984
P J Westervelt USA 1985
E J Richards UK 1986
M R Schroeder Germany 1987
D G Crighton UK 1988
H E von Gierke USA 1989
F J Fahy UK 1990
M Heckl Germany 1991

Tyndall Medal
John Tyndall (1820-1893) was active in acoustics before Rayleigh, and indeed Rayleigh actually succeeded Tyndall as Professor of Natural Philosophy at the Royal Institute.
Born in County Carlow, Ireland, he studied chemistry, physics and mathematics at Marburg University (under Bunsen) and was elected a Fellow of the Royal Society in 1852. Later he investigated the acoustic properties of the atmosphere and his volume of lectures On Sound has been reprinted many times.
Tyndall was a distinguished experimental physicist but is remembered primarily as one of the world's most brilliant scientific lecturers.
The Medal named after him, a silver-gilt medal, is awarded to a citizen of the UK, preferably under the age of 40, for achievement and services in the field of acoustics.
The following is the list of recipients:

M E Delany 1975
H G Leventhall 1978
R K Mackenzie 1980
F J Fahy 1982
R G White 1984
J G Charles 1986
M F E Barron 1988
N G Pace 1990

A B Wood Medal
Albert Beaumont Wood was born in Yorkshire in 1890 and graduated from Manchester University in 1912. In 1915 he became one of the first two research scientists to work for the Admiralty on anti-submarine problems and he later designed the first directional hydrophone for use in submarine detection. He was well known for his many contributions to the science of underwater acoustics and for the help he gave to his younger colleagues.
The A B Wood Medal and Prize, instituted after his death and as a result of the generosity of his friends on both sides of the Atlantic, is aimed at younger researchers whose work is associated with the sea.
The silver-gilt medal, parchment scroll and cash prize were awarded from 1970, prior to the formation of the Institute of Acoustics, by the Institute of Physics. The award is made alternately to acousticians domiciled in the UK and in the USA/Canada.
Recipients of the A B Wood Medal are as follows:

P A Crowther UK 1976
P R Stepanishen USA 1977
A D Hawkins UK 1978
P H Rogers USA 1979
I Roebuck UK 1980
R C Spindel USA 1981
M J Buckingham UK 1982
P N Mikhalevsky USA 1983
M J Earwicker UK 1984
T K Stanton USA 1985
P D Thorne UK 1986
D Chapman Canada 1987
V F Humphrey UK 1988
M G Brown USA 1989
A P Dowling UK 1990
M B Porter USA 1991

Honorary Fellowships
Honorary Fellowships are awarded to distinguished persons intimately connected with acoustics, or a science allied thereto, whom the Institute wishes to honour for exceptionally important services in connection therewith, and any distinguished person whom the Institute may desire to honour for service to the Institute or whose association therewith is of benefit to the Institute, shall be eligible to become Honorary Fellow of the Institute. The total number of Honorary Fellows shall not exceed 2 per cent of the number of persons elected as Corporate Members of the Institute.
Honorary Fellows are:

L W Cremer Germany 1977
J Lighthill UK 1978
W A Allen UK 1978
E J Richards UK 1978
J Lamb UK 1980
W Taylor UK 1980
F Ingerslev Denmark 1981
C A Taylor UK 1985
B Pippard UK 1985
P V Bruel UK 1986
C M McKinney USA 1986
M E Delany UK 1989

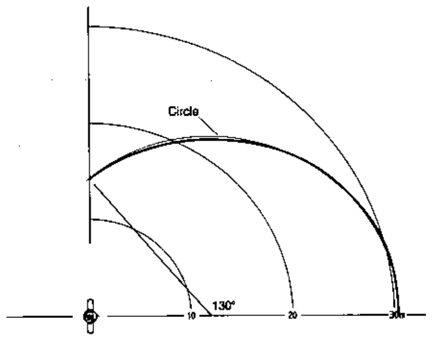

Fig. 5 Profile for Limiting Speech Intelligibility for a Speaker in a Theatre. A Fine Line Circle has been Drawn Adjacent to the Profile.

approximately a constant factor times the direct sound energy. The value of the factor varies from theatre to theatre. In this case the value of the factor has been taken as 3, implying two reflections of energy equal to the direct sound.

The late sound is calculated from the reverberation time (1s) and auditorium volume (5000m^3). It is assumed that only sound energy entering the auditorium (i.e 72%) will contribute to the late sound; energy entering the stagehouse is assumed to be absorbed. Measurements in real theatres (and concert auditoria) show that late sound energy arriving more than 50ms after the direct sound is a function of source-receiver distance; the level decreases for more distant receiver positions. This aspect is also included, according to the revised model in [10].

The assumed quantities were all chosen on an arbitrary but realistic basis. Figure 5 shows the profile of 50% values for the early energy fraction in such a theatre. It proves to be very close to a segment of a circle. The enclosed angle is 260°, identical with the Bordeaux Grand Theatre!

Relevance to modern design

The circular plan form is obviously inappropriate for a proscenium theatre due to poor sightlines. However if one superimposes a circular acoustic profile on a fan-shaped visual profile we arrive at a familiar plan form. For spectators to see a reasonable proportion of the stage, they should not lie beyond a line inclined at, say, 30° to the main axis of the theatre taken through the edge of the proscenium. (In earlier theatres with deep perspective stages the angle should have been even smaller.) These two profiles leave us with a plan form very close to the horseshoe, which proved to be almost ubiquitous for theatre design in much of Europe during the eighteenth and nineteenth centuries, Figure 6.

A further criticism can be levelled at such an exercise in developing an optimum profile: it assumes the actors only face directly onto the auditorium. As soon as an actor changes his orientation the profile rotates with him. In the case of the thrust-stage theatre (which does not have a proscenium opening) actors are obliged to perform at times with audience behind them. In this case the optimum profile is a circle with the actor at its centre.

It is interesting to compare this last observation with the experience of the two major thrust-stage theatres in Britain. It is generally accepted that the acoustics of the Sheffield Crucible perform better than those of the Chichester Festival Theatre. In the case of the Crucible, the plan is octagonal with its centre at the principal acting area. The actor facing forward has to project only 18m. On the other hand, the centre of the hexagonal Festival Theatre is over audience in front of the stage; the actor has to project 23m here. There are in fact several additional reasons for the acoustic superiority of the Sheffield theatre but this analysis highlights one significant factor.

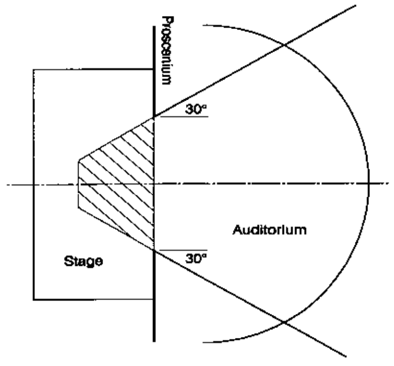

Fig. 6 'Development' of the Horseshoe Plan Form from the Combination of the Circular Acoustic Profile and the Fan-shaped Visual Profile.

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Based on a paper presented at Acoustics '88 at the University of Cambridge

Michael Barron MIOA is in the School of Architecture and Building Engineering at the University of Bath

1990 Autumn Conference
Speech and Hearing
Windermere, 22 - 25 November

The 1990 Autumn Conference on Speech and Hearing was attended by 149 delegates. Some 75 papers were submitted, so the organisers had to decide whether to have these presented in parallel sessions, with the attendant problems of choices and clashes, or to choose some other format. They decided to adopt a mixture of oral and poster presentations. They identified four themes: Aspects of Prosody, Units of Representation, Low Level Processing and Composite Signal Analysis. Oral sessions were organised for each of these themes, and the rest of the papers were presented as posters.

This format appeared to work well. The poster sessions enabled the delegates to talk at length to the authors whose work interested them most, whilst the oral sessions brought everyone together for the presentation of four or five papers followed by a general discussion.

Reports on each of the sessions are given below by the Chairmen of the oral sessions.
Bill Ainsworth, Programme Committee Chairman

Aspects of Prosody.

The first morning began with a lively and varied poster session on the three themes of voice source analysis, dysfunction and aids for the handicapped, and aspects of prosody. The theme of prosody was taken up again in the following formal session, where four oral papers were delivered. Alex Monaghan (CSTR) described the design of a speech corpus that was to serve as the database for deriving prosodic rules in English. Since the more frequent characteristics of English intonation have received much attention over past years, this corpus would be used to investigate more marginal phenomena, such as parentheticals. Tim Gillott (British Telecom) then spoke on a method for assigning natural-sounding intonation to synthesised number strings, and played some convincing examples. Third was Ian Murray (Dundee University), who spoke on ways of simulating vocal emotion by rule for the output of a DECtalk speech synthesiser, demonstrating the result by playing some 'emotional' synthetic speech.

Finally Kate Morton (University of Essex) spoke on her work on improving the naturalness of synthetic speech by using resynthesised human speech.

In the half-hour discussion period that followed, there was clearly much interest in the emotional-sounding speech synthesiser. However, many difficulties with it became apparent, such as the need to determine which emotions are the most 'basic', or the question of whether the acoustic parameters manipulated were limited more by the capabilities of the particular synthesiser used than by analysis of the strategies used by human speakers. Be that as it may, such a high degree of interest indicated that those modelling the acoustic behaviour of the vocal organs might soon have to reckon with the demise of the 'stiff upper lip'!
Briony Williams, CSTR

Units of Representation

A wide range of papers and posters was presented in this session, most being about units of representation or various techniques in automatic speech recognition.

P Green, A Simons (University of Sheffield) and P Roach (University of Leeds) discussed progress being made on the SYLK project, while L Boucher (University of Sheffield) reported in some detail on the use of a syllable classifier as the front end to their recognition system, while A Simons, in a separate paper, continued reporting on his work developing object-oriented techniques for extracting information from speech signal traces. I Howard (University College London) discussed enhancing a neural network recogniser by incorporating a priori knowledge, resulting in a performance better than a reference Hidden Markov Model recogniser.

S Smyth (British Telecom) presented a method of handling temporal variations in speech using a neural network based recogniser, while G Tattersall and P Linford (East Anglia) used Kohonen networks to search for natural temporal features of speech which might subsequently be mapped to phonemes or some other sub-word unit.

M Huckvale and I Howard (University College London) reported further on their work aimed at constructing a continuous phonetic feature description of speech signals using sub-linguistic equal time interval segmentation with a view eventually to developing an automated procedure for performing phonetic analysis.

L Wood and D Pearce (GEC-Marconi) reported on experiments using a hidden Markov Model recogniser with continuous probability distributions; their conclusion called for the use of appropriate statistical models to match distributions occurring in the data, and the ability to train the model parameters from a limited amount of training data.

A demi-syllable model was chosen by D Howell (Howell Associates) for his recognition system for Chinese, while A Breen, S Kapadia, S Whitaker (British Telecom) and S Young (University of Cambridge) discussed experiments in phoneme-based recognition.

Finally, turning to speech synthesis, J Verhoeven (University of Edinbugh) discussed text-to-speech system being developed at CSTR which uses context-sensitive diphones extracted from natural speech as its basic units.

M. Tatham (University of Essex) introduced the SPRUCE project by discussing the usefulness of syllable-sized units as the basis for a text-to-speech system. Several of the presenters touched on the problem of abstraction of representation and the need to be certain of the level of any particular representation and its relationship to other representations at other levels of abstraction. There seems to be a clear indication of theoretically motivated progress in this field which can only lead to improvements in the technology itself.

Marcel Tatham, University of Essex

Low-level Processing

This session spanned a range of topics from experiments in auditory perception through the use of psychoacoustic and physiological models for speech recognition to the presentation of results with statistically derived spectral transformations in a recognition system.

Experiments reported by Andew Lea and Quentin Summerfield (MRC Institute of Hearing Research, Nottingham) showed evidence that listeners can use the shoulders of formant peaks as well as the locations of the peaks themselves in vowel identification.

In a paper co-authored by Malcolm Crawford, Martin Cooke described their beliefs on how large-scale spectral integration should be used to generate an effective representation for speech recognition.

A paper by N Blackwood, G Meyer and W A Ainsworth presented by Bill Ainsworth dealt with a physiological auditory model that is unusual in that the modelling has been extended to cover the auditory nerve and the cochlear nucleus. Tests with voiced plosives (extended to voiceless plosives since the written text was submitted) show an encouraging clustering according to place of articulation, though it is not yet clear whether it represents an advance in this respect over more conventional representations.

A paper by Melvyn Hunt, Steve Richardson and Martin Abbott (Marconi Speech and Information Systems) described how a statistically derived spectral transformation called IMELDA had brought large improvements in recognition accuracy and robustness under acoustic degradations and how it had been incorporated into an Alvey Demonstrator for air traffic control. The presentation included examples of voice manipulation and diphone-based speech ouput for the air traffic control application.

Finally, in a paper co-authored by M A Browne shifted from the preceding poster session, Martin Henery (UMIST) described their psychocoustically scaled spectrograms. The session was punctuated by the chairman waving his arm at a slightly over-running speaker and sending a full glass of water flying acoss the desk, narrowly failing to soak the front row but succeeding in drowning his own viewgraphs.

The discussion period that followed was centred on the question of how one can judge new, opers of new representations as metaphysical and felt that the problem of how to discriminate between good and bad ideas without resorting to somewhat crude recognition tests was a central question in speech research.

Quentin Summerfield commented that we could at least compare the outputs of alternative representations and see which seemed to explain the data better; and John Holdsworth (MRC Research Institute, Cambridge) added that they had found that recognition experiments had improved their auditory models. He offered to test other people's models.

If I may abuse my privilege here with a personal comment, it seems to me that one could sometimes detect a degree of contempt towards approaches to acoustic representation and recognition found in current real-time recognition

Poster Session in Full Swing.

sophisticated acoustic representations. Phil Green, argued that we should look for the insight that they provide into the speech signal and Martin Cooke warned of the danger of leaping into recognition tests with possibly crude recognition algorithms that will give a misleading impression of the effectiveness of the acoustic representation. Clearly, the optimum choice of front-end processing depends on what follows it. While accepting these points, Laurie Moye characterised much of the arguments put forward by devel-

systems. While everyone agrees that the search for more effective alternatives should be encouraged, the attitude expressed by some of their proponents reminds me of that shown by devotees of expert-systems approaches to speech recognition towards 'unintelligent' statistical approaches before their own systems were shown to fail so badly. New methods can only be taken really seriously when they begin to overtake the methods currently being used and contempt will be justified only when they do so not in some

slow, expensive simulation but on cheaper, real-time hardware.
Melvyn Hunt, Marconi Speech and Information Systems

Composite Signal Analysis

The final session of the conference began with three parallel poster sessions on Man-machine Interaction, Speech Generation, and Composite Signal Analysis. The posters on Man-machine Interaction illustrated a range of current concerns with human factors in the use of automatic speech recognisers. Those on Speech Generation, formed a heterogeneous group describing work on the automatic generation and analysis of lip shapes, improved synthesis by rule of allophonic variations, and detailed comparisons of acoustic and electropalatographic speech data. The posters on Composite Signal Analysis addressed questions about the perception of speech in noise and the related issues of how listeners analyse concurrent sources of sound and separate the speech of competing talkers.

The latter two topics recurred in the final formal session of the conference. The session began with a paper from Valerie Beattie and Steve Young who described an adaptation of the standard Hidden Markov recognition procedure designed for robustness in noisy environments. In their adaptation, similar vectors are averaged together, thus smoothing out effects due to the noise. The resulting benefit is particularly impressive in the negative range of signal to noise ratios (SNRs) where it is equivalent to an improvement in SNR of about 7dB.

John Culling then described investigations of the ability of listeners to identify each member of pairs of simultaneously-presented vowels as a function of the difference in fundamental-frequency (fo) between them. His experiments added to what is already known about this task by demonstrating that the improvement in performance with small differences in fo is probably due to consequences of beating between corresponding harmonics rather than to pitch-guided processes of harmonic selection.

Next, Michael Hollier described a new noise-cancelling handset designed to make telephony possible in high levels of background noise. Higher-frequency background noise is attenuated by the geometry of the handset, while lower-frequency background noise is cancelled by an FIR adaptive filter. The necessary differential sampling of signal and noise is achieved by locating two microphones in the handset so as to sample the talker's voice at different points in its pressure gradient, but the background noise in the far-field and thus at equal points in its pressure gradient.

The fourth paper was presented by Sheila Williams, Richard Nicolson, and Phil Green. They reviewed some of Albert Bregman's work on the conditions giving rise to perceptual grouping of sound sources and related it to attempts to implement computational models of auditory scene analysis.

Finally, Mike Goldsmith and Mike Taylor described effects on the fo of the voice of vibrating a talker's body at the 9Hz rate characteristic of aircraft cockpits. Major effects include distortions due to resonances of the anterior chest and abdominal wall. Talkers attempt to counteract these effects with increased muscle tension which imparts a positive skew to the distribution of larynx periods, a factor which may need to be taken into account in the design of speech recognisers for use in aircraft.

As a minor innovation in this session, the audience were allowed to pose questions immediately following each paper, rather than bottling them up for a supposedly effervescent general discussion. The experiment was a partial success with fizzy observations and enquiries made after each paper. However, the general discussion was in danger of falling flat until it was decided to uncork comments on the style and organisation of the whole meeting.

Two proposals met with general approval. The first was the suggestion that the IOA should review its policy of subsidising its other activities from the charges made for attending the Autumn Conference. It was pointed out that the policy was particularly detrimental to attempts to bring graduate students to the conference. Several speakers urged that consideration be given to lowering charges made to graduate students. The second exhortation was that the organising committee should review submitted abstracts and organise formal sessions around coherent themes, possibly introduced by tutorial papers. Despite these criticisms, much appreciation was expressed for the hard work of the conference organisers and the session closed with appreciative applause for Bill Ainsworth, Roy Lawrence, and Cathy Mackenzie.
Quentin Summerfield, MRC IHR, Nottingham

Sonar Transducers for the Nineties

University of Birmingham, 17 - 19 December 1990

This was the 7th International Conference in a series organised by the Underwater Group specifically on SONAR transducers. Like its predecessors it was held in the School of Electronic and Electrical Engineering at the University of Birmingham. The first Conference in the series, Transducer Workshop was held in December 1976.

Originally 25 papers, seven of which were from overseas authors, were to be presented, but because of illness and other reasons three authors withdrew at the last minute and so 22 papers were actually read. There were 72 delegates, of whom 21 were from overseas. The papers were published in an Institute Conference Proceedings, Volume 12 Part 4.

As in most other areas of science and technology the processing power of modern computers is continuing to have an impact on transducer research and design. In particular numerical methods, such as the finite element method (FEM) and boundary element method (BEM), are becoming increasingly used for predicting the dynamical behaviour of particular designs and for predicting their resulting acoustic radiation characteristics. Altogether seven of the papers dealt with either FEM or BEM, or a combination of both; of these, three were mainly concerned with improvements in the methods and the remainder dealt with applications. One further paper looked at the implementation of computer-aided design techniques. It would seem that over the next decade these numerical methods applied to SONAR transducers will become standard tools.

These numerical methods are particularly useful for the study of designs in which two or three dimensions need to be retained, as in some low frequency transducers, such as flextensional types. One of the main limitations with these flextensional structures is their limited operational depth capability. A couple of the papers addressed this problem and in one a novel design which exploits the Helmholtz resonator principle was proposed.

In transducers where a one dimensional description is adequate, such as in sandwich transducer applications and also in high frequency applications, numerical methods are not necessary and equivalent circuit modelling is still appropriate. There were three papers in the programme which looked at equivalent circuits and sandwich type designs. The main parameter of interest was the bandwidth and various ways of increasing this were discussed. It would seem that interest in this area will continue for some years to come.

Array design was the subject of four papers, with the accurate control of beamwidth and sidelobe levels being the main topics of interest. In one design at 100kHz this aperture taper was realised by applying sensitivity control to the array elements, whereas in another design based on PVdF the taper was realised by varying the width of the array continuously over its length. There was also a paper which looked at the acoustic coupling between array elements using TV-holography. Noise in PVdF arrays formed the subject of two further papers, but unfortunately one of these was not able to be presented through illness, although the paper appears in the Proceedings. The current state of optical fibre hydrophones was reviewed.

Finally piezoelectric-polymer composite materials was the subject of two papers. This is an area where interest is growing, not only in underwater applications, but also in the field of ultrasonic inspection.

One important feature of the Conference was the launch of the book Underwater Electroacoustic Transducers by D Stansfield. This is a book which has been promoted by the Underwater Group and the Institute and published by the Bath University Press. During the Conference Dinner the Institute's President, Mike Ankers, gave a short address outlining the history of the book and introducing Dennis Stansfield, who then recounted some of his experiences in transducer design and in the preparation of the manuscript. During the Conference twenty copies of the book were on sale at a special prepublication-date price and these were quickly snapped up by the delegates. Dr. Stansfield then had a busy time autographing the copies.

As the Conference Organiser it is not appropriate for me to comment on the success or otherwise of the Conference, however from my point of view everything seemed to run smoothly with the help of course of the Institute Secretariat. Certainly any success claimed would be largely attributable to the authors, who gave clear and interesting presentations throughout and to the delegates who participated in lively questioning.

B V Smith MIOA, University of Birmingham.

High Intensity Noise

Dartmouth House, London, 5 December 1990

This meeting was held in collaboration with the Society of Environmental Engineers at the English Speaking Union in London on 5 December 1990. Twenty delegates attended, including two from France, and enjoyed a pleasant day reviewing the current state of high intensity noise work and its application to vibration testing. The programme was guided through the day under the chairmanship of Stuart Bennett, Head of Environmental Research Branch of British Coal.

Ann Dowling opened the proceedings with a keynote paper starting with the theory of unsteady combustion noise. From this she showed the dynamic means of noise reduction, using as examples anti-noise where the source produced broad band random noise and active control in tonal or resonance conditions. This latter method was demonstrated to the audience with the use of a Rijke tube when it was shown that the resonance noise could be significantly reduced by changing the boundary conditions with the application of a low level of acoustic energy. The low dependence on phase demonstrated a major difference between the anti-noise and active control methods. This paper concluded with a description of current work examining the practical application of active noise to aircraft gas turbines and afterburners.

Instrumentation developments were discussed in the next two papers. Clive Greated described optical techniques that are currently being assessed for application to high intensity noise measurements. Laser doppler methods can be used for point measurements while the PIV method allows for flow mapping and has been used to study acoustic streaming. These optical methods have the advantage of being non-intrusive and show the greatest potential for measurements above about 100dB.

The next paper was produced at short notice as the planned speaker was unable to attend. Martin Armstrong gave a presentation describing a new probe microphone designed to overcome the previously inherent resonance problems of this type of transducer. By impedance matching within the microphone housing, a uniform high impedance is presented at the probe tip and a wide working bandwidth obtained. Applications for this microphone include measurements in cavities down to 1cc in volume and in temperatures up to 700°C.

After lunch Derek Sims gave a resume of the characteristics of typical high intensity noise sources that cause vibration in equipment. It was shown that the application of high intensity noise in the laboratory for vibration stimulation has been demonstrated to be simple and efficient in the aerospace and military fields and has application in many other areas. As an example the application of noise to the vibration testing of PCB's was examined. From this, methods of generation using air modulators and the control systems available to meet current test specifications were presented and the various system components described.

Two test facilities were then examined. The design features of a facility originally built for the examination of fatigue failure mechanisms in nuclear power plant cooling systems were first described by Ron Enderby. Vibration and noise isolation are an important requirement to prevent interference with external working conditions, requiring the use of under floor isolators and the integral construction of expansion chambers and attenuators for exhausting the transducer air. Instrumentation and safety requirements were described as were the requirements for testing spacecraft and aircraft equipment.

The final paper described another facility designed for testing aircraft-carried weapons and other stores. This was presented by David Elson who detailed the special design features required for this application. In addition to the application of high intensity noise it is also necessary to apply mechanical vibration and high or low temperatures simultaneously. This puts stringent requirements on the chamber construction and noise attenuation and these special details were discussed. Again the special requirements for spacecraft testing were reviewed.

The low attendance at this meeting reflects the specialised nature of the subject matter. However the meeting provided a forum for workers in this area to discuss their special requirements as was demonstrated by the lively question and discussion periods between papers and during the breaks.

D Sims MIOA, D Sims Associates ❖

New Products

SERAC
Pratisol Panels

The French company SERAC has developed and begun marketing standard insulating panels to make booths, screens and partitions. Called PRATISOL, these panels can accommodate made-to-measure requirements as well as limited budgets.

PRATISOL panels are 400mm wide and can be delivered at the height desired by the customer. They are easily installed vertically on a frame that is built to the customer's specifications. Sturdy and attractive, they are easy to put up and to take down. The panels have an average absorption coefficient of 0.9.

The product line includes several different models:

S1: one solid frame, the other perforated.
S2: same as S1 but with an internal membrane.
S3: solid double-faced panel.
S4: double faced perforated panel with internal membrane.

Regardless of the model selected, PRATISOL panels all boast certain features as standard: exterior ribbed steel metal; mineral wool with a density of 55kg per cubic metre measuring 50mm in thickness; and an interior ribbed perforated sheet metal. The metal is galvanised and then lacquered with epoxy in white, beige or green.

When PRATISOL panels are used to make soundproof booths the customer will enjoy a finished product that is extremely practical in design and economical to purchase and maintain.

Further information on this product may be obtained by contacting M Roux, Société SERAC (Société d'Etudes et de Réalisations Acoustiques), Z.I. la Mariniére, Rue Gutenberg, Bondoufle, 91037 EVRY cedex, France. Tel: (010 33) 60 86 43 19 Fax: (010 33) 60 86 54 59. Telex:602 668.

Boral Edenhall
Noisemaster Blocks

Boral Edenhall Concrete Products Limited are offering, free of charge, a 12 minute audio cassette which demonstrates the acoustic advantages of their NOISEMASTER sound absorbing structural masonry units. The cassette briefly covers acoustic theory, indicating why these units are effective in promoting acoustic comfort, and utilises on-site recordings to prove their efficiency in reducing reverberation times and reverberant sound pressure levels.

To receive a copy, or copies, of this cassette, please contact P G Avison or Mrs Helen Shaw on 0768 890202 or write to Boral Edenhall Concrete Products Limited, Barbary Plains, Edenhall, Penrith, Cumbria CA11 8SP.

Dynamic Engineering
Sysnoise Program

Dynamic Engineering is a company specialising in noise and vibration and structural analysis and has announced a new version of their SYSNOISE program for modelling acoustic fields, running on PC's.

SYSNOISE-PC offers all of the functions of the other versions on work-stations and mainframes - including interior and exterior acoustic fields, with finite elements and boundary elements and fluid-structure interaction.

Minimum requirement is a 386 PC with maths co-processor, VGA graphics, 4Mb and 60Mb hard disc. SYSNOISE interfaces to PC-based processors and structural analysis programs, such as ANSYS-PC.

Application fields include noise inside and outside vehicles and aircraft, ship hull-water interaction, domestic appliances and audio equipment.

Dynamic Engineering expect SYSNOISE-PC to expand the range of uses and make the software more accessible to smaller companies.

Further details may be obtained from Dynamic Engineering, Aizlewood's Mill, Nursery Street, Sheffield S3 8GG. Tel:0742 823141.

Bruel & Kjaer
High Frequency Module For Bruel & Kjær Analysers

A new high-frequency module for Bruel & Kjær's type 2123 and 2133 signal analysers broadens and extends applications areas in underwater acoustics, transient analysis, and fast analysis of stationary signals.

With the ZT 0318 High-frequency Module the analysis range of Bruel & Kjær's real-time frequency analysers is extended by a factor of eight.

The module can be installed in either analyser to enable single-channel spectra to be measured in real time at higher frequencies.

Of particular value in underwater acoustics measurements are increases in octave and 1/3rd octave analysis maximum centre frequencies to 63kHz and 80kHz respectively.

Excellent for QC applications are 1/12th octave analysis up to 21.8kHz for either one or two channels, and 1/24th octave analysis up to 11.1kHz single-channel.

Installation of the two modules in the dual-channel analyser extends the real-time frequency range of dual-channel measurements.

The high-frequency digital filters of the ZT 0318 are in accordance with ANSI S1.11-1986, IEC 225-1966 and DIN 45652.

Measurements via the ZT 0318 are simply added to the screen display.

All post-processing capabilities can be applied to the high-frequency data.

Although the new module significantly advances the analysis power of the instruments there are no changes in operation.

Further information on this or on any other product in the current range may be obtained by contacting Les Minikin, Bruel & Kjær (UK) Limited, 92 Uxbridge Road, Harrow, Middlesex HA3 6BZ. Tel: 081 954 2366. Fax: 081 954 9504 Telex: 934150 BK UK G.

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Cirrus Research

Cirrus Crl 702 Data Logging Sound Level Meter

The CRL702 Data Logging Sound Level Meter is built to the full requirement of type 1 IEC 651 (BS 5969) and IEC 804 (BS 6689) and has over 60 functions accessed via the 16 keys on the meter's key pad.

The exact functions of the CRL 702 can be factory configured, as a standard instrument, or using an optional Cirrus configuration program to amend the instrument to perform any 16 functions.

The factory configured instrument is "locked" and can only be "freed" using the reconfiguration software. If the instrument's keypad has changed, a new key plate can be printed out, and inserted behind the key plate membrane. The instrument configuration consists of combinations of Sound Exposure Level (SEL),$L_{EP,d}$, Dose, Peak, SoundLevel, L_{eq}, and Statistical Levels such as L_{10}, etc.

The CRL 702 logs acoustic data in two ways both as a summary in the event format or in detail as Short L_{eq}'s. The user defined event register can be arranged to operate on both keypad control or timed events, and typically gives a report containing the event number, it's start time and duration, L_{eq}, and parameters such as L_{90}, L_{95}, Peak, and $L_{EP,d}$. This format is ideal for long term monitoring, as the report is a text file for use with computer databases or word processor report packages.

The CRL 702 can itself perform some calculations and print out the event report on to a standard printer. Additionally, the CRL 702, acquires up to 32,000 Short L_{eq} samples allowing in excess of 18hrs to be logged at an acquisition rate of 2 seconds.

The acquired data can either be transferred to an MS-DOS computer for analysis allowing the user to examine the total noise history or use the base data to re-analyse the data calculating new indices or L_{eq}'s for part of the logged noise period. During operation the instrument can display any of the keypad functions on its display without affecting the data acquisition.

The CRL 702 can be used in all circumstances where an older analogue sound level meter could be used, normally with a big increase in ease of use and much improved data gathering. When measuring factory noise all that would be required would be to walk round a factory pressing RUN then STOP at each location to perform a survey - being a dual channel instrument it is able to measure both the dose related parameter, $L_{EP,d}$ and the PEAK level in dBC. For monitoring environmental noise in inclement weather, a waterproof kit is available.

For further information contact Duncan Brown, Cirrus Research Ltd., Acoustic House, Bridlington Road, Hunmanby, North Yorkshire, YO14 0PH. Tel: 0723 891655.

Cirrus Research Ltd is a KEY SPONSOR of the Institute

Loughborough Sound Images

Dual Processor VME Board

Loughborough Sound Images, the DSP specialists, has launched the DPV30 Dual Processor VME Board that is designed to provide a powerful, general purpose, Digital Signal Processing system for the VMEbus. The board's specification features a 66 MFLOPS processing engine using two Texas Instruments' TMS320C30 processors, a substantial memory configuration as standard and optional analog interface. The DPV30 is the first VME board to offer a highly optimised signal processing architecture which allows multiple processors to share data using DPRAM to maximise throughput. Applications of the DPV30 include radar/sonar, real-time processing of speech and audio, image processing, test and measurement systems, robotics, numerical/array processing, vibration analysis, telecommunications and many more.

The DPV30 is well supported by a comprehensive range of software tools for both development and system integration. These include TI's Assembler/Linker and C Compiler tools, debug Monitors and Interface Libraries from LSI and the SPOX DSP operating system Real-time and SunOS device drivers are provided as standard and applications can be developed in DOS or Unix environments using PC AT compatible VME hosts or Sun SPARC workstations respectively. The DPV30 can function as an application development platform in Sun workstations (SPARC station 330, 390, 470 etc), or as an embedded signal processor to a real-time VME based host.

Loughborough Sound Images Ltd is a SPONSORING ORGANISATION of the Institute

GenRad

Vibration Controller Gr2518

The GR2518 employs versatile,general-purpose hardware which provides the processing power for precision vibration control and signal analysis functions.

A wide and expanding array of software modules allows the user to tailor the system to the exact requirements of the application, and to add new test capability as the need arises.

The system is designed to take the complexity and tedium out of vibration testing. All system operations are controlled via the keyboard and monitor using menu-driven software. The user is supplied with all the data and graphics displays needed to monitor and interact with the testing process. The system features high-resolution colour graphics, and a lower-cost monochrome option is also available.

Comprehensive test data is automatically stored to hard disk or floppy. The entire process can be automated by using a remote computer or environmental chamber controller to supervise the vibration test. Outputs to printer and to host computer, PC or workstation are available. Operator and product safety are ensured by a range of alarm and abort facilities.

Software for vibration control includes a RANDOM package which provides accurate, closed-loop testing using true-Gaussian random-drive signals; a SINE package designed for digital, closed-loop, multi-input swept-sine tests; and SHOCK software which subjects the product to simulated shock environments, including pyro-shock, earthquake and other complex tests. In addition, software for mixed-mode testing offers both random-on-random and sine-on-random capabilities. Testing meets MIL-STD requirements where appropriate.

Further to vibration control, the GR2518 can be equipped with software for a variety of real-time measurement and analysis tasks, including data acquisition, frequency response, coherence, auto-spectrum and cross-spectrum analyses. Software for advanced modal analysis is also available.

Further information is available from GenRad Limited, 3 Roxborough Way, Foundation Park, Maidenhead, Berks. SL6 3UD. Tel: 0628 826941 Fax: 0628 822332 Telex: 848321

Procurement Services International Ltd

Acoustic Barrier System

PSI specialise in solving material problems in the construction industry. PSI have released information on their new demountable, self-supporting and re-usable acoustic barrier system called Psilentform. Blocks are laid dry and lock together through a tongue and groove arrangement. The system was designed with the assistance of Colin English of Arup Acoustics and tests at Salford have returned values of Rw = 40 dB. Test data is available by contacting A D Precey on 081 310 3000.

ANC Report

Noise is defined as "unwanted sound" and it has been suggested that the Association of Noise Consultants could therefore be renamed the Association of Unwanted Sound Consultants. This might avoid confusion of our initials with those of another, slightly better-known organisation, but we remain the ANC and our members even have ANC site signboards to prove it. The choice of a colour for this was one of the less momentous decisions of Council last year, although one member was fortunate not to have his tie sent to the signwriters as a colour sample.

The ANC exists to promote the image, activities and professional standards of independent acoustics consultants and to represent their views to policy-making bodies. We have been consulted by, or represented on, most of the relevant committees and working parties over the last year, and our views have had some influence in the revised Building Regulations (Approved Document E), the Report of the Noise Review Working Party 1990, the UKELA initiative and a variety of less well-known but relevant publications. Perhaps the most important document on noise to emerge last year was the new BS 4142-1990 which has already aroused much controversy (rumours that the lower temperature limit on measurements was added by the ANC representative to avoid frostbitten hands have been strongly denied). The Association also commented on the draft revision of BS 6472, although with what effect is not known.

The Association's second conference was held in June 1990 at Goodwood, on the subject of Outdoor Leisure Noise. This was a joint venture with the IOA and its success was confirmed by a healthy operating surplus, from which a substantial donation went to the Institute of Acoustics. This will be used to assist with archiving the papers of the late R W B Stephens. An encouraging aspect of this conference was the dialogue between consultants and delegates from local authorities, all keen to establish standard methods to evaluate noise nuisance. Another meeting on Living with Leq is planned for some future date and we hope that these meetings will become a regular feature of the acoustician's calender.

The ANC's long-term activities include assessing calibration methods to ensure uniformity between consultants without necessarily incurring the cost and inconvenience of full NAMAS registration, and evaluating the state of the consultancy market in the European Community in preparation for 1992. Several consultancies from abroad have already shown considerable interest in Britain and we hope that British consultancies will not miss the boat (or, indeed, the Channel Tunnel). The title "Towards 1992" is thought to refer to the date of the first meeting of an ANC working party on Europe.

One question which may be of wider interest is the IOA self certification scheme for Competent Persons in respect of the Noise at Work Regulations 1989. Although some members of ANC firms have registered through the IOA, the Association of Noise Consultants have taken the view that this is not necessary as ANC members should be competent to carry out such work in any case.

BEPAC's First Anniversary

BEPAC, which stands for Building Environmental Performance Analysis Club, was formed in 1987 to provide a forum for all concerned with the prediction of environmental conditions in buildings.

The scope of BEPAC includes thermal, visual and acoustic environmental design, with a particular interest in sharing data, methods and experience within and between these fields.

In early 1990, the Acoustics Task Group was formed. It has now passed its first anniversary and has successfully consolidated into a small group of enthusiastic members.

The Group believes that it has a role to play that differs from other acoustics related organisations. The Acoustic Group's principal functions are:-

1) To promote information interchange and interaction between Consultants, Industry, Research and Educational Establishments. This is a general function of BEPAC which is aided by:-

- BEPAC Task Group Meetings; the Acoustics Group Meetings are held on a 3-monthly basis at which an informal lecture is given by an invited speaker on an acoustics related topic followed by general discussion.
- BEPAC Workshops and Seminars.
- BEPAC Conferences, the first of which, Building Environmental Performance '91 will be held on 10/11 April 1991 in Canterbury.

2) To encourage communication and co-operation between Industry and Research/Educational Establishments on projects of mutual interest for the benefit of each party and acoustics research as a whole.

3) To seek topics recognised by Industry and Designers as in need of research and to disseminate this information to Colleges and Universities as suggestions for undergraduate and postgraduate projects.

4) To undertake specific projects and oversee the publication of Technical Notes and Research Papers. With regard to this latter aim, specific projects on which the Acoustics Group is currently working is a Directory of UK Acoustic Testing Facilities. Once completed, the directory will be available for purchase from BEPAC as a Technical Note, from BEPAC Administration, Building Research Establishment, Bucknalls Lane, Garston, Watford WD2 7JR Tel 0923 664132.

To assist in this task, any Acoustics Testing Facility which might wish to be included in this directory should contact the Acoustics Group Chairman on the telephone number below.

The Group is eager to attract a wider membership and would welcome new members from all fields. More information on the Acoustics Group or other BEPAC Task Groups, contact Peter Henson at Bickerdike Allen Partners, 121 Salusbury Road, London NW6 6RG, Tel: 071 625 4411.

Airport Noise Monitoring System

The noise levels within Birmingham's International Airport are to be assessed on a regular basis.

The airport's Safety Officer, John L'Amie, has taken delivery of a new monitoring system from Lucas CEL Instruments to enable regular checks to be made of the noise levels in all areas of the airport complex, outbuildings and apron areas.

The objective is to assess the sound levels affecting up to 300 staff working within the airport's environs so that measures can be taken to limit noise exposure and to identify areas where ear protectors should be worn.

Information on CEL portable noise monitoring systems can be obtained from: Lucas CEL Instruments Ltd., 35-37 Bury Mead Road, Hitchin, Herts. SG5 1RT Tel 0462 422411 Fax: 0462 422511

Lucas CEL Instruments Ltd is a KEY SPONSOR of the Institute

Representative Named for UK

Quantitech Limited, of Milton Keynes, has been appointed the sole UK representative for RION noise monitoring equipment.

The RION range, manufactured in Japan, includes both Type 1 and Type 2 noise meters, a combined sound level meter and octave band analyser, and a one third octave band real time analyser.

Contact K Golding, Quantitech Ltd, 75 Garamonde Drive, Wymbush, Milton Keynes, Buckinghamshire, MK8 8DD Tel 0908 56414 Fax 0908 260554

Name Change

Norwegian Electronics announce a change of name to Norsonic AS effective from the first February 1991.

The name change results from a growing need for a name giving a better description of the Company's activities - supplying instrumentation for acoustics and vibration measurements.

The new name is close to the original title - Nortronic, the well known name the Company has been prevented from using outside Norway since early 1979. In spite of this many customers still refer to Nortronic throughout the world, further motivating the change from Norwegian Electronics to Norsonic.

Gracey & Associates, High Street Chelveston Northants NN9 6AS - are the UK exclusive agents. Tel. 0933 624 212 Fax 0933 624608

Gracey & Associates is a SPONSORING ORGANISATION of the Institute

BS 5750 Part 2 Registration

Ferguson & Timpson, the established Glasgow company, have gained BS 5750 Part 2 registration, with BSI Quality Assurance. This is the international ISO 9002 quality control standard.

Ferguson & Timpson, specialise in processing noise control and sealing materials, used for example in computers, banking terminals, oil production equipment and domestic 'white goods'.

The company have branches and production facilities in London, Birmingham, Liverpool and Hull.

For further information contact: Peter Timpson, Ferguson & Timpson, 5 Athol Avenue, Glasgow G52 4UA Tel 041 882 4691 ext. 401 Fax 041 810 3402

From the Vice-President, Groups and Branches

Members will I am sure have noticed that a new Group has been formed, namely Electroacoustics. This was approved by Council at their December Meeting. It is hoped that in a future issue of the Bulletin more details about this Group, its aims, objectives and coverage will be given. I don't know whether its something in the air or whether its the time of the year, but there is also a suggestion under consideration that another Group be formed, however, more about that at a later time if approval is given.

I am delighted to be able to report that the long awaited book, "Underwater Electroacoustic transducers" by Dr D Stansfield has now been published. It was formally launched at the December Conference, Sonar Transducers for the Nineties, where it was well received. The Underwater Acoustics Group are to be congratulated for initiating this project, for then persevering with it over the long gestation period and finally for achieving a successful birth. I am sure this book will enhance the Institute's reputation in the eyes of the underwater acoustics community both inside and outside the UK. Our thanks go to Dr Stansfield for all his efforts and for his patience.

About a year ago the Institute created the post of overseas co-ordinator. One of the terms of reference of this post is to promote the Institute and its activities in countries where no national body exists. Towards this end Dr R Orlowski, who was appointed by Council to this post, has proposed that various people in such countries be identified and invited to promote the Institute locally. For this service they would receive complimentary copies of the Bulletin and other material normally circulated to members. Although this proposal has yet to receive formal approval from Council it would be useful at this stage for any Institute Member who knows of anyone overseas who might be prepared to act in this way to pass on that person's name to me. Incidentally another of the tasks of the co-ordinator is to encourage contact between overseas members and the Institute, so if there is anybody out there who feels neglected let him speak.

The last couple of Bulletins were a little short of reports from Groups and Branches so can I please urge you to write in and keep us up to date with your activities and plans.

Brian Smith, Department of Electronics and Electrical Engineering, University of Birmingham, PO Box 363 Birmingham B15 2TT.

North West Branch Visit to Pilkington Glass Plc

On the 6 March 1991 twenty one members of the North West Branch visited Pilkington Glass Ltd at St Helens. This was the third visit to Pilkingtons made by the branch and Cliff Inman from the Environmental Advisory Service had arranged a tour around yet another part of the works and this time Pilkington Architectural was selected. This part of the business is responsible for manufacturing a wide range of glazing products used in buildings including double glazed units, planar components and a variety of intricately shaped windows.

The group were shown around the production lines and were impressed at the size of some of the glazed panels, at the relative ease with which holes were cut and at the variety of ceramic finishes now being applied to curtain walling. The toughening process was also explained and illustrated.

Following the tour members were treated to a buffet tea in the Glass Museum and Cliff gave an illustrated talk on the development of Pilkington's current range of acoustic double glazing products including the Rw range. It was noted that the development had been carried out in collaboration with the University of Salford culminating in the design of a double glazed unit with an Rw index of 45dB. Cliff used results from the tests to illustrate the limitations of Rw when dealing with traffic noise and brought the branch members up to date with the thinking in both ISO and CEN where the introduction of a traffic noise index is actively being considered.

Following the meeting members were free to browse and view the many and varied exhibits in the Pilkington Glass Museum. Our thanks go to Cliff Inman for once again providing the Institute with an excellent meeting.

Geoff Kerry

London Branch Meeting
Sound Systems at Football Grounds

The London Branch meeting evening speaker on 16 January 1991 was Jim Griffiths of Travers Morgan. Jim's excellent talk on sound systems at football grounds, emphasised the safety requirements that are needed in emergency situations. Jim explained that the principle of "talking people out of danger" lies at the heart of a good sound system.

It was noted that the high technical quality required of the overall design adds to the cost, but this has to be set against the value of human life; and there is the possibility of partially offsetting the extra cost by using the sound system for increased advertising.

The Interim Report from Lord Justice Taylor into the tragic disaster at Hillsborough was discussed. Among many others the Interim Report carries the following recommendations:

1) consideration should be given to 'sound proofing' the control room from external noise,

2) within the control room there should be public address systems linked to individual areas in the stadium, and

3) emergency announcements should start with a loud preannouncement tone.

Lord Justice Taylor's Final

Report provides more details, including the need for public address systems outside and inside of the grounds and the requirement for long term back-up power supply.

Jim explained the need for a Code of Practice for the licensing and operation of sound systems and supplied a check list for licensing inspectors which included:

1) establish a chain of command,
2) examine previous certification - check for conditions,
3) establish contact with sound system operators,
4) inspect the main equipment racks room,
5) inspect documents - maintenance test procedures
6) inspect and test back-up power supplies.
7) check that emergency microphones over-ride all other sound systems
8) check for audibility using a pre-announcement tone or chime - (noting audience noise can be 95 dB (A)),
9) check intelligibility with the ground full

Jim concluded this talk with a pictorial run through the excellent sound system that he and his Company have designed for Wembley Stadium. His brief was to design the best system in the world regardless of cost! When results were put to the test even the Rolling Stones Road Manager had to admit it was pretty good.

Ken Scannell

Non-institute Meetings

1991

9-11 April Active Control of Sound and Vibration, Japan. Contact: Acoustical Socity of Japan, 2-7-7 Yoyogi, Shibuya-ku, Tokyo

23-25 April Noise in Metropolitan Cities, Madrid. Contact: Secretariat, Central de Congresos, Ave. General Peron, 26-28020 Madrid.

28 April Acoustical Society of America. Contact: 50C Sunnyside Blvd, Woodbury NY11797 USA.

7-9 May 9th FASE Symposium, Hungary. Contact: Optical Acoustical and Filmtechnical Society. H-1371 Budapest, PO B 433, Hungary.

21-23 May Flow Induced Vibration, Brighton. Contact: IMechE, 1 Birdcage Walk, London SW1H 9JJ

1 4 July Ultrasonics International '91, France. Contact: M Kukovojac, Butterworth Scientific Ltd, PO Box 63, Westbury House, Bury Street, Guildford

2-4 July COMDEM 91, Southampton. Contact: Dr R Rao, Southampton University.

14-16 July NOISE-CON 91, America. Contact: PO Box 2469, Arlington Branch, Poughkeepsie. NY12603, USA.

15-19 July 4th Recent Advances in Structural Dynamics, Southampton. Contact: ISVR, The University, Southampton S09 5NH

19-24 August 12th International Congress on Phonetic Sciences, France. Contact: Secretariat, Université de Provence, 29 Avenue Robert Schuman, 13621 Aix en Provence Cedex 1 France.

4-7 October 91st AES Convention, New York. Contact: AES, 60 East 42nd Street, New York NY 10165.

26-28 November Western Pacific Regional Acoustics Conference 4, Australia. Contact: Conference Organiser, PO Box 15, North Quay, Queensland, Australia 4002.

2-4 December INTER-NOISE 91, Australia. Contact: Conference Secretariat Uniresearch Ltd., PO Box I, Kensington, NSW 2033, Australia.

4 -5 December Auditory processing of complex sounds. Contact: The Royal Society, 5 Carlton House Terrace, London.

1992

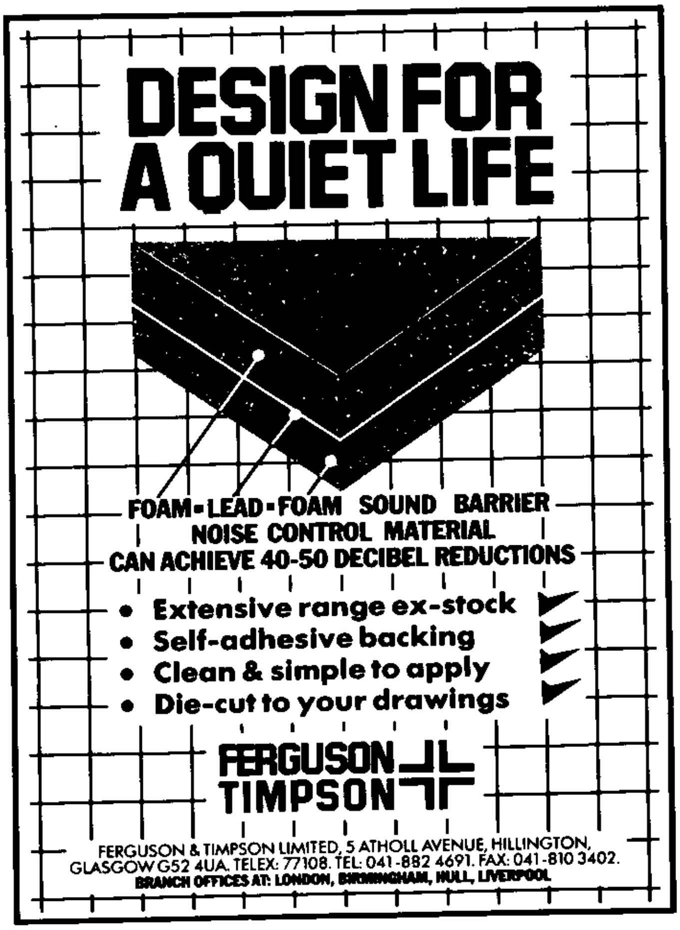
23-28 March 16th Wegemt School on Noise, Vibration and Shock On Board Ships, Genoa. Contact: CETANA, Via al Molo Giano, 16126 Genoa Italy

April 2nd French Conference on Acoustics, France. Contact: Congres Francais D'Acoustique, Mecanique Physique, Université de Bordeaux 1, 33405 Talence Cedex, France.

18-22 July INTER-NOISE 92, Toronto, Canada.

3-10 September 14th International Congress on Acoustics, China. Contact: 14th ICA Secretariat, c/o Institute of Acoustics, Chinese Academy of Sciences, PO Box 2712, Beijing 10080. China.

26-27 November Australian Acoustical Society Annual Conference, Ballarat, Australia. Contact: Australian Acoustical Society, Australian Road Research Board, PO Box 156 Nunawading, Victoria 3131, Australia.



THE WORLD'S FINEST MEASURING MICROPHONES

Surprised to see the Larson-Davis name on this ad? So is the competition! But then, Larson-Davis has introduced a lot of surprises lately. With our fast growing high-tech product family, it shouldn't be too surprising that the company with the most advanced electronics for acoustics test now offers the most advanced precision microphones, power supplies and accessories.

The introduction of our new precision microphone family is the result of nearly a decade of continuous research and development by our laboratory personnel. Dramatic improvements have been achieved that propel Larson-Davis microphones into the forefront of the measuring microphone technology. Consider the features and benefits:

- Our proprietary metal diaphragm material is significantly stronger and more durable than the competition's.
- Industrial acids and corrosives which can evaporate competitive microphone diaphragms in seconds will not harm Larson-Davis diaphragms. Our new diaphragms, are much more impervious to environmental influences than even specially coated competitive microphone diaphragms.
- Larson-Davis microphones exhibit no permanent change in frequency response, or sensitivity at operating temperatures beyond 150 C°.
- Larson-Davis diaphragms do not exhibit a tendency for pin-hole failures.
- Computer controlled parts tolerances guarantee more consistent microphone specifications, and optional precision phase/amplitude matching of cartridges.
- Larson-Davis microphones cost less to buy and substantially less to maintain.
- Should you ever manage to damage a microphone, we will rebuild it to full traceability for less than half the cost of a new microphone.
- Finally, switching to our microphones is painless because of the virtually identical frequency characteristics and exact mechanical interchangeability with competitive microphones.

Contact our representatives, or the factory for additional information.

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