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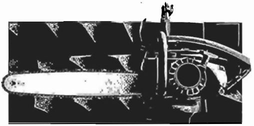

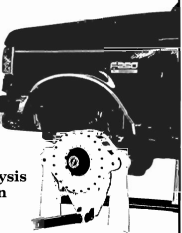

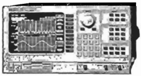

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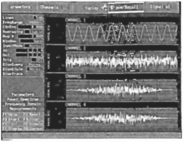

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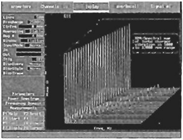

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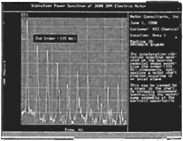

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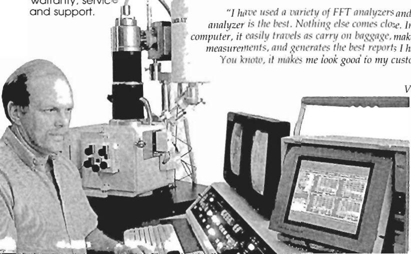

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Editorials

FROM THE PRESIDENT

This issue of Acoustics Australia marks a significant occasion. It is the inaugural issue from the new editorial team of Neville Fletcher, Marion Burgess, Joseph Lai and Leigh Kenna. Not only do we wish them well for the task but we (i.e., all the members of the Society) also express our gratitude to them. The Society operates largely on the voluntary efforts of Councillors, Committees and others throughout the country, with many people giving much time to Society matters. The efforts of all are much appreciated.

We also say an editorial farewell to Howard Pollard, who has relinquished the position of Chief Editor after 12 years of sterling service. Howard was responsible for implementing the change from "The Bulletin" to Acoustics Australia, and under his guidance the journal has developed and maintained a standard of excellence. A most sincere thank you, Howard.

The new Chief Editor might be too modest to announce this, so I shall do it for him. Dr. Neville Fletcher has been awarded the Lyle Medal of the Australian Academy of Science.This is a notable honour. The citation from the Academy reads as follows:

"Professor Neville Fletcher has done pioneering work in many branches of applied physics. He trained as a solid-state physicist, and did notable design and development work on high-power transistors and related semiconductor devices. He then turned to the physics of ice and related materials and is particularly known for his work on the surface structure of ice and water. He also did important work on the theory of heterogeneous nucleation of phase changes, particularly in relation to the physics of rain clouds. More recently he turned his attention to acoustics, initially in relation to the nonlinear acoustics of musical instruments and related vibrating systems, and then to the analysis of acoustic systems in biology, where similar methods could be applied. In both of these fields he has also made notable contributions. He has written four definitive post-graduate texts, as well as publishing widely in the scientific literature. The Lyle medal is appropriately awarded to this physicist sui generis who is no conformist in a narrow field but has turned his hand to the physics of everything from ice crystals to handbells."

Congratulations Neville.

Robert Hooker

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FROM THE EDITORS

Following a very long period under the editorial guidance of Howard Pollard in Sydney, we have agreed to carry the torch in Canberra and this is our first issue. We hope to maintain the high standards of content and production set for our journal by Howard, and we plan no major changes in form or in editorial content. Our aim is to make Acoustics Australia an interesting technical journal for all members of the Society, not just for specialists, and to make it also a channel for communication of news and views about matters of importance to our professional community. If you have any comments or suggestions, we would be delighted to hear from you.

We live in interesting times --- perhaps under the influence of that classic Chinese curse --- and many things about the future are unsure. What is sure, however, is that the problems of noise and its control, the use of acoustic and vibrational techniques to investigate materials and structures, including the human body, and the imaginative employment of acoustics to enhance our enjoyment of speech and music, will assume increasing importance to society in the years to come. We may not need thousands of acousticians in Australia, but what we will continue to require is a smaller group of well trained, experienced and imaginative professionals to cover this wide spread of important topics. As well as looking to our own interests, therefore, we must plan ahead to educate the new generation who will carry on the work. Acoustics Australia aims to provide one link in this chain.

Almost above all, however, scientific and technical professions are fun! We enjoy testing our skills against new problems, we enjoy seeing the advance of the profession with new techniques and new instruments, and we enjoy the community of interest with fellow acousticians. We trust that our journal will reflect all these positive sentiments, even though we may have cause at times to be gloomily realistic about other things.

Neville Fletcher

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Letters to the Editors are invited on any relevant matters.

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Impact Descriptors Versus Exposure Indices In Environmental Assessment

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Department of Government, Economics & Logistics
University of Southern Queensland
Toowoomba, Qld, 4350

ABSTRACT: Environmental noise impact in Australia is measured indirectly using noise exposure indices rather than directly in terms of impact descriptors. This focusing on exposure rather than on impact can result in environmental assessments which seriously under-estimate the true noise impact of a development proposal on residential communities. This article recommends the use of impact descriptors in addition to an exposure index to ensure that assessments provide developers, residents and decision-makers with a complete picture of potential impacts. Aircraft noise is used as an example to illustrate how impact descriptors can be applied.

1. INTRODUCTION

In environmental assessment, the impact of noise on residential communities is described indirectly in terms of a noise exposure index. The most widely used general exposure index is Leq (often with a weighting for night-time noise), but a variety of other indices have been developed for specific noise types. For example, traffic noise indices include the L10(18 Hour) [1] and the Traffic Noise Level [2], and artillery noise can be measured by the C-weighted Day-Night Level [3] or the Accumulated Peak Level [4]. In the case of aircraft noise, exposure is described in terms of the Ldn index in the US, and in terms of the Australian Noise Exposure Forecast (ANEF) index in Australia. The latter index was developed from a socio-acoustic study [5], and has been adopted by planning authorities for aircraft noise assessment throughout Australia. A major problem is that noise exposure indices, such as ANEF, are being inappropriately applied in environmental assessment, and as a result, the impact on residents around airports is under-estimated when decisions are made.

2. ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment (EIA) was introduced into Australia with the Commonwealth *Environment Protection (Impact of Proposals) Act 1974* whose stated object is: "to ensure, to the greatest extent that is practicable, that matters affecting the environment to a significant extent are fully examined and taken into account" [s.5(1)]. The legislation comprises the Act, a set of Regulations, and a set of Administrative Procedures, the latter specifying the requirements for the preparation of environmental impact statements (EIS). In addition to the Commonwealth legislation, each of the states has its own statutes on EIA, but there are agreements covering procedures where there is overlap with the Commonwealth [6].

The Australian legislation was derived from the US *National Environmental Policy Act of 1969*, but differed in that it provided for much more ministerial discretion. The stated rationale for this high level of discretion was to avoid the costly delays experienced in the US, but according to Formby, "a major reason for the discretionary wording was to leave the government wide flexibility in implementation" [7, p.211]. Essentially, all government decision-making is political and, therefore, partly irrational [8]. The EIA process is designed to increase the rationality involved by increasing the range of relevant information that is available. Thus, the environmental effects and not just the economic aspects of proposals are purportedly considered by those making the final decision about a proposal.

For major proposals, the developer is required to provide an EIS which serves three functions:

1) as a guide to developers seeking to minimise impact;
2) as a stimulus for input from those affected; and
3) as a source of information for decision-makers.

Most EISs are prepared by consultants who have expertise in the various aspects of environmental impact, with the noise impact usually estimated by a specialist acoustical consultant. After a draft EIS is prepared, it is forwarded to the relevant minister and released for public comment. The final EIS includes the draft plus a supplement which responds to the public comments submitted. The formal assessment phase involves the relevant minister seeking advice from technocrats (expert public servants) on the final EIS before making a decision, or in the case of major proposals, before presenting it to the Cabinet which supposedly takes account of the environmental impact before making a fully informed decision.

3. TYPES OF IMPACT

What is meant by "impact"? Although this term is central to the theory and practice of environmental assessment, there is no consensus on its meaning. The Impact of Proposals Act does not provide a definition. Impact can be defined simply as "influence or effect" [9]. A more precise definition is as follows: "The environmental impact of an action is the difference between the state or condition of the environment which occurs as a result of that action being taken or with-held, and the state or condition which would otherwise occur" [10]. On this definition, it is important to distinguish three categories of impact:

1) *Negligible impacts* are those effects which can be regarded as either trivial or of undoubted minor consequence; such impacts can be ignored in environmental assessment because they are clearly not "significant" as required by the legislation;
2) *Critical impacts* are those effects which exceed criteria specified by planners or regulatory authorities; critical impacts form the basis for most of the analysis in environmental assessment;
3) *Notable impacts* are those effects which are neither negligible nor critical, but which contribute to the information needs of developers, of those affected by the development, and of those charged with decision-making responsibilities.

Of these three types of impact, it is the notable impacts that cause problems because they are often ignored in EISs. Where an impact does not exceed a specified criterion level, it is a matter of convention and/or discretion whether the impact is treated as "non-significant" and is, therefore, not even mentioned. To ignore notable impacts in an EIS is to deny those affected by a proposal access to information that is relevant to their interests. Also, unless those deciding on the fate of a proposal have all the information relevant to describing the various non-negligible impacts (i.e., notable impacts as well as critical impacts), they will not be able to make a thorough evaluation or an informed decision.

4. EXPOSURE INDICES VS IMPACT DESCRIPTORS

For the assessment of environmental noise, the convention is to describe the amount of noise to which the community will be subjected by a proposed development. Thus, the primary focus is on exposure rather than on impact per se. Using an exposure index, contours for different noise levels are plotted indicating exposure at various distances from the noise source, be it an airport, an entertainment venue, a freeway, a railway, a factory or a military range. However, the exposure index does not, itself, tell us anything about the effects on the community. In order to determine noise impact, one needs to consult a "dose/response" curve which shows the relationship between noise exposure level and subjective reaction of residents. The measure of reaction is usually expressed in terms of the percentages of residents experiencing a certain amount of reaction for increasing levels of noise exposure.

A major problem with this focus on exposure rather than impact is that only criterion exposure levels are considered. Planners, environmental consultants, and decision-makers often seem to forget that dose/response relationships are continuous curves without any steps or clear cut-offs, and that the criterion has been arbitrarily chosen to designate a critical level, not a level below which there is no impact. The EIS, therefore, concentrates on critical impacts and usually ignores notable impacts. For example, with traffic noise from a proposed freeway, an EIS would be likely to include a map with plots of exposure contours above the criterion levels specified by the relevant planning authority. The EIS may then use a dose/response curve and population density data to predict the impact on residents in terms of the numbers of people "highly annoyed" or "seriously affected". However, the impact in areas outside the criterion exposure contours will invariably not be reported, and will be not be taken into account in the assessment of impact. Consequently, the overall impact will be under-estimated.

This problem can be overcome by the use of an impact descriptor in addition to an exposure index in environmental assessment. An impact descriptor is defined as a measure which provides a direct estimate of the effect of an environmental factor. In the case of noise, as well as plotting contours showing levels of exposure, the EIS would plot contours to indicate various levels of impact using descriptors such as "percentage moderately affected" and "percentage seriously affected". The total impact in terms of numbers affected can then be readily estimated using population density data covering the different exposure zones down to the cut-off level for a notable impact.

5. AIRCRAFT NOISE IMPACT

The approach recommended here for environmental impact assessment can best be illustrated in the case of aircraft noise. The ANEF index is based on the US index NEF, but uses a different weighting for night-time noise (6dB rather than 12dB) and includes an extra weighting of 6dB for noise during evening hours. The study from which the ANEF index was derived comprised noise measurements and social surveys of 3500 residents around five airports [5]. This index was found to be the best predictor of community reaction to aircraft noise in Australia [11]. The ANEF index has been incorporated into the Australian Standard AS-2021 [12], and is the noise measure used in EISs for developments of and around airports. Levels of less than 20 ANEF are designated in the standard as "acceptable" in residential areas and levels above 25 ANEF are rated as "unacceptable" [12, p.6]. Although it is an exposure index, the primary function of ANEF is to predict the effect on residents of different amounts of aircraft noise - it is thus an indirect measure of environmental impact.

It is important to note that the criterion levels derived from the ANEF dose/response curve are arbitrary. The "acceptable" level of 20 ANEF is not one below which there is no reaction - in fact, this level results in 45% of residents being "moderately affected" by aircraft noise with 10% of them "seriously affected" (see Ref 12, Figure B1). A particular problem with the ANEF index has been that the dose/response curve provided in the standard AS-2021 covers exposure only down to 15 ANEF. This has apparently led many, if not most, people to assume that the impact below this level can be ignored, in other words, that it is a negligible impact. Such an assumption may be reinforced by the fact that the original report on which ANEF is based [5] did not include residential areas with exposures below 15 ANEF when calculating the numbers of people seriously and moderately affected around the five airports studied. However, the assumption of negligible impact below 15 ANEF is invalid. At this exposure level, the community reaction is 7% seriously affected and 33% moderately affected (see Ref 12, Figure B1), clearly a notable impact that should be taken into account when assessing a proposal. A recent example of an EIS ignoring impact below 15 ANEF is that produced for the Sydney Airport third runway proposal [12] where the numbers for the populations moderately and seriously affected by the various options were all appreciably under-estimated.

What is needed is a revised dose/response curve covering community reaction down to negligible levels. Figure 1 provides such a curve which was derived from the original study data [5] using probit analysis to estimate reaction down to an exposure of -5 ANEF [14]. It must be pointed out that an exposure level of 0 ANEF does not indicate zero aircraft noise - in fact, the formula used to calculate ANEF has an arbitrary correction factor of minus 88 - thus, an exposure of 0 ANEF would result from 8 aircraft overflights per day producing noise levels of 79 EPNdB.

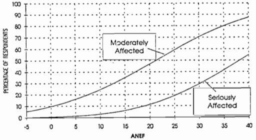

Figure 1. Dose/reponse curves for "moderately affected" and "seriously affected" as a function of aircraft nose exposure in ANEF. (Based on probit analysis of data in Ref 5)

As shown above, the community reaction below 15 ANEF cannot be ignored if an accurate picture of impact is to be provided to decision-makers and a valid assessment made. But what reaction level in terms of "percentage moderately affected" can be regarded as defining the minimum notable impact that should be reported, that is, below which the reaction would be deemed to be a negligible impact that can legitimately be ignored? Before attempting an answer, it must be emphasised that human reaction to aircraft noise is subjective and varies markedly for different people [5]. However, it is reaction not exposure that defines impact. Thus, a person living in an area with a low exposure of 10 ANEF but who is seriously affected by the aircraft noise they hear, suffers a greater impact than a person exposed to 40 ANEF who experiences only a moderate reaction to aircraft noise. Planners can decide that a certain exposure level is "acceptable", but they cannot dictate what reaction people exposed to that level should have. Nor should planners dismiss as exaggerated or hyper-sensitive the reaction of those residents who are seriously affected by so-called "acceptable" noise levels.

Further, it is worth examining what it means to be affected by aircraft noise. The data from the original socio-acoustic study [5] has been used to derive Figure 2 which illustrates what it means to be moderately and seriously affected in terms of a wide variety of subjective reactions to aircraft noise. When a person is described as "moderately affected", we see from Figure 2 that they are certain to hear aircraft noise (100% chance), that there is a 75% chance that they will be at least "slightly annoyed", a 68% chance they will experience disturbance to listening activities, and a 55% chance they will rate the neighbourhood as "bad" for aircraft noise. Similarly, saying a person is "seriously affected" means there is a 93% chance they will rate the neighbourhood as "bad" for aircraft noise, a 65% chance they will be at least "considerably annoyed", a 55% chance they will experience sleep disturbance, and a 50% chance they will claim their health is affected.

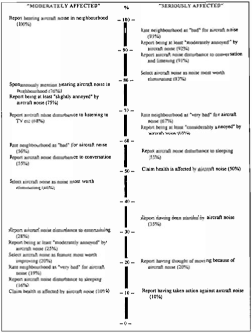

Figure 2. What it means to be "moderately affected" and "seriously affected: Percentage of respondents experiencing various reactions to aircraft nose. (Derived from data in Ref 5).

So, what impact level is appropriate as that below which the effect of aircraft noise can be regarded as "negligible"? From Figure 1, we see that the impact level of "10% moderately affected" corresponds to "0% seriously affected" suggesting that any community reaction below this can reasonably be ignored in assessment. However, by examining Figure 2, we see that those who are described as "moderately affected" have only a 40-70% chance of experiencing the more serious effects of aircraft noise such as annoyance and activity disturbance. Consequently, the level of "10% moderately affected" is probably too low to define a notable impact (i.e., the minimum which should be reported in assessment). Also, the unreliability of estimates of low aircraft noise exposure levels would pose considerable practical problems for an impact descriptor of less than about "20% moderately affected". Therefore, it is recommended that the cut-off for a notable impact in the case of aircraft noise be "20% moderately affected".

Adopting the recommended approach would mean that an EIS would include contour plots of the impact descriptors "20% moderately affected" and "10% seriously affected" to directly describe the impact of a proposal. An example of such impact contours is provided in Figure 3. Because there will be a lack of precision in the estimate of the lower level descriptor (20% moderately affected) it should be represented by a broken-line contour. In practical terms, the aircraft noise exposure would be estimated using established procedures, and then the impact descriptors would be derived from the dose/response curve provided in Figure 1.

The proposed approach means that estimates of the populations affected by the different options under consideration would cover areas with aircraft noise exposure levels down to about 8 ANEF. Although this level is commonly regarded as "low" noise exposure, it should be remembered that the purpose of the impact descriptor is to designate the area in which there is a notable impact that cannot reasonably be ignored in decision-making. One advantage of impact descriptors is that they provide a basis for comparing "acoustical apples and oranges" [15]. Thus, one can readily compare the relative impacts of high noise exposure in a small population area with low noise exposure in a large population area, or any other possible combination.

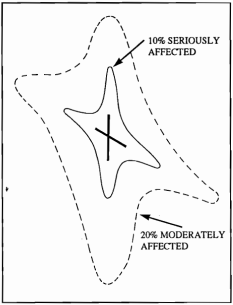

Figure 3. Example of contour plots around an airport showing impact descriptors "10% seriously affected: and "20% moderately affected".

6. CONCLUSION

We have seen that there are three categories of impact that need to be considered in environmental assessment: negligible impacts which can be disregarded, critical impacts which exceed regulatory criteria, and notable impacts which provide relevant information. It has been shown that the sole use of a noise exposure index in environmental assessment can lead to misinterpretation of the likely impact. Specifically, many people erroneously regard an "acceptable" level of noise exposure as one below which there is no reaction, that is, a negligible impact. Also, in the case of aircraft noise, community reaction in areas with an exposure of less than 15 ANEF is totally ignored when estimating the numbers affected. Such problems can be avoided by using impact descriptors in addition to an exposure index.

The impact descriptor "20% moderately affected" is recommended as defining a notable impact for aircraft noise, that is, an impact that must be reported for assessment purposes. Such a descriptor can be represented in environmental assessments by a contour which directly describes the impact of development proposals on residential communities. The estimates of numbers moderately and seriously affected should be derived from the dose/response data for all areas described as having at least a notable impact and not just within the critical noise exposure contours which are currently used in assessments. Similarly, for other noise types, it would be necessary to plot contours for impact descriptors and to estimate the numbers affected down to the notable impact cut-off level. The advantage from using this approach is that decision-makers would be presented with a more complete and hence more valid assessment of impacts.

REFERENCES

1. Department of Environment. "Calculation of Road Traffic Noise Levels", Her Majesty's Stationery Office, London, 1975.
2. Hede, A.J. "Traffic Noise Level: An improved index for estimating community exposure", Proceedings Australian Acoustical Society Annual Conference, Leura, NSW, 1985.
3. Schomer, P.D. "Community reaction to impulse noise: Initial Army survey", Army Construction Engineering Research Laboratory Report No.100, 1981.
4. Bullen, R.B., Hede, A.J. & Job, R.F.S. "Community reaction to noise from an artillery range", Noise Control Engineering Journal, **37**, pp.115-128, 1991.
5. Hede, A.J. & Bullen, R.B. "Aircraft Noise in Australia: A Survey of Community Reaction", National Acoustic Laboratories Report No.88, Australian Government Publishing Service, Canberra, 1982.
6. Hollick, M. "Environmental impact assessment in Australia: The federal experience", Environmental Impact Assessment Review, **3**, pp.330-336, 1980.
7. Formby, J. "The Australian Government's experience with environmental assessment", Environmental Impact Assessment Review, **3**, pp.207-226, 1987.
8. Davis, G., Wanna, J., Warhurst, J., & Weller, P. "Public Policy in Australia", 2nd edn, Allen & Unwin, Sydney, 1993.
9. Macquarie Library. "The Macquarie Dictionary", Macquarie University, NSW, 1985.
10. Williams, A.G. Correspondence dated 25 June, 1993.
11. Bullen, R.B., & Hede, A.J. "Time-of-day corrections in measures of aircraft noise exposure", Journal of the Acoustical Society of America, **73**, pp.1624-30, 1983.
12. Standards Association of Australia. "Acoustics - Aircraft Noise Intrusion - Building Siting and Construction", AS-2021, 1985.
13. Kinhill Engineers Pty Ltd. "Draft Environmental Impact Statement: Proposed Third Runway Sydney (Kingsford Smith) Airport", September, 1990.
14. Bullen, R.B. Correspondence dated 17 May, 1993.
15. Anonymous referee, June 1993.

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Abstract: Preformed thermal pipe insulations intended to control heat transfer to and from small diameter pipes are manufactured in Australia from plastic foams and fibrous materials in a wide range of sizes. It has been found that when preformed thermal pipe insulations are applied directly to pipes which are radiating sound, the insulated pipes generally become more effective radiators at low frequencies. This is presumably due, in part at least, to the fact that a preformed thermal pipe insulation, being moulded or extruded to fit closely onto a specific pipe, can be forced to vibrate by the vibrating pipe wall and being of larger diameter than the bare pipe, radiates more sound than the bare pipe. This paper presents the results of sound intensity measurements which were made to assess the improvement in the insertion loss which is associated with fitting these preformed thermal pipe insulations so that there is an air gap between the pipe and the insulation. Measurements to assess the effect of wrapping preformed thermal pipe insulations with a limp impervious barrier are also presented. The data presented in the paper are intended to aid in the effective acoustic use of the preformed thermal pipe insulations which are widely used in Australia.

1. INTRODUCTION

A wide range of preformed thermal pipe insulations is manufactured in Australia from a variety of materials. Common uses of preformed thermal pipe insulations are for insulating hot water pipes in buildings and for insulating pipes associated with refrigeration and air-conditioning systems. Generally these preformed thermal pipe insulations are used with relatively small diameter pipes (<100mm). However, some are suitable for use with much larger pipes. The usual way of attenuating the airborne sound radiated by pipes is to lag the pipes with porous and impervious layers such as fibreglass blankets and metal cladding sheets. Because of their convenience of use, preformed thermal pipe insulations are attractive to use in such constructions.

The few publications in the readily accessible literature relating to the acoustic performance of pipe laggings generally have been concerned with presenting experimental data relating to laggings typical of those used in the process industries for relatively large diameter pipes. The papers of Hale and Kugler [1], Hale [2], Smith et al [3] and Loney [4] are typical. An indication of the commercial importance of this type of pipe lagging is given by the recent publication of an ASTM Standard Test Method on a laboratory method for measuring the insertion loss of a pipe lagging [5]. More recently, Byrne [6] has presented experimental data which show the acoustic performance of preformed thermal pipe insulations of Australian manufacture. Sound intensity measurements were used to determine the frequency dependent sound insertion losses produced by preformed thermal pipe insulations manufactured from four different materials in three typical thickness when applied to 25, 51 and 76mm outside diameter copper pipes carrying turbulent water. Two of the materials were closed cell flexible foams with nominal thicknesses of 10, 15 and 20mm. The other two materials were a rigid closed cell polystyrene foam and glasswool with nominal thicknesses of 25,38 and 50mm.

Generally all of the combinations tested produced negative insertion losses over much of the frequency range of interest. The previously cited ASTM Standard Test Method refers to the fact that negative insertion losses may be produced by pipe laggings at low frequencies and suggests that measurements should not be made at frequencies below 500 Hz. Although it would be expected that a pipe lagging made of a material such as a rigid polystyrene foam would be unlikely to attenuate the sound radiated by a pipe, it is somewhat surprising that a preformed thermal pipe insulation made of glasswool could significantly increase the sound radiated by a pipe over much of the frequency range. Figure 1, which is extracted from [6], shows the insertion losses produced by three different thicknesses of a preformed thermal pipe insulation manufactured from glasswool applied to a 25mm diameter copper pipe.

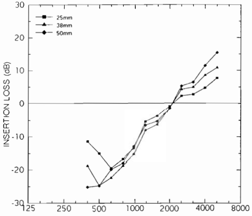

Figure 1. 1/3 Octave Band Sound Insertion Losses for 25, 38 & 50mm Wall Thickness Glasswool Preformed Thermal Pipe Insulation Applied to a 25mm Copper Pipe. (Figure 14 of [6])

It can be seen from Figure 1 that the insertion losses are negative up to the 2000 Hz 1/3 octave band. The suggestion was made in [6] that this negative insertion loss effect is due to the fact that the insulated pipe is of larger diameter than the bare pipe. Because a preformed thermal pipe insulation is moulded or extruded to fit closely onto a specific pipe, it will be forced to vibrate by the vibrating pipe. Vibrations associated with bending waves in the pipe are the cause of much of the sound radiated from the pipe. At low frequencies, the sound power radiated per unit length of a rigid vibrating cylinder is proportional to the fourth power of the cylinder diameter. The preceding points suggest that it is not unexpected that the observed negative insertion loss effect occurs and that the sound insertion loss produced by a preformed thermal pipe insulation should be improved by having an air gap between the pipe and the insulation. This paper presents the results of measurements which show the effect of including an air gap on the insertion losses produced by three types of preformed thermal pipe insulation. The insertion loss of a pipe lagging is usually enhanced by including an outer impervious barrier in the construction of the lagging. The results of measurements which show the effect of such a barrier applied over the preformed thermal pipe insulations are also presented.

Frequently, noise problems associated with small diameter pipes arise because of rigid connections between these pipes and effective radiating elements such as walls which support them. However, it should be noted that this paper is specifically related to the problem of attenuating airborne sound directly radiated from small diameter pipes.

2. MEASUREMENT METHOD

The sound insertion loss produced by a particular insulation construction was determined by measuring in 1/3 octave bands what was effectively the level of the sound power radiated from a particular 1.5m long segment of a 51mm copper pipe carrying turbulent water with and without the insulation fitted to it. The essential features of the test rig used to make the sound intensity measurements are shown in Figure 2.

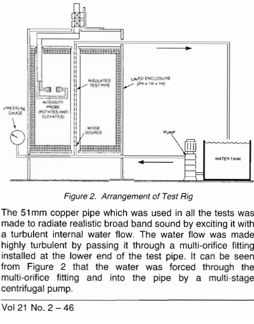

Figure 2. Arrangement of Test Rig

The 51mm copper pipe which was used in all the tests was made to radiate realistic broad band sound by exciting it with a turbulent internal water flow. The water flow was made highly turbulent by passing it through a multi-orifice fitting installed at the lower end of the test pipe. It can be seen from Figure 2 that the water was forced through the multi-orifice fitting and into the pipe by a multi-stage centrifugal pump.

The pressure upstream of the fitting could be monitored by an accurate pressure gauge. The multi-orifice fitting was in fact the so-called "installation noise standard" described in ISO 3822/1 - 1983 'Acoustics - Laboratory test on noise emission from appliances and equipment used in water supply installations - Part 1. Method for measurement'. The significant features of this "installation noise standard" are shown in Figure 3.

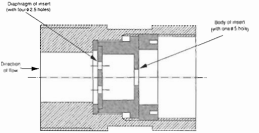

Figure 3. Details of Installation Noise Standard

The sound powers radiated from the 1.5m long segment of the bare and insulated pipe were determined in 1/3 octave bands by sound intensity measurements. A Bruel and Kjaer 2133 analyser fitted with a Bruel and Kjaer 3545 Sound Intensity Probe was used to make the sound intensity measurements. The recommendations given in ISO 9614/1-1992 'Acoustics - Determination of sound power levels of noise sources using sound intensity - Part 1. Measurement at discrete points' relating to sound power measurements using point intensity measurements were followed in making the sound power measurements. The intensity levels normal to the measuring surface were measured in 1/3 octave bands at 60 points evenly distributed over a 500mm diameter, 1000mm long cylindrical surface with spherical ends whose axis was aligned with the pipe. This measurement surface was located centrally on the 2000mm long pipe which was installed in a 2000x1000x1000mm lined enclosure designed to attenuate both the ambient sound and the reverberant sound in the enclosure.

Instead of determining sound power levels, average intensity levels were used as the intensity measurements were made with equal areas associated with each measurement point on the measurement surface. Thus the sound insertion loss associated with a particular frequency band, IL(f), then could be determined from equation (1) in which $L_{Iwo}(f)$ and $L_{Iw}(f)$ are the average intensity levels for the bare (without insulation) and insulated (with insulation) pipes.

$$IL(f) = L_{Iwo}(f) - L_{Iw}(f) \qquad (1)$$

Three sets of measurements were made in each series of tests. If an air gap between the pipe and the preformed thermal pipe insulation was required soft nitrile rubber collars of nominal thickness 15mm were first fitted to the pipe every 500mm along its length. The soft nitrile rubber collars insured that the preformed thermal pipe insulations were centred on the bare pipe but did not touch it. A preformed thermal pipe insulation and a 4 kg/m^2 impervious loaded plastic barrier were then fitted. Thus, the preformed thermal pipe insulations were not susceptible to strong mechanical excitation by the vibrating pipe. All of the preformed thermal insulations were of the split type and could be readily fitted over the collars.

The first set of measurements which gave the average 1/3 octave band intensities was then made. The impervious loaded plastic barrier was then removed and a similar set of measurements was made. Finally the preformed thermal pipe insulation itself was removed and the average intensities in 1/3 octave bands of the sound radiated from the bare pipe were measured. The three sets of measurements in each series of tests were usually made in one session of measurements. Subtraction of the results of the first or second set of measurements from the results of the third yielded the 1/3 octave band insertion losses.

The microphones of the intensity probe were set at a 12mm spacing. The residual pressure intensity index of the intensity measuring system for this spacing was measured before and after the three sets of measurements which comprised each series of tests. A typical result is shown in Figure 4. It can be seen that the residual pressure intensity index exceeded 20 dB in all bands above and including the 160 Hz 1/3 octave band and so for these bands the sound intensity at a point could be measured to within ± 1 dB so long as the difference between the mean sound pressure level and the intensity level was less than 10 dB.

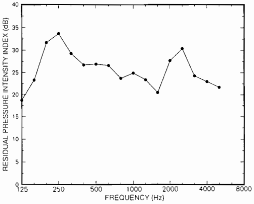

Figure 4. Typical Residual Pressure Intensity Index for the Intensity Measuring System.

The bare pipe was found to radiate little sound at frequencies below about 500 Hz. This is to be expected as the critical frequency of the bending mode of this pipe in air was about 300 Hz. The upper frequency limit of 5000 Hz was fixed by the 12mm microphone spacing of the intensity probe.

The sound power radiated from the bare pipe could be determined with an accuracy grading of "Precision" as defined in ISO 9614/1-1992 in all 1/3 octave frequency bands from 500 Hz to 5000 Hz. Briefly, this grading is appropriate when the uncertainty of the sound power determination has a standard deviation of 1.5 dB in the 1/3 octave bands from 200 Hz to 630 Hz and 1 dB in the 1/3 octave bands from 800 Hz to 5000 Hz. It is necessary, if the "Precision" grading is to be appropriate, that three field indicators related to the sound field have specified values. The three relevant ISO 9614/1-1992 field indicators, F2, the global pressure intensity index, F3, the negative partial power index and F4, the field non-uniformity indicator for the bare pipe are plotted in Figure 5 (a).

The high insertion losses produced by some constructions resulted in the ISO 9614/1-1992 requirements for the "Precision" grading not being satisfied in all frequency bands, particularly at higher frequencies. The field indicators for the pipe insulated with a construction involving a 12.5mm air gap, 50mm of fibreglass and finally the 4 kg/m^2 impervious loaded plastic barrier are plotted in Figure 5 (b). The values of these indicators are such that the "Precision" grading is not satisfied in the 3.15kHz, 4kHz and 5kHz 1/3 octave bands.

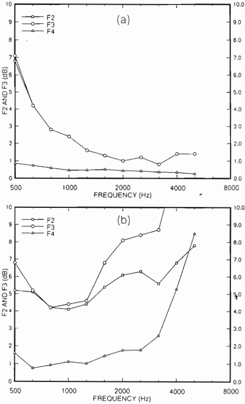

Figure 5. Field Indicators F2, F3 and F4 for the Bare Pipe (a) and the Pipe Fitted with a Construction Formed of a 12.5mm Air Space, 50mm of Fibreglass and the Impervious Plastic Barrier (b).

The corresponding average intensities in 1/3 octave bands are plotted in Figure 6(a). The points determined with the "Precision" grading are indicated by unfilled symbols. The remaining points are indicated by filled symbols. The insertion losses derived from the two average intensities are plotted in Figure 6(b). Again points derived from two "Precision" intensity measurements are indicated by unfilled symbols and the remaining points are shown by filled symbols.

3. TEST PROGRAMME

The test programme involved measurements to determine the 1/3 octave band insertion losses provided by constructions of three different materials, with and without a 12.5mm air space between the pipe and the preformed thermal pipe insulation and with and without an external wrapping cut from 4kg/m^2 loaded plastic sheet.

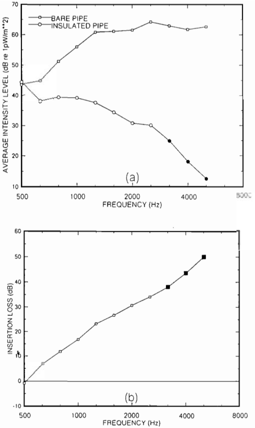

Figure 6. Average 1/3 Octave Band Intensities for the Bare Pipe and the Pipe Fitted with a Construction Formed of a 12.5mm Air Space, 50mm of Fibreglass and the Impervious Plastic Barrier (a) and the Corresponding Insertion Losses (b). (Unfilled Symbols Derived from "Precision" Measurements).

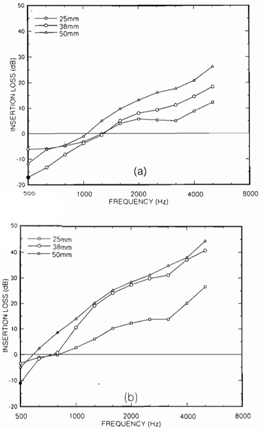

Figure 7. 1/3 Octave Band Insertion Losses for 25, 38 and 50mm Wall Thickness Glasswool (Material A) Insulation Fitted to the Pipe without the Air Space and without the External Wrapping (a) and with the External Wrapping (b). (Unfilled Symbols Derived from "Precision" Measurements)

The three materials from which the preformed thermal pipe insulations which were used in the tests were manufactured, are described below.

Material A was a rigid moulded glasswool with a nominal density of 85kg/m^3 and a thermal conductivity of 0.032 W/mK at 20°C. Insulations of this material were tested with wall thicknesses of 25, 38 and 50mm.

Material B was a rigid closed cell expanded polystyrene foam with a nominal density of 13.5kg/m^3 and a thermal conductivity of 0.038 W/mK at 20°C. Insulations of this material were tested with wall thickness of 25, 38 and 50mm.

Material C was a flexible closed cell polyethylene foam with a nominal density of 55kg/m^3 and a thermal conductivity of 0.035 W/mK at 20°C. Insulations of this material were tested with wall thicknesses of 15 and 20mm.

4. RESULTS

The results obtained when there was no air gap between the pipe and the insulation are given in Figures 7 to 9 and the corresponding results obtained with an air gap of 12.5mm are given in Figures 10 to 12.

5. COMMENTS ON THE RESULTS

An inspection of the data plotted in Figures 7(a), 8(a) and 9 (a) shows that preformed thermal pipe insulations applied directly to pipes and left unwrapped are not effective in reducing the noise such pipes radiate. This result was also found in [6].

The effectiveness of wrapping preformed thermal pipe insulations which are applied directly to pipes can be seen by comparing figures (a) and (b) in Figures 7 to 9. A surprising result is the good acoustic performance obtained when the rigid closed cell polystyrene insulation is wrapped with the impervious loaded plastic barrier.

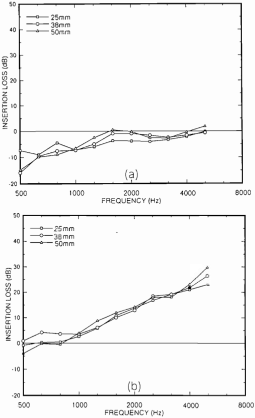

Figure 8. 1/3 Octave Band Insertion Losses for 25, 38 and 50mm Wall Thickness Polystyrene (Material B) Insulation Fitted to the Pipe without the Air Space and the External Wrapping (a) and with the External Wrapping (b). (Unfilled Symbols Derived from "Precision" Measurements)

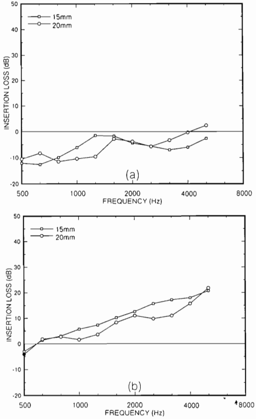

Figure 9. 1/3 Octave Band Insertion Losses for 15 and 20mm Wall Thickness Polyethylene (Material C) Insulation Fitted to the Pipe without the Air Space and without the External Wrapping (a) and with the External Wrapping (b). (Unfilled Symbols Derived from "Precision" Measurements)

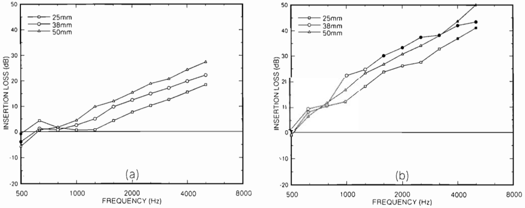

Figure 10. 1/3 Octave Band Insertion Losses for 25, 38 and 50mm Wall Thickness Glasswool (Material A) Insulation Fitted to the Pipe with a 12.5mm Air Space and without the External Wrapping (a) and with the External Wrapping (b). (Unfilled Symbols Derived froM "Precision" Measurements)

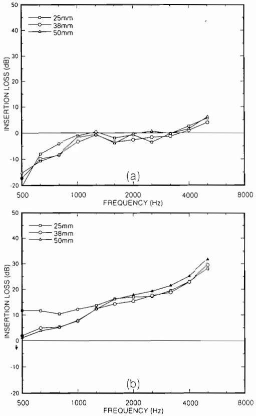

Figure 11. 1/3 Octave Band Insertion Losses for 25, 38 and 50mm Wall Thickness Polystyrene (Material B) Insulation Fitted to the Pipe with a 12.5mm Air Space and without the External Wrapping (a) and with the External Wrapping (b). (Unfilled Symbols Derived from" Precision" Measurements)

A comparison of figures (a) of Figures 7, 8 and 9 with figures (a) of Figures 10, 11 and 12 indicates that the provision of an air gap between the pipe and the insulation generally improves the acoustic performance of these preformed thermal pipe insulations. However, in the case of the polystyrene insulation there was no clear benefit in providing an air gap.

The best acoustic performance was obtained by providing an air gap between the pipe and the insulation and then wrapping the insulation with the impervious loaded plastic barrier.

It should be remembered that the data presented in this paper were obtained using a 51mm diameter copper pipe. This data, along with that presented in [6] can be used to give an indication of the likely acoustic performance of similar constructions applied to smaller and larger pipes.

Finally, it should be noted that the costs of the constructions tested vary widely in both the material costs and the application costs and this fact should be borne in mind in assessing the cost effectiveness of a particular construction.

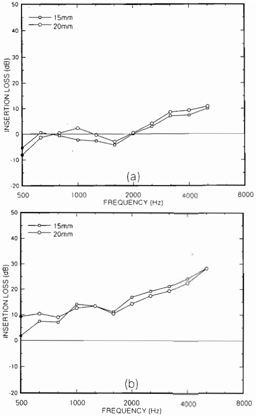

Figure 12. 1/3 Octave band Insertion Losses for 15 and 20mm Wall Thickness Polyethlene (Material C) Insulation Fitted to the Pipe with a 12.5mm Air Space and without the External Wrapping (a) and with the External Wrapping (b). (Unfilled Symbols Derived from "Precision" Measurements)

ACKNOWLEDGEMENT

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REFERENCES

1. Hale, M.E. and Kugler, B.A. The Acoustic Performance ofPipe Lagging Systems, ASME Winter Annual Meeting, Houston, Texas, 1975.
2. Hale, M.E. A Comparison of Several Theoretical Noise Abatement Methods for Pipe Lagging Systems. 96th Meeting of the Acoustical Society of America, Honolulu, Hawaii, 1978.
3. Smith, T., Rae, J.M. and Lawson, P. Pipe Lagging - An Effective Method of Noise Control? Applied Acoustics, **13**, 393-404,1980.
4. Loney, W. Insertion Loss Tests for Fibreglass Insulations, J. Acoust. Soc. Am., **76** (1), 150-157, 1984.
5. ASTM E1222-90, "The Laboratory Measurement of the Insertion Loss of Pipe Lagging Systems."
6. Byrne, K.P. The Acoustic Performance of Plastic Foam and Fibrous Thermal Pipe Insulations for Small Diameter Pipes, Western Pacific Regional Acoustics Conference IV, Brisbane, 112-119, 1991.

Water, Movement And Sound A Musical Sculpture At Hornsby, N.S.W.

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Abstract: An unusual sculpture in a public square at Hornsby, NSW, includes a 17 note Carillon or Chime Set, of the type known as "Harringtons" Chimes, using Tubular Bells. Some features of such instruments are examined, and some problems in tuning are discussed.

1. INTRODUCTION

A unique piece of public sculpture, commissioned by the Council of the Shire of Hornsby, has been installed in the Florence Street Mall at Hornsby, N.S.W. Entitled "Man, Time and the Environment", this mobile water sculpture incorporates a seventeen-note tubular bell carillon or chime set, cast in bronze, which is designed as an operating musical instrument as well as to ring-in the hour. Tuned to concert pitch, it is intended to be played on festive occasions with or without an accompanying orchestra. The tubular bells are based on a 250-year-old design located in an old English church.

Included in the sculpture are representations in bronze of fauna of the Hornsby Shire, including Tawny Frogmouth, Rainbow Lorikeet, Pied Cormorant, Fairy Penguin, Pelican, Water Dragon, Blue Tongue Lizard, Goanna, Fruit Bat, and Possum, the whole surmounted by a life-sized Sea Eagle with a 2.1 metre wingspan. On the base is Homo Sapiens, as a mother and child.

The "Time" aspect of the work is implicit in its three water clocks, modified from ancient designs: a IVth century BC Greek "clepsydra" or filling clock, an XIth century Chinese water wheel clock, and a XVIIth century Swiss pendulum clock. The water driven pendulum clock is said to be the largest ever built, and is one of the largest pendulum clocks in the world. The whole sculpture including clocks and carillon is mounted on a pontoon which rotates twice every 24 hours.

The entire work was conceived, designed, engineered and sculpted by Victor Cusack and, together with his partner Rex Feakes, was built at their Fineart Bronze Foundry.

2. 17-NOTE CARILLON

Although tubular bells are considered to be harder to tune than conventional bells, they fitted in much better with the overall concept of the sculpture. In seeking to overcome the technical problems of producing such an instrument, the sculptor visited the 450 year old Whitechapel Bell Foundry (UK). The Managing Director advised that "bells" were much easier to tune than "tubes", and he knew of no one that could help. He did, however, remark that they were once asked to maintain a carillon which turned out, to their horror, to be tubular. They were astounded at the quality of the tone, but they were unable to discover the secret of how such quality was achieved. From their records, the sculptor tracked the carillon down to St Wilfreds Church at Haywards Heath in Sussex, England, where it has been in operation for over 100 years. As it was exactly the size required, he decided to duplicate the design, which seemed to have overcome the considerable problems in tuning and eliminating discord.

The Tubular Chimes instrument was originally invented 250 years ago and patented by Harringtons of Coventry, which went out of business about 50 years ago. The actual tubes, hammers, configuration of playing mechanism and tuning of the Hornsby version are all identical to the Harringtons Chimes, but with additional notes, so as to include all tones and semitones of the octave above middle C plus D, E and F above and the G below. The total mass of the tubes is now approximately one tonne, of bell bronze (80% Cu, 20% Sn). Also, the frame has become a bronze sculptural form, as shown in Figure 1, rather than the box-like timber frame of the original.

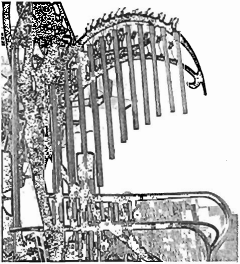


Figure 1. Tubular Bell set on sculptured support frame.

By definition a Carillon should cover two octaves, either as 16 full notes, which is clumsy, or 25 half notes. The instrument at Hornsby has 17 tubular bells arranged as one octave including half notes, plus four additional notes, and it could therefore technically be defined as a "Chime Set" rather than a carillon. Also, the instrument is played by pulling on handles attached to ropes, rather than by a carillon keyboard.

There are a number of other Harringtons Chimes in various churches, but most have only 6 or 9 notes. An earlier model at St George the Martyr's Church in Ramsgate, England, is not as effective as that at Haywards Heath, and in Australia there are several copies of various quality, some of which have not been well maintained. One which is still used regularly is in St Andrews Church, Summer Hill N.S.W.

TUNING TUBULAR BELLS

The sounds produced by tubular bells originate in transverse vibrations of the long, relatively thin tubes. In this they resemble the steel bars of the glockenspiel and the celesta, and in fact the transverse natural frequencies of tubes may be calculated using the solutions to the thin-bar problem given by Rayleigh (1877). From this we find that the frequency of the nth mode of a bar of length L is

$$f_n = K\,(\pi/8L^2)\,(E/\rho)^{1/2}[3.01^2, 5.00^2, 7^2,\ldots,(2n+1)^2] \qquad (1)$$

where K is the moment of inertia, E the Youngs modulus and ρ the density. For a tube of inner and outer radii r and R, the moment of inertia is $K = 0.5\,(R^2 + r^2)^{1/2}$.

From equation 1, the first six modal frequencies of a uniform metal bar are in these approximate ratios:

1.00 : 2.76 : 5.40 : 8.93 : 13.35 : 18.64

which clearly is not a set of harmonics, so it may seem a little mysterious that such bars (or tubes) can produce musical notes. In fact, none of the modes of vibration is at a frequency anywhere near the pitch of the strike tone which we hear.(Fletcher and Rossing, 1991).

The clue is in the ratios between the 4th, 5th and 6th modal frequencies; these are "close enough" to the ratios 2:3:4 for the ear to consider them nearly harmonic, and to subjectively establish a "pitch", or perceived strike tone. Thus the strike tone which we hear lies approximately one octave below the frequency of the 4th transverse vibrational mode.(Fletcher and Rossing, 1991).

Equation 1 does not take into account rotary inertia and shear, which tend to lower the frequency of the higher modes progressively as the ratio of length to width (or diameter) becomes smaller. One way to compensate for this is to "mass load" one or both ends of a tube; this will lower the frequency of all modes, but the higher modes will be affected less, hence the ratios between the frequencies of modes 4, 5 and six can be "stretched" to be closer to the desired 2:3:4.

EMPIRICAL TUNING

The tubes were cast in two diameters : outer diameter = 92 mm and inner diameter = 66 mm for the seven lower notes, and, correspondingly, 82.5 mm and 56.5 mm for the ten higher notes. The density of a measured sample was 8.90. Initially, the tubes were cut with lengths considerably greater than required, to allow for tuning by trimming the length. Holes, 25 mm in diameter, are drilled transversely through each tube. The top edges of the holes, 95 mm from the end, are the points of support on 19 mm pins which are, in turn, supported by steel cables.

The untrimmed tubes were hung on the carillon frame. Measurements were made of their transverse vibrations, using small accelerometers attached to the side of each tube with optical wax. The carillon strike mechanism consists of a rebounding nylon tipped iron mallet which strikes the bell transversely adjacent to the top edge, thus exciting all the "free-free" modes. Frequency analysis of the accelerometer signals showed that, for each of the seven larger tubes, the modal frequencies were approximately in the expected ratios, viz

2 : 2.90(sd 0.02) : 3.86(sd 0.2)

However, when the predicted frequencies for the measured lengths were calculated from first principles (applying equation 1), the strike note frequencies, equal to half the 4th mode frequencies, differed from the measured values of this quantity by a semitone or more. This is to be expected in view of the less than integral relationships between the 4th, 5th and 6th modes. To improve the accuracy of tuning, it was decided to use the following empirical approach.

If any of the modal frequencies fn were plotted against length, the relationship should be of the form (see equation 1)

$$f = a\,L^b$$

where b = -2 approximately.

The inverse problem is to find the length L corresponding to a desired frequency f. Using the least squares regression technique, a straight line was fitted to (ln L) versus (ln f_4) for the measured results , producing, for the larger tubes,

$$\ln L = 4.164 - 0.525 \ln f_4 \qquad (2)$$

Using this equation none of the calculated lengths differs from the measured ones by more than the equivalent of 10 cents (0.1 semitone), which is less than the pitch discrimination of most people. The required lengths were then calculated for the six notes C_4(middle C) to F_4 inclusive, and for G_3(below middle C), using standard pitch (A_4=440 Hz). To keep within a 10 cent tolerance, it was determined that the tubes needed to be cut to length within 9mm for the longest, ranging down to 6mm for the F_4 tube.

To be cautious, two of the longer tubes were cut first, and the modal frequencies of these were re-measured. They were reassuringly close to the predicted values, so the six tubes C_4 to F_4 were cut to the finished size. When the tubes were cut to the predicted lengths, the frequencies of the critical 4th modes were correct within the specified tolerance. Figure 2(a) shows the measured spectrum for G_4 (nom 392 Hz), for which the expected 4th, 5th and 6th modal frequencies are 784, 1141, and 1552 Hz. The measured frequencies are 785, 1130 and 1515 Hz, the ratios of which are 2 : 2.88 : 3.86 . Subjectively, the strike pitch sounded "correct".

The largest tube, nominally G_3, was first cut to a length corresponding to a predicted F_3#. Although the expected modal frequencies were measured, there were other unexplained frequencies, and subjectively the strike tone sounded too high and not very musical. Changing the support point produced some improvement, and the tube was then cut to its final length of 2.79 metres, with a finished mass of 79 kilograms. There is a strong first overtone in the sound of the bell, maybe due in part to the ear's lower sensitivity to the low frequency sound of the perceived fundamental, but it also appears that the support position is more critical than realised at first. This is discussed in more detail in the section on perceived strike pitch and hum.

From measurements on the ten untrimmed smaller tubes, the ratios between the modal frequencies were found to be

2 : 2.87(sd .02) : 3.85(sd .06)

Following the same least squares procedure as for Equation 2, an equation was fitted to the measured results, producing

$$\ln L = 4.295 - 0.555 \ln f_4 \qquad (3)$$

The ten tubes did not fit this equation quite as well as was the case for equation 1, no doubt due to the bigger range, but the mean difference of 5.6mm was good enough to use the equation to predict the lengths for the seven notes F_4# to C_5, and for D_5, E_5 and F_5. All the final lengths are listed in Table 1.

When the smaller tubes were re-mounted and played, seven of the notes sounded "correct", but the three highest did not have a clearly defined tone at all. Examination of the modal spectra showed that the modal frequencies were not close enough to the required ratios, and needed to be "stretched" as mentioned above. Instead of adding mass, this was achieved by machining down the outer diameter to 76 mm except for the end above the support point, and then shortening the tubes to bring them back up to the desired frequencies. The calculations for this took into account the empirically derived variation from the theoretical thin bar frequencies. The final sound of these three bells is quite pleasing, but it differs from the others; this is discussed in the next section.

PERCEIVED STRIKE PITCH AND HUM

When the tubes had all been cut to size and the set reassembled on its frame, each note was played in turn and recordings were made of the sounds, using a sound level meter as detector. At the same time subjective assessments were made of the perceived timbre. The latter seemed to vary greatly between tubes, for both the perceived strike tone and for the hum tone which persists long after.

Frequency analyses of the recorded sounds revealed that much of the variation is attributable to the differing rates of decay of the various modes. As expected, the higher modes die away more rapidly, so that the important 4th, 5th and 6th modes can become swamped in time by lower modes.

In Figure 2(a), the G4 strike pitch of 393 Hz is clearly defined by the modes at 785 Hz, 1130 Hz and 1515 Hz, but after 5 seconds we see in Figure 2(b) that the higher modes have decayed to such a degree that the persisting 4th mode at 785 Hz , ie an octave higher, is all that is heard.

In another example, (Figure 3(a) and 3(b)), a perceived strike pitch C_4 is followed by a persisting hum at the 3rd mode,which is close to E_4, ie an interval of a third.

For the three highest notes, however, the persisting hum is a rather pleasant fifth below the perceived strike note, due to the persistence of the 2nd mode and the "stretching" effect of the end mass loading. From the available modes we can see that the hum pitch must be either, roughly, an octave above (4th mode), a third above (3rd mode) or a fifth below (2nd mode) the strike pitch.

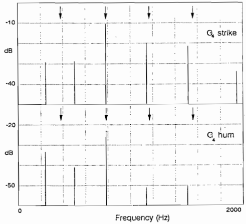


Figure 2(a). Strike spectrum for G4 bell. The arrows indicate the perceived strike pitch and 3 of its harmonics. 2(b) Hum spectrum for G4 bell.

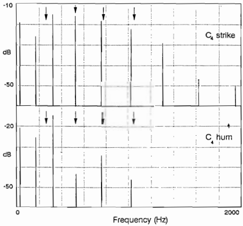


Figure 3(a). Strike spectrum for C4 bell. 3(b) Hum spectrum for C4 bell.

For the G_3 tube the support point had been moved from 95 mm to the node of the 4th mode, at 207 mm from the top which produced a considerable improvement in the general musicality of the sound. However, the strike pitch is still not as clearly defined as in the other bells. It was observed that the 5th mode is initially dominant, with the 4th mode within about 3 dB, but that the 6th mode is 15 dB lower. This may be attributable to the new position of the support point. Figure 4 shows some of the modes of a tube, calculated using 50 cylindrical elements in a Finite Element Analysis. The model suggests that the support very close to the node of mode 4, places it about halfway to the antinode of mode 5 and, more particularly, of mode 6, which could tend to suppress these modes which are so critical to the ear's assessment of the strike pitch. From the F.E.A. model it seems that a re-positioning of the support point by only 35mm could make a noticeable difference. All of the other tubes are still supported at 95mm from the upper end.

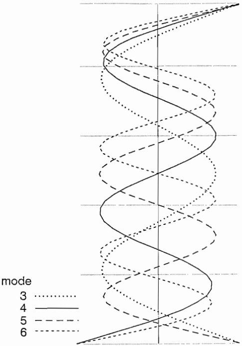


Figure 4. Shapes of the important modes of a tubular bell, from F.E.A. model.

Table 1 lists the nominal strike pitch and the hum pitch for all 17 tubes, in musical terms. Where the interval is significantly stretched or contracted it is marked "+" or "-".

CONCLUSION

The water sculpture in Florence Mall, Hornsby, has already attracted much attention, and no doubt will continue to do so. Some of this attention is due to the unusual Harringtons Chimes, or Carillon, for which it is hoped music will be specially written. Indeed, a work for this carillon and accompanying orchestra, composed by Robert Young, was performed at the opening ceremony.

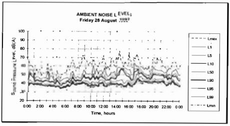
Table 1

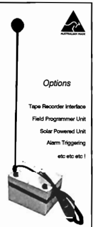
f_4 (Hz)	L(m)	strike pitch	hum pitch	interval
392	2.79	G_3	G_4	octave
520	2.396	C_4	E_4	third
555	2.325	$C_4\#$	F_4	third
585	2.255	D_4	$F_4\#$	third
615	2.188	$D_4\#$	G_3	fifth+
655	2.122	E_4	A_3	fifth
695	2.058	F_4	A_3	fifth+
745	1.870	$F_4\#$	B_3	fifth
785	1.811	G_4	G_5	octave
840	1.754	$G_4\#$	C_5	third
890	1.699	A_4	$C_5\#$	third
925	1.645	$A_4\#$	D_5	third
985	1.593	B_4	$D_5\#$	third
1050	1.543	C_5	E_5	third
1180	1.410	D_5	G_4	fifth
1320	1.314	E_5	A_4	fifth
1420	1.269	F_5	B_4 -	fifth-

It has been shown that the accuracy of tuning a set of tubular bells such as this can be improved by using least squares regression to obtain an empirical formula for the lengths. Even so, some fine tuning is still needed for some of the bells. Finite element analysis has shown that the position of the supports can be quite critical, and ought to be individually adjusted for each of the bells. Both frequency analyses and subjective observations have revealed that the tubular bells of this instrument have certain inherent peculiarities of timbre, both in the perceived strike pitch and in the persisting hum. Whilst most of the bells hum at a third above the strike, the unusual treatment of the top three bells has created a design which, generating a hum at a fifth below the strike and stretching the modes, produces a particularly sweet sound. On the other hand, the G3 bell needs more attention. Such peculiarities cannot all be "corrected", and, indeed, lend to the instrument its unique character and pleasing sound.

REFERENCES

1. Rayleigh, Baron. "The Theory of Sound", 1877. vol 1, pp 28-284, 289-294.
2. Eshbach,O.E.(ed). "Handbook of Engineering Fundamentals" Wiley (U.S.A.) 1946 p 22.
3. Fletcher, N.H. & Rossing, T.D. "The Physics of Musical Instruments Springer-Verlag (U.S.A.) 1991 pp 57-59, 549-550.





The Development Of Acoustic Volume Velocity Sources

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The President's prize, established in 1990 by the Australian Acoustical Society, is awarded to the best technical paper presented in the Annual Australian Acoustical Society Conference. Those awarded the prize in 1990 and 1991 were Michael Norton with J. Soria and Bruce Manser respectively.

Abstract: Acoustic volume velocity sources can be useful in experimental acoustics. They can be used, for example, to determine the particle velocity information needed in measuring acoustic impedance. The development of modern signal processing instrumentation has allowed volume velocity sources to be used conveniently. Two volume velocity sources developed at The University of New South Wales are described. One is based on a modified acoustic horn driver and the second is a specially constructed device. The methods used for calibrating the devices are described and the results of a performance test based on measuring the input and transfer impedances of a closed end tube are given.

1. INTRODUCTION

Certain acoustic measurements can be undertaken conveniently if a source of known volume velocity is available. Examples of such measurements are given in references [1] and [2]. Reference [1] describes how a volume velocity source can be used to measure the normal incidence specific acoustic impedance at the surface of acoustic materials. The physical arrangement of the device is shown in Figure 1(a). Reference [2] describes how a volume velocity source can be used in experiments relating to the finite element modelling of an acoustical cavity. The "driving force" in many mathematical models of acoustical systems is usually one or more volume velocity sources. The physical arrangement of the system referred to in [2] is shown in Figure 1(b).

Historically, the attraction of volume velocity sources for use in acoustic measurements has been their ability to obviate the need to measure acoustic particle velocity which is a difficult quantity to measure directly. Volume velocity sources and in particular constant volume velocity sources have been developed with the aim of being useful in measuring the acoustic impedance in systems as diverse as vocal tracts, musical instruments, machinery manifolds and at the surface of acoustical materials. The development of phase matched microphones has enabled acoustic particle velocity to be found easily and so has reduced the role of volume velocity sources as a means of establishing known particle velocities. However, modern digital signal processing has allowed volume velocity sources to be used in a more versatile manner than before. The technique described in [1] is an example of how modern digital signal processing can be used with a volume velocity source.

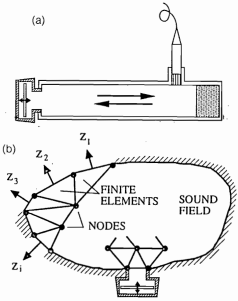


Figure 1. Applications of Volume Velocity Sources (a)Impedance Measurements (b)Verification of Finite Element Model

Salava [3] has described some of the types of volume velocity source which have been constructed. Briefly there are two basic types of volume velocity source and they are shown in Figure 2. The first type, shown in Figure 2(a), involves a driver, a microphone and a resistive element such as a disc of sintered metal, whose resistance is much greater than the impedance of the system attached to the volume velocity source. The volume velocity produced by the source is obtained from the pressure measured by the microphone and the flow resistance of the resistive element. An obvious disadvantage is the requirement that the system which is attached to the volume velocity source must have a much lower impedance than that of the resistive element. The second type, shown in Figure 2(b), incorporates a diaphragm or piston whose motion is measured. The motion

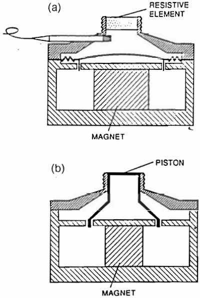


Figure 2. Types of Volume Velocity Sources (a)Resistive Element Type (b)Piston Type

can be measured directly by devices such as capacitive displacement transducers, accelerometers, and velocity coils or indirectly by measuring the pressure fluctuations in a closed cavity behind the piston or diaphragm.

2. THE UNSW VOLUME VELOCITY SOURCES

The two types of volume velocity source which have been developed at The University of New South Wales are variations of the piston type shown in Figure 2(b). The main features of the two types are shown in Figure 3. The main difference is in how the motion of the diaphragm or piston is measured. The horn driver type of volume velocity source shown in Figure 3(a) was constructed by modifying a horn driver so that a microphone could be inserted into the sealed cavity behind the diaphragm. As the diaphragm moves and gas is displaced into and out of the throat of the horn driver the pressure in the sealed cavity alters and this can be sensed by the microphone. The rate of change of the pressure can be related to the volume velocity. Although the modified horn driver type of volume velocity source can be made readily in that all that needs be done is to machine a hole into the body of the horn driver for the microphone, it has several major disadvantages. Firstly, it has a large coupling volume between the diaphragm and the exit plane of the device. Little can be done to reduce this volume. Secondly, the microphone in the closed cavity which backs the diaphragm may not be able to sense accurately the pressure changes in the cavity because the cavity is partitioned into several volumes by the gap in which the coil moves. However, this can be overcome to some extent by greatly widening sections of the gap annulus.

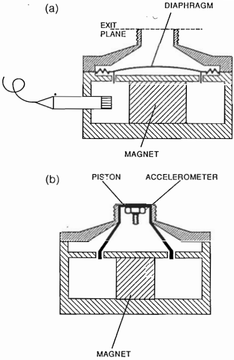


Figure 3. UNSW Volume Velocity Sources (a) Horn Driver Type (b)Piston Type

The compliance of the coupling volume can cause serious measurement errors when the impedance presented by the load at the exit plane of the volume velocity source is high. Under such a circumstance, the volume velocity delivered to the load will be small despite large excursions of the diaphragm of the horn driver. In principle this problem can be overcome by measuring the acoustic pressure near the exit plane of the volume velocity source. The arrangement of the volume velocity source to allow this to be done is shown in Figure 4(a). The compliance of the coupling volume can be established by blocking the exit plane of the volume velocity source and measuring the transfer function which relates the pressure measured by the microphone in the cavity to the pressure measured by the microphone close to the exit plane. The model of the modified horn driver is shown in Figure 4(b). This model can be used to consider both the effect of the compliance volume and the calibration procedure.

The piston type of volume velocity source is intended to overcome the preceding shortcomings of the modified horn driver type of volume velocity source. The device shown in Figure 3(b) was constructed from standard components which included a ceramic magnet, a loudspeaker drive coil and a low mass accelerometer. The accelerometer allows the motion of the piston to be determined. A detail of the device which is important to its functioning is the sealing between the piston and the fixed throat parts. Several sealing techniques were used. The one which ultimately was found to be the most successful used an "O" ring.

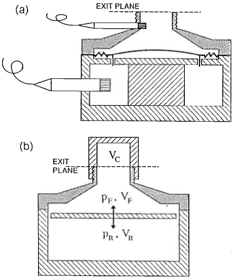


Figure 4. (a)Modified Horn Driver with Pressure Measurement near Exit Plane (b)Model Used for Analysis of Modified Horn Driver

3. EQUATIONS FOR MODIFIED HORN DRIVER

The equations which govern the behaviour of the modified horn driver can be determined from the model shown in Figure 4(b). The equilibrium absolute pressure in the regions of volume V_R and V_F on either side of the diaphragm is P_0. The region of volume V_F extends up to the exit plane of the device. If the diaphragm is moved a small distance upwards so that it displaces a small volume ΔV, the acoustic pressures p_R and p_F associated with each of the volumes are as given by equations (1).

$$p_R = -(P_0\gamma / V_R)\Delta V \qquad p_F = (P_0\gamma / V_F)(\Delta V - A\Delta x) \qquad (1)$$

These equations are based on the assumptions that the gas in the regions of volumes V_R and V_F behaves adiabatically and that ΔV is small compared to both V_R and V_F. γ is the specific heats ratio of the gas. A is the cross-sectional area of the exit plane of the device and Δx is the movement of the gas particles at the exit plane. Equations (1) can be used to derive equation (2), which shows that if V_R and V_F are known and $\mathbf{p}_F$ and $\mathbf{p}_R$ are measured, the volume velocity, $\mathbf{U}$, can be found.

$$\mathbf{U} = -j\omega[(V_F/P_O\gamma)\mathbf{p}_F + (V_R/P_O\gamma)\mathbf{p}_R] \qquad (2)$$

$\mathbf{p}_F$, $\mathbf{p}_R$ and $\mathbf{U}$ are the complex representations of the pressures and volume velocity which are varying in a simple harmonic manner with an angular frequency of ω. In view of the fact that the microphone in the closed cavity which backs the diaphragm may not be able to sense accurately the pressure changes in the cavity because of the complex shape of this cavity, it is advantageous to consider this volume to be a frequency dependent complex quantity denoted $\mathbf{V}_R(\omega)$. Thus equation (2) can be written as:

$$\mathbf{U} = -j\omega[(V_F/P_O\gamma)\mathbf{p}_F + (\mathbf{V}_R(\omega)/P_O\gamma)\mathbf{p}_R] \qquad (3)$$

Usually it is required to find the pressure, $\mathbf{p}$, at some point in an acoustical system per unit volume velocity of the source and so from equation (3):

$$\mathbf{p}/\mathbf{U} = (\mathbf{p}/\mathbf{p}_R)/-j\omega(\mathbf{V}_R(\omega)/P_O\gamma)[1+(V_F/\mathbf{V}_R(\omega))(\mathbf{p}_F/\mathbf{p}_R)] \qquad (4)$$

It can be seen that to determine $\mathbf{p}/\mathbf{U}$ it is necessary to determine two transfer functions. The first, $\mathbf{p}/\mathbf{p}_R$, relates the pressure at the point of interest to the pressure in the cavity behind the diaphragm. The second, $\mathbf{p}_F/\mathbf{p}_R$, relates the pressure at the front of the diaphragm to that in the cavity behind it. This transfer function allows the effect of the load impedance to be considered.

4. CALIBRATION PROCEDURE FOR MODIFIED HORN DRIVER

The calibration procedure, which essentially involves determining V_F and $V_R(\omega)$, was undertaken by attaching five small cavities of volumes V_C to the source as shown in Figure 4 (b) and measuring the transfer functions $\mathbf{p}_R/\mathbf{p}_F$. Since the volume velocity entering the calibration volume is $j\omega(V_C/P_O\gamma)\mathbf{p}_F$, equation (3) gives

$$(\mathbf{p}_R/\mathbf{p}_F) = -(V_F + V_C)/\mathbf{V}_R(\omega). \qquad (5)$$

When $V_C = 0$ the corresponding transfer function, denoted $(\mathbf{p}_R/\mathbf{p}_F)_0$, is given by equation (6).

$$(\mathbf{p}_R/\mathbf{p}_F)_0 = -V_F/\mathbf{V}_R(\omega) \qquad (6)$$

Transfer functions for non-zero values of V_C can be divided or "equalised" by equation (6) to give equation (7).

$$(\mathbf{p}_R/\mathbf{p}_F)/(\mathbf{p}_R/\mathbf{p}_F)_0 = \frac{1}{V_F} x V_C + 1 \qquad (7)$$

At each frequency the five values of the equalised transfer functions measured with the five calibration cavities were used to least squares fit a straight line of the form of equation (7). The reciprocal of the gradient of this line gives V_F. The calibration cavities had a common diameter of 25 mm and nominal lengths of 0, 3, 8, 13 & 18 mm. The values of the real and imaginary components of the equalised transfer functions at 1000Hz. for the five volumes are shown in Table I.

TABLE I
Equalised Transfer Function Components At 1000Hz With Various Calibration Cavities

Nominal Cavity Length (mm)	Cavity Volume (m^3)	Real Component	Imaginary Component
0	0	1.00	0.000000
3	1.7328×10^{-6}	1.05	0.000290
8	4.0644×10^{-6}	1.13	-0.000025
13	6.5483×10^{-6}	1.22	-0.000725
18	8.9045×10^{-6}	1.30	-0.002820

A feature of this table is the relatively small magnitudes of the imaginary components of the equalised transfer functions. This is of course expected from equation (7) and it supports the validity of the model which leads to equation (7).

Figure 5 shows the values of V_F determined at 2Hz intervals by the least squares process. Several features of Figure 5 are noteworthy. The major spike evident at about 550Hz is probably associated with resonances in the individual corrugations of the corrugated circular flexure which supports the diaphragm. It can be seen that the average value of V_C is slightly different below and above 550Hz. The rising trend of the graph at frequencies above about 1200Hz is associated with wave effects in the volume in front of the diaphragm and the calibration volumes.

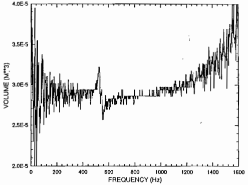


Figure 5. V_F Versus Frequency

Figure 6 shows, at 2Hz intervals, the real and imaginary components of $V_R(\omega)$ which were obtained from equation (6). The values of V_F given in Figure 5 were used in equation (6). The major spike evident at about 550Hz in Figure 5 is again evident in the imaginary component in Figure 6. It will be seen subsequently that this spike has little effect.

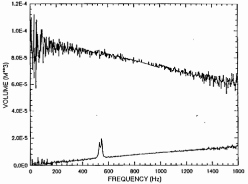


Figure 6. Real (Upper) and Imaginary (Lower) Components of $V_R(\omega)$

5. EQUATION FOR PISTON TYPE

The attraction of the piston type source when compared with the modified horn driver type source is that the coupling volume is very small and in fact will be zero if the mean position of the piston can be adjusted so that it lies in the exit plane of the source. Thus the complication of compensating for the effects of this volume is avoided. Further, the volume velocity can be determined directly from the motion of the piston which is sensed by the accelerometer. The volume velocity, $\mathbf{U}$, is simply given by equation (8). A is the piston area and **a** is its acceleration.

$$\mathbf{U} = \mathbf{Aa/j\omega} \qquad (8)$$

Since it is usually required to find the pressure, $\mathbf{p}$, at some point in an acoustical system per unit volume velocity of the source, equation (8) gives

$$\mathbf{p/U} = \mathbf{j\omega p/Aa} \qquad (9)$$

6. CALIBRATION PROCEDURE FOR PISTON TYPE

It can be seen from equation (8) that, if there is no leakage around the piston, the calibration of the volume velocity source depends upon the calibration of the accelerometer. The exposed outer face of the piston, as shown in Figure 3 (b), allows the accelerometer calibration to be checked by conventional back-to-back calibration with a reference accelerometer.

The volume velocity, U, produced by the source also can be determined by measuring the pressure, **p**, in a small volume V_c attached to the source in the manner shown in Figure 4 (b). The analysis used to give equations (1) can be applied again to give equation (10).

$$\mathbf{U} = j\omega(V_C/P_O\gamma)\mathbf{p} \qquad (10)$$

The ratio of the volume velocities determined by equations (8) and (10) should be unity. The real and imaginary components of this ratio are plotted in Figure 7.

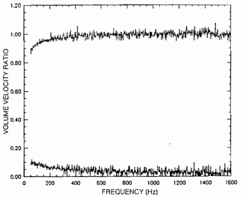


Figure 7. Real (Upper) and Imaginary (Lower) Components of the Ratios of the Volume Velocities Determined by Equations (8) and (10)

7. EVALUATION OF PERFORMANCE

A useful test to evaluate the performance of volume velocity sources is to use them to determine the driving point and transfer impedances for a column of gas in a tube. Singh and Schary [4] used such a test to assess the accuracy of a technique for measuring the acoustic impedance of flow manifolds. Pratt et al [5] adopted a similar test to evaluate a procedure used for measuring the acoustic impedance of brass instruments. The significant features of the test system used here are shown in Figure 8.

The acoustic waves in the tube are attenuated as they travel along the tube largely as a result of viscous and thermal effects at the tube walls. The attenuation rate can be

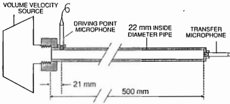


Figure 8. Test System for Assessing the Performance of the Volume Velocity Sources

expressed in terms of the Helmholtz-Kirchhoff wall-attenuation coefficient $\alpha\omega$ and so the complex representation of the acoustic pressure the positive and negative travelling plane waves can be written as:

$$p_+ = P_+\exp[-\alpha_W x]\exp[j(\omega t-kx)]$$
$$\text{and } p_- = P_-\exp[+\alpha_W x]\exp[j(\omega t+kx)]. \tag{11}$$

Temkin [6] gives the expression defined by equation (12) for $\alpha\omega$. It involves the speed of sound c_0, the angular frequency ω, the kinematic viscosity ν_0, the tube radius R, the specific heats ratio γ and the Prandtl Number P_r.

$$\alpha_W = \frac{1}{c_0}\left(\frac{\omega\nu_0}{2R^2}\right)^{1/2}\left(1+\frac{\gamma-1}{P_r^{1/2}}\right) \tag{12}$$

The complex representations of the longitudinal particle velocities associated with each wave are given by $\mathbf{u}_+ = \mathbf{p}_+/\rho c$ and $\mathbf{u}_- = \mathbf{p}_-/\rho c$. The boundary conditions are $\mathbf{u} = \mathbf{u}_+ + \mathbf{u}_- = U/A$ at $x = 0$ and $\mathbf{u} = \mathbf{u}_+ + \mathbf{u}_- = 0$ at $x = L$. These boundary conditions lead to the following equation which relates the pressure at $x = L^*$, $\mathbf{p}_L^*$, to $\mathbf{U}$, the volume velocity at $x = 0$.

$$p_L^*/U = -j(\rho c/A)(\cos[(k-j\alpha_W)(L - L^*)]/(\sin[(k-j\alpha_W)L]) \tag{13}$$

Equation (13) gives the driving point impedance when $L^* = 0$ and a transfer impedance when $0 < L^* < L$.

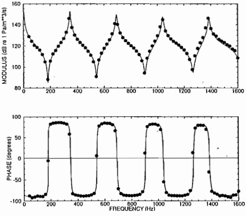


Figure 9. Modulus and Phase of the Computed (-)and Measured (•) "Driving Point Impedance": (Modified Horn Driver Source)

Figure 9 shows the modulus and phase of the "driving point impedance" computed from equation (13) with $L^* = 0.021$ m. Ideally, the driving point impedance would be obtained with $L^* = 0$. However, the microphone could not be located at the plane defined by $L^* = 0$. The measured values are shown as points on Figure 9. The tube internal diameter $2R$ was 0.0222 m and the tube length, L was 0.500 m. The measurements were made with an air temperature of 20°C for which the velocity of sound, c_o is 343 m/s, the density, ρ is 1.21 kg/m^3, the kinematic viscosity, ν_o is 1.5 x 10^{-5} m^2/s, the specific heats ratio, γ is 1.4 and the Prandtl Number P_r is 0.709. The measured values were obtained with the modified horn driver volume velocity source.

Figure 10 shows the modulus and phase of the transfer impedance computed with $L = L^* = 0.500$ m. The parameter values used in evaluating equation (13) were as previously given. The measured values, which are shown as points on Figure 10, were obtained with the piston type volume velocity source.

8. CONCLUDING COMMENTS

It can be seen from Figure 9 that the differences between the computed and measured values, although small, increase with frequency. The dynamic range of the modulus is in excess of 70 dB. It is noteworthy that the irregularity present in the plot of Figure 5 at about 550 Hz produces no obvious effect in Figure 9.

There is superior agreement between the computed and measured values shown in Figure 10. This is probably due to the fact that a transfer impedance is involved, with a smaller dynamic range, rather than the fact that the piston type volume velocity source was used.

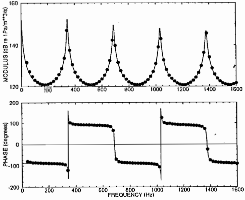
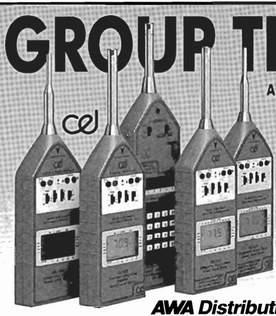


Figure 10. Modulus and Phase of the Computed (–) and Measured (•) Transfer Impedance (Piston Type Source)

REFERENCES

1. Byrne, K. P.,Transfer Function Technique for Impedance and Absorption Measurements in a Tube Using a Volume Velocity Source, International Conference on Noise Control Engineering, Sydney, 1057-1060, 1991.
2. Byrne, K. P., A Combined Finite Element and Experimental Method for Determining the Impedance Components at the Non-Rigid Internal Surfaces of a Cavity, Computational Methods in Engineering : Advances & Applications, World Scientific, pp 237-244, 1992.
3. Salava, T., Sources of Constant Volume Velocity and Their Use for Acoustic Measurements, Journal of the Audio Engineering Society, 22, 3, pp146-153, 1974.
4. Singh, R. And Schary, M., Acoustic Impedance Measurement Using Sine Sweep Excitation and Known Volume Velocity Technique, J. Acoust. Soc. Am. **64** (4), pp 995-1003, 1978.
5. Pratt, R. L., Elliot, S. J. And Bowsher, J. M., The Measurement of the Acoustic Impedance of Brass Instruments, Acustica, **38**, pp236-246, 1977.
6. Temkin, S., Elements of Acoustics, John Wiley and Sons, 1980.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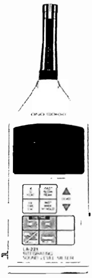
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PROFILES OF ACOUSTICIANS

Howard Pollard

Interviewed by Graham Caldersmith

This is the second interview in a series featuring currently active acousticians.

When I sat down to interview Howard Pollard for Acoustics Australia in the library adjoining my workshop I was aware of his career in teaching and research at the University of New South Wales, his research visits to Holland, England and Sweden and some of his published work in transients and timbre analysis. I was also aware of his enthusiasm for life in general and music in particular, having heard his organ recital with Neville Fletcher on flute at a Music Acoustics Conference, as well as his dedication to his profession in his continuing research and in editorial service after his retirement from university appointment in 1980. I was not aware of his advanced and imaginative approach to teaching which distinguished his university career, nor of the breadth of his research ethos, the generous and conscientious spirit of which I hope is indicated in the transcript following.

Howard Frank Pollard was born in 1920, educated at Perth Modern School and at the University of Western Australia, graduating with BSc (Hons) in 1943, then appointed Assistant Research Officer at the National Standards Laboratory in Sydney. He completed an MSc in 1946, was appointed lecturer in physics at Sydney Technical College in the same year and later completed his PhD in 1963 after the college was converted into the University of New South Wales. He became an Associate Professor of physics in 1972 and was appointed Honorary Research Scientist there after his retirement in 1980. During his overseas research visits between 1958 and 1979 he extended his research programs in crystal structure, material and architectural acoustics and in transient and timbre analysis. He is a Fellow of the Australian Acoustical Society, Fellow of the Australian Institute of Physics and Member of the Institute of Physics (UK), Acoustical Society of America and Catgut Acoustical Society. He was co-founder and chairman of the Organ Institute of NSW. Howard has served on committees of the Australian Institute of Physics, the Standards Association of Australia and the Australian Acoustical Society, and was Chief Editor of Acoustics Australia from 1981 to 1993.

GC: School days - do you have memories of scientific interests way back then?

HP: Yes, I went to Thomas Street Primary School in Perth, awful reputation, but it was next door to the Perth Modern School where my father was teaching mathematics. In the last two years of primary school, one afternoon was given over to either woodwork or basic science - demonstrations of interesting phenomena held in the woodwork shed. That teacher was very resourceful, particularly in setting individual assignments on scientific or technical topics which we took turns in presenting to the class as mini-research papers. It quickly became apparent that certain boys had talents in specific areas; I remember two boys talking about electricity and even constructing primitive devices. I remember doing a project on the Davy safety lamp. I was one of two from Thomas St who were the first to pass the entrance exam to the Perth Modern School which was a cause of great celebration for the headmaster who made an embarrassing speech about it at an assembly.

***GC:* And so you went to the Perth Modern School. What was the science curriculum there? Physics, chemistry, etc?**

HP: Yes, basic science subjects before we chose our streams in later years. Our teachers were good, experimentally inclined, and in third year we used the Dalton system of learning by self-pacing assignments. I liked chemistry at first, in fact, right through to the Leaving Certificate, even though I was getting better marks in physics. Funny thing that I was never sure then what physics was!

***GC:* Can I quote you on that? Do you know what physics is yet?**

HP: I'm still finding out! We did get some clues from a visiting lecturer who came once a term, a thoroughly Scottish physics professor, Alexander David Ross; he did the rounds of high schools trying to recruit future undergraduates. He was a jolly man who was also the chairman of the Music Board in Western Australia.

***GC:* Did you do any music in high school?**

HP: I had started piano at age 6 and in first year high school I won a scholarship at a piano exam but I had to soft pedal music after that because it clashed with my studies. In first year at university I took my A Mus A though it was difficult to fit in with the other subjects I was supposed to be studying. I played a bit through university, with choirs and soloists, but during my honours year I started organ lessons with the organist of Wesley Church, Mr Craft.

***GC:* Did you run into the musical Professor Ross at university?**

HP: Yes. I switched allegiance to physics at university and went through my undergraduate years in his department. Professor Ross was a good lecturer who had met Einstein and some of the other big wheels in physics. He always encouraged initiative and knew all the right connections when we eventually sought employment. I came to know him well. He set up an optical munitions laboratory in the physics department and spent a lot of time flying around Australia in DC3's in connection with this work. Being wartime, university students had been excluded from direct military service being classified as a reserved occupation and encouraged to complete our degrees before being assigned to work with radar or munitions.

***GC:* So your honours year was an extension and consolidation of your undergraduate courses.**

HP: Yes. Professor Ross used to say that you never understand your subjects in the year you take them; you may hopefully gain a glimmer of understanding in the next year. He wanted us to gain a perspective in our honours year - to see the implications of details we had learnt as undergraduates.

***GC:* Then came the prospect of employment - no postgraduate degrees going then in 1943?**

HP: It was possible to do a masters degree but for anything further it was customary in those days either to go overseas or to find employment and then look for further degrees later. The armed forces had now decided that there were enough radar officers; the current national priorities being radiophysics, meteorology, electrophysics and optics. I applied for a position in the optics division of the National Standards Laboratory just set up at Sydney University. Initially the work was testing telescopes, periscopes and rangefinders, then I went into photometry and finally colour measurement. The latter formed the starting point for a project under Dr Giovanelli, head of the optics division. The outcome was the development of a photoelectric colorimeter, but MIT in America had been doing similar work and put a device on the market before we could think about patents - the same old story. I'm afraid we still haven't learnt our lessons in the marketing game. Eventually I wrote up this work for an MSc from the University of WA.

My appointment at the Standards Laboratory was only temporary and there was some uncertainty about permanent positions after the war. So when Sydney Technical College came around recruiting lecturers in 1946, moving towards university status, I was confronted with an offer I could not refuse. But Dr Briggs, the head of physics at NSL, advised me to arrange my contract so that I could continue part-time research at NSL since there would be no research facilities at the college for some years. With his support this condition was accepted and I continued research at NSL until 1950.

***GC:* Thus began your teaching career.**

HP: Yes. My first class was a group of ex-servicemen coming for retraining: a two-year diploma course. I took them for first year physics and they were a marvellous bunch of students - it was a stimulating and rewarding class. But my pride and joy at the time was a class that fell to me because no-one else would touch it! When the East Sydney Technical College started, the head of the Food and Nutrition unit came to see Gordon Godfrey, head of physics at Sydney Technical College, and arranged for her girls to take a basic physics course to equip them for dealing with all the appliances they would use in their work. She requested that one staff member be dedicated to this course to provide continuity and to promote confidence with an unfamiliar subject. Well, I was the new boy and I was it. My colleagues thought this class would be a real giggle and called it the 'Food and Nuts Course'. But it turned out that these girls were very bright students and in fact I can say that two of them were the best students I have ever taught. In the second year the course ran one girl was brilliant: she was the only student I ever taught who regularly scored 100% in physics - I could not fault her work. She ended up teaching science in the country somewhere, rather than go into domestic science or the food industry.

That course was still running when we moved into the new building at Kensington; it had then become part of a degree course. As the course developed I introduced them to the design of their own experiments and self-marking exams. These were considered to be a bit heretical then, but proved effective in both assessment and learning. They were particularly good at self-study projects (which were a flashback to my days at Perth Modern School) enabling me to concentrate on tutorial and individual teaching. A bonus for teaching this course was that the girls would bring in fresh cakes and other edibles from their cooking classes at the end of term. Naturally there was no corruption involved! You look suspicious, just like my fellow lecturers.

***GC:* Sounds a bit cosy to me. But what was happening with the National Standards research while you were growing fat on the spoils from the Food and Nuts class?**

HP: As part of the colour measurement program I was responsible for a new recording spectrophotometer including its calibration and maintenance. Occasionally I was called in urgently from the academic cloisters if a problem arose. Eventually the vice-chancellor of the new university decided it was time to start our own research programs and that was when I finished my work at NSL.

***GC:* OK. Now how did the research start at the University of Technology?**

HP: One of the first group of professors appointed to the university was Professor Astbury as head of the School of Applied Physics. He was a specialist in electrophysics but he was also keen on music and acoustics. He would often come to the Great Hall at Sydney University when I gave a lunchtime organ recital and turn the pages for me!

***GC:* Coincidence or better! Serendipity perhaps!**

HP: Indeed. In fact I have always found musical talent in physics establishments. At the National Standards Laboratory there were many excellent amateur musicians who performed regularly at our own music club. Many of the staff sang at lunchtime in the Sydney University Musical Society. The director of the choir, Mr Allman, was university organist with whom I continued my organ studies. That's how I started giving lunchtime recitals which were usually broadcast by the ABC. I also gave some Sunday afternoon recitals on the Town Hall organ until 1954 when I decided to concentrate on my PhD work. I had about ten years of active organ recital performance.

***GC:* Now back to the research at the University of Technology.**

HP: That was only one of its names. First it was called the Institute of Technology, then within a year the Technical University, then the University of Technology and, eventually as more faculties were added, University of New South Wales. Professor Astbury suggested initiating acoustic research with ultrasonic measurements to measure wave velocities in solids. I set up some equipment involving resonating bars and measured absorption rates as well as velocities. I began a PhD project there in 1952 but the going was hard since there was no structure for postgraduate research nor any substantial research ethos in Australia at that time. So I didn't make much progress until I took study leave in 1958. With the aid of a Netherlands Government scholarship I travelled with my wife and two young children to Delft Technical University to work in the Acoustics

Department under Professor Kosten - a top man in acoustics. He put me on to measuring wave speeds in wood, of all things, despite the fact that there were hardly any trees in Holland at that time. After spending six months there I was offered a part-time position at Imperial College, London, in the Department of Acoustics with Dr Stephens. He brought a lot of ideas together for me, so that by the time I came back to Kensington I had a definite direction.

***GC:* What was the direction?**

HP: It was to develop a system for measuring wave velocity and attenuation in a range of materials; wooden, metal and plastic bars. Theoretical aspects were treated by developing an analogous transmission line theory which was also applicable to composite materials. It turned out to be a powerful technique and later was used by a number of my postgraduate students.

***GC:* So after your thesis was completed in 1962 you continued the research with postgraduate students?**

HP: We set up a Physical Acoustics Laboratory, one of the major studies being the application of our ultrasonic techniques to monitor changes in the properties of resonating crystals during neutron irradiation. Some of this work depended on the support of AINSE at Lucas Heights. I was teaching general acoustics, too, and did some organ pipe research on the side. At first the school was reluctant to fund music acoustics research because they thought it was outside the scope of their main interest - solid state research. However they tolerated me working in that area as a 'private' interest. Eventually, after I had made some progress in this field, the school agreed to support teaching and research in basic acoustics including an option in a Master of Physics course - much to the dismay of many of the physics staff who thought physics should be above the humdrum of acoustics. Of course I continued the ultrasonics research but tapered it off towards my retirement as I built up the acoustics research.

***GC:* What about your overseas connections in the latter years?**

HP: I went twice to ISVR (Institute of Vibration and Sound Research) at the University of Southampton in 1968 and 1974. I found it a lively place, very strong on the use of computers for data processing and the development of simulations as an aid to experiments. In 1979 I spent six months at the Royal Institute of Technology in Stockholm with Erik Jansson, not long after you left, I believe. I worked on the analysis of musical transients, looking for a parallel between analogous problems of colour assessment and transient sound perception. Despite the obvious physiological differences, I felt that similar brain processes were called forth in dealing with sound spectra and visual spectra. Erik took some convincing about that, but when he saw what I was driving at, he gave full attention and we published a paper on perception of sound and visual information.

***GC:* So what happened when you returned from Sweden?**

HP: I came back in 1979 with my 60th birthday coming up in 1980 when I would be routinely removed from the permanent roster and offered temporary employment renewable annually. As the administration was keen to employ younger staff I opted for retirement both because there were a few things I wanted to do and because I was finding working conditions becoming increasingly restrictive - we were not getting the research funds we needed and more administrative tasks were falling to academic staff.

***GC:* Now you have published a number of papers on musical timbre research, what do you think is the future of that research?**

HP: The next step would be to find out how the brain deals with the ten or more separate factors that contribute to musical timbre; how it weights the factors in different situations or decides on the dominant factors for a given sequence of sounds. Artificial intelligence techniques could be explored but I don't think these systems are advanced enough yet. We are reaching the limits of present-day understanding of how the brain operates. There are mistakes being made through technological enthusiasm wherein sets of data are being collected which are virtually meaningless without a model of brain function relating to sound perception.

***GC:* Do you expect progress there?**

HP: I've got a feeling that the breakthroughs will come when we begin to overcome the artificial boundaries between physics, acoustics, physiology and psychology and move towards a natural integration of all the relevant information on brain function. We know that the earlier theories of the brain as a computer are inadequate and now descriptions in terms of giant proteins, chemical pathways and holograms are floating about: the subject is obviously in its infancy.

***GC:* So this will be your direction for the future?**

HP: Ideally timbre measurements would mimic brain function. But whether an adequate model will emerge in the next few years is a good question. Certainly we have to look beyond the decibels versus frequency descriptions that many authors continue to peddle.

***GC:* What about the physics crisis we read of in all the journals? What is happening there?**

HP: Like Neville Fletcher in your earlier interview, I think we are seeing a redefinition of physics as it disperses into other areas of study and practice, no matter what labels we choose to give them. The important thing is that the methodology is continuing. One problem is that the bureaucrats and politicians who dole out the funds want labels as a substitute for an understanding of scientific thinking and practice.

***GC:* Yes, the funding process is a problem. But I also detect a general cynicism about science for all the wrong reasons and particularly among young people. Why do you think that is happening?**

HP: A lot of science teaching is appallingly conservative. It shows no imagination. Ordinary lectures have been shown to be the most inefficient way of delivering information. Entertainment is an unpopular word to use in academic circles, but for groups above about 60 students you must devise techniques for engaging their attention: feedback, computer simulations, active participation during the lecture, etc. Ultimately, I don't believe in teaching as such; all we can do is to create the best conditions for learning where the students' brains are encouraged to function somehow on the relevant material.

***GC:* The central question of brain function again! Understanding our understanding.**

HP: I agree. We cannot ignore our own intelligence functions. We have to grapple simultaneously with breadth and depth - just like the best natural scientists have always done.


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Output 2
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Power
200V
Mic. UP 1
On
Mic. UP 2
MPS2-R


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Excellence In Acoustics Awards

The Excellence in Acoustics Awards, previously held only in NSW, have gone national with arrangement for the 1994 awards now underway. The task of co-ordinating and presenting the Awards will be carried out by a different State Division of the Society each presentation year. To get the ball rolling the NSW Division will be presenting the first national series of awards to coincide with the 1994 National Conference. The Excellence in Acoustics Awards Committee are keen to see an expanded number and variety of entries for which due recognition of excellence can be given.

Details will be forwarded to each member in coming months, however in the meantime, further information can be obtained from 1994 Excellence in Acoustics Awards Committee, *c/- AAS NSW Division, Private Bag 1, Darlinghurst NSW 2010.*

Inter-Society Collaboration

The Society of Acoustics (Singapore) was established in April 1991. Since its incorporation, efforts have been made to collaborate with neighbouring societies from Australia, China, South Korea and India in organising conferences, symposia, talks, etc. Collaboration with the Australian Society has been proceeding smoothly thanks to the efforts of **Don Woolford**, who has been acting as a coordinator between the societies.

Mr Woolford attended a SAS Committee Meeting in November 1992 at which various suggestions for inter-society collaboration were discussed. Among these were: the exchange of information on international conferences for publishing in Society Newsletters; that members of AAS visiting Singapore be invited to address SAS, and that members of SAS offer to address AAS if visiting Australia; and that members of SAS be encouraged to submit papers for publishing in Acoustics Australia.

After the Committee meeting, Mr Woolford gave a talk on "Acoustics, Psychoacoustics and Hearing in Sound Broadcasting and Recording".

As an effective way of inter-society collaboration, **Dr W S Gan**, President, Society of Acoustics (Singapore): "warmly invites Australian acousticians visiting Singapore, particularly members of AAS, to address our Society on any topic of their choice related to acoustics". Prospective speakers can write or fax Dr Gan, allowing a few weeks to effect arrangements.

Dr W S Gan, President Society of Acoustics (Singapore), *c/- Acoustical Services Pty. Ltd., 29 Telok Ayer Street, Singapore 0104, Republic of Singapore. Telephone 65-791 3242. Fax 65-791 3665.*

1993 ANNUAL CONFERENCE

Progress in Acoustics, Noise and Vibration

This conference is to be held on Tuesday 9 to Wednesday 10 November, 1993 at the Ramada grand Hotel in Moseley Square, Glenelg, South Australia.

Approximately thirty papers will be presented addressing recent progress in the knowledge of acoustics and developments in noise and vibration control, architectural acoustics, community noise and hearing conservation. An overseas speaker has been invited to give the keynote paper which will address the relationship between psychology and noise.

A trade display will be held in conjunction with the conference.

Glenelg is located on the beach front a few kilometres from the centre of Adelaide and is convenient to the airport. There is ample accommodation in and around the conference venue at a range of rates. Note that the Conference will closely follow the Adelaide International Formulae 1 Grand Prix which is to be held on Sunday 7 November.

The Conference Registration fees, which will include proceedings, lunches and coffee for the two days will be:

Full Registration	$200
AAS members' rate	$160
Conference Dinner	$ 50

(Discount rate for AAS students and retired members is $100. Sustaining members of the Society are entitled to member rate for up to 3 delegates)

Further information and registration brochure: Bob Boyce, 7 Hank St, Lockleys, SA 5032, Tel (08) 439 331 or John Lambert Tel (08) 207 2080 (bus) or (08) 390 3567 (ah) Fax c/-Hansen (08) 303 4367.

Physics: A Vision For The Future

A report with that title has been published by the National Board of Employment, Education and Training of the Australian Research Council. The report was prepared by a Working Party of the National Committee for Physics of the Australian Academy of Science and is a review of the current state of Australian physics, and a strategy for strengthening the contribution of physics to Australian society.

The report comments:

"Acoustics, ultrasonics and vibrational analysis are important and growing areas of physics, with valuable applications in biophysics, medical diagnostics, non-destructive evaluation, and materials modification and processing. There is considerable activity in government agencies (CSIRO, DSTO, ANSTO), some in industrial laboratories (BHP), and a little in the higher education sector, mostly in engineering faculties.

"The Department of Health and Community Services' National Acoustics Laboratory is well equipped but its acoustic facilities are almost unused. The laboratory represents a valuable resource that would be difficult to replace and should be more widely utilised.

"It is difficult to recruit PhD physicists, with experience in ultrasonics, mainly due to the lack of significant activity in the Australian tertiary sector. Fruitful but neglected areas for basic research training in ultrasonics include transduction, propagation and scattering in inhomogeneous and disordered materials, non-linear interactions of ultrasound with liquids and solids, acoustic phase conjugation, and acoustic propagation in multi-layered structures."

The report recommends:

"At least one tertiary institution should develop physics-based PhD training in ultrasonics and acoustics in order to supply Australian strategic and industrial research programmes with staff experienced in the applications of these techniques."

The Australian Acoustical Society would welcome input from its members on the means for implementing the recommendation quoted, or on any relevant aspect.

Low Frequency Noise Research

Current building trends have resulted in an increase in noise problems at frequencies 250 Hz and below. There has been very little work on how people react to indoor noise in spaces such as offices, lecture and meeting rooms, where the background sound is the noise of high velocity air conditioning (HVAC) systems. The Noise Criteria (NC) curves do not evaluate the potential for annoyance due to rumble or other low-frequency noise from HVAC systems. ASHRAE has recently awarded a research contract to **Dr Norman Broner** of Vipac Engineers and Scientists to generate a practical philosophy and procedures for evaluation of the acceptability of low-frequency HVAC sound, and to provide the technical basis for development of low-frequency design criteria for future publication in ASHRAE handbooks.

News From NML

The CSIRO Division of Applied Physics (NML) publishes biennially a booklet "Tests and Measurements" which describes the many calibration services provided. The 1993 edition is available from July and incorporates a section on Acoustics. A new service has been introduced whereby the Electrostatic Actuator frequency response of the "STANDARDS" pattern type 4160 and 4180 microphones can be made. The general charge rate for 1993/4 remains unchanged with some services becoming considerably cheaper. Also NML will quote for non-standard tests should they be required. Customers of NML will automatically receive the 1993 Tests and Measurements book with test reports. Copies can be obtained from the Standards Liaison Officer, *Glenda Sandars, CSIRO NML, P.O. Box 218, LINDFIELD NSW 2070. Phone (02) 413 7211*

New Publication

Published by the International Institute of Noise Control Engineering (I-INCE), Noise/News International is a new quarterly journal and the successor to two newsletters, Noise/News of INCE/USA and the Newsletter of I-INCE. Contents of Vol 1, No 1 1993 include "Design and Performance of a Hemi-Anechoic Room for Measurement of the Noise Emitted by Computer and Business Equipment", the Technical Program for Inter-Noise 93, and news from the member societies of I-INCE (including Australia). Subscription rate for 1993 is SFr 80, surface mail delivery.

Subscriptions to: *I-INCE General Secretariat, Celestijnenlaan 200 D, B3001, Heverlee-Leuven, Belgium.*

Editorial correspondence to: *Mr George C Maling Jr, Managing Editor, NNI, c/o INCE/USA, PO Box 3206, Arlington Branch, Poughkeepsie, NY 12603, USA.*

Moves

Tony Hewett, presently the NSW EPA Regional Manager for Inner Sydney, will be retiring as of 1 July 1993. He will be taking a well earned holiday in the UK then enjoying life on his rural property near Sydney.

Having recently left a Sydney acoustic consultancy firm, **Stephen Samuels** will take up the position as Head of Transport Engineering in the School of Civil Engineering at the University of NSW.

Selby, Australian agent for Quest instruments, has new phone and fax numbers for the Melbourne office - phone (03) 263 4300; fax (03) 562 7953. Selby also has introduced a Custom Net 13 telephone numbers for Australia wide service. The "13" numbers are linked to product ranges, namely laboratory products -13 2991, scientific instruments -13 2990 and the newly formed Faulding imaging for medical and industrial products -13 2992.

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NEW MEMBERS

We welcome the following new members whose gradings have now been approved.

New South Wales

Member
Dr V D Gillies
Mr S Kanapathipillai

Subscriber
Mr S. Suine
Mr M. Gross
Mr A. Hundley

Victoria

Member
Mr I D McLeod

Queensland

Subscriber
Miss G. Adams
Ms H Nave

Books...

HANDBOOK OF ACOUSTICAL MEASUREMENTS AND NOISE CONTROL, 3rd Edition

Cyril Harris (Editor-in-chief)

McGraw-Hill, 1991, pp 1,024, hard covers, ISBN 0 07 026868 1.
Aust Distributor: McGraw-Hill Aust, PO Box 239 Roseville, NSW 2069. Tel (02) 417 4288, Fax (02) 417 5687. Price A$ 235.

For this third edition of the Handbook, edited by Cyril Harris, the coverage has been expanded with more material on noise measurements and this is reflected in the additional words in the title. The previous two editions, published in 1957 and 1979, have proved to be valuable reference books for all those working in the area of noise control. "What does Harris have on this?" has been an often asked question when a difficult point has been reached in a project.

The latest edition comprises 54 chapters with contributions from 76 experts from around the world. There has been considerable updating of the material on the technical, physiological, psychological and legal aspects of noise control. The nine new chapters include information on recent developments in measurement and analysis techniques. Some of the chapters which were in the second edition, have new authors so that the content and the presentation has changed.

Uniform terminology, symbols and abbreviations as well as the simultaneous use of international and US units, all help to produce consistency throughout even though there have been so many contributors. The stated aim of the editor was to ensure that the technical information is made accessible by the use of simple charts and written explanations rather than highly technical formulae. A quick scan through the handbook reveals that there are only a few formulae given and these are particularly important ones and the significance is described in the text.

As well as including new material, the latest edition has an improved layout which makes searching for information easier. The headings for the sections within each chapter are in large bold type and underlined. Also the subheadings are clearly separated from the surrounding text. The text itself is easier to read as it is in a larger sized type face.

The first chapters of the Handbook cover introduction to acoustics, sound propagation and measuring instrumentation. Then follows a number of chapters on measurement techniques for various types of noise and vibration. The next six chapters deal with various aspects of hearing conservation and this is followed by some chapters on noise annoyance. Techniques for control of vibration and noise in different environments and for different sources comprises the next chapters. The final chapters cover environmental noise issues.

For a book covering such a diverse range of topics, it would not be possible for everything to be included. The specialist will undoubtedly consider that some essential aspects have been omitted. However a "Handbook" should be a basic reference for a range of topics and all chapters have reference lists for those seeking more detail. One drawback from the Australian perspective is the strong reliance on US practices in the sections dealing with acceptability criteria and regulations. Also some currently important fields have little coverage (the only indexed reference to active noise control is one paragraph).

This third edition of Harris is recommended as an essential addition to the reference library of any organisation involved with noise control - the high price probably precludes the addition to the personal library. It is an excellent reference for students and should find a place in the libraries of educational establishments. It is the type of book which will be consulted on many occasions.

Marion Burgess

Marion Burgess is a research officer in the Acoustics and Vibration Centre at the Australian Defence Force Academy, Canberra and has experience with many noise control projects as well as teaching and research.

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HANDBOOK OF HUMAN PERFORMANCE, Volume 1: The Physical Environment

A P Smith & D M Jones (Editors)

Academic Press, 1992, hard covers, ISBN 0 12 650351 6.
Aust Distributor: Harcourt Brace Jovanovich Aust, Locked Bag 16, Marrickville, NSW 2204. Tel (02) 517 8999, Fax (02) 517 2249. Price A$ 117.60

This is the first of three volumes which are devoted to studies of factors which can influence human performance at work. This volume covers the influences of the physical environment, and includes studies which have traditionally been of interest in occupational health and psychology. Review chapters by experts in their field cover each of the following environment characteristics:

> Noise, Irrelevant Speech, Vibration, Heat, Cold, Air Pollution, Organic Solvents, Hyperbaric Environments, Electrical Fields, Ionization, Visual Environment and Visual Display Units.

The second volume will consider the influences of health (nutrition, drugs, alcohol, illness, etc) on performance while the third will look at the more slowly changing states of individuals (aging, anxiety, mood, sleep deprivation, fatigue etc).

Of most interest to readers of this journal will be the chapters on noise and vibration. The motivation to limit noise and, to a lesser extent, vibration stems usually from the need to keep within exposure standards which are designed to minimise the risk of damage to health, eg the impairment of hearing. The effects on human performance of these characteristics of the environment should also be considered since they can help to justify control measures.

The first chapter reviews both field and laboratory studies designed to find the influence of noise on accidents, errors and worker productivity. The field studies do indicate decrements in performance with increases in noise level, but experiments in the field are extremely difficult to control for the many other factors which are present. Generalizations cannot be made because results depend on the nature of the tasks involved, the characteristics of the noise and the noise level change which can be made in intervention studies.

Laboratory studies show little effect of noise levels on physical performance, but more significant effects on reducing performance in cognitive tasks. Some mechanisms to explain these effects are given. The second chapter, on irrelevant and distracting speech goes into more detail about this particular type of noise and its effects on cognition. As work moves away from factories and into offices, the focus of noise reduction could move into this area.

The chapter on vibration is written by Professor M.J. Griffin, Head of the Human Factors Research Unit of the Institute of Sound and Vibration Research at the University of Southampton, who has done pioneering experimental work in this area. He shows quite substantial effects of vibration on vision, as measured by reading speed and errors. Decrements are higher when the display alone is vibrating than when the person is subject to vibration and the display is stationary, because of the human ability to adapt to the vibration within certain limits. Effects of vibration on manual control are found to be substantial in many cases although generalizations are again difficult because of variations in the difficulty of the tasks and the variability of vibration characteristics. However, the discussion by Griffin suggests strategies for minimizing vibration effects in certain circumstances.

Vibration influences on performance have been found to depend mainly on magnitude, frequency and the axes about which the vibration occurs. Contrary to the requirements of the International Standard on evaluation of human exposure to whole body vibration, ISO 2631 (adopted in Australia as Australian Standard AS 2670.1-1990), experimental evidence generally does not point to a significant effect on performance from the *duration* of the exposure to vibration. In fact, performance may improve with exposure as subjects get accustomed to the vibration.

While only about one quarter of the book concerns noise and vibration, those sections are well written and up to date reviews which can save a great deal of time on literature searches. The remainder of the book will also be of great interest to anyone involved in broader issues of occupational health and safety.

Mike Stevenson

Mike Stevenson is Head of the Ergonomics Unit at Worksafe Australia and an Associate Professor in Occupational Medicine at the University of Sydney. He is active in research, teaching and consulting in occupational ergonomics.

✦ ✦ ✦

MASTER HANDBOOK OF ACOUSTICS, 2nd Edition

F Alton Everest

TAB Books Inc, 1989, pp 366, hard covers and soft covers, ISBN 0 8306 9096 4 and 0 8306 9096 3 respectively.
Aust Distributor: McGraw-Hill Aust, PO Box 239 Roseville, NSW 2069. Tel (02) 417 4288, Fax (02) 417 5687. Price hard cover A$ 54.95, soft cover A$ 39.95.

This has a very grand title and initially one wonders how all of acoustics can be covered in only 366 pages. The introduction gives the hint that the author is concentrating on the aspects of acoustics related to the use of sound as a means of communication. Thus the physical and psychophysical aspects for sound are considered in relation to audio technology. Within this area of acoustics, this book is very comprehensive and perhaps deserves the grand title.

The first three chapters deal with the fundamentals of sound and human hearing. The easy-to-follow and practical style of the author is immediately apparent. The text is complimented with clear diagrams and photographs. The mathematics is kept to a minimum. Suggested experiments, using equipment which would be readily available to the audio technician are scattered through the chapters.

The next five chapters deal with sound waves and sound fields in various types of spaces. The concept of comb filters, echoes, modes and reverberation are introduced and their significance clearly explained. The following chapter on noise, speech and music is probably the least comprehensive chapter. To deal with these sound sources in only 20 pages was surely an impossible challenge. It is clear that the author is mainly concerned with ensuring faithful reproduction of the sounds and not interested in just allowing comprehension.

Absorption and diffusion are covered in the next three chapters. Photographs of commercial products, especially of diffusers, are worthwhile inclusions in this section as they show the features referred to in the text and the line diagrams. A short chapter on controlling the noise from the air conditioning system covers the principles and concludes with a listing of seven practical suggestions. The acoustics requirements for the home listening room, the recording studio, the control room and multi-track recording are each covered in a separate chapter. Once again photographs assist with understanding the features discussed. The final chapter on acoustical measurements has considerable emphasis on time delay spectrometry. The book concludes with a glossary, reference listing and an index.

This book provides a useful overview of the various aspects necessary for recording and reproducing sounds. The easy style makes it an excellent book for those needing a thorough introduction to acoustics as related to audio technology. It would also provide a useful reference book for those currently working in the field. The reasonable price makes it worth considering as a personal purchase.

Marion Burgess

Marion Burgess is a research officer in the Acoustics and Vibration Centre at the Australian Defence Force Academy, Canberra and has experience with teaching and implementing room acoustics considerations.

New Products...

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The High Performance Ceiling System is suitable for both walls and ceilings and offers significant benefits over the use of concrete. The key to the system is the CSR Gyprock Resilient Mount, a proprietary component used for fastening two layers of 16 mm Gyprock Fyrechek to the underside of a timber floor. The sound transmission class (STC) of 57 is far in excess of the STC 45 prescribed as a minimum in the Building Code of Australia.

Further information: CSR Gyprock, tel (02) 332 3088

BRUEL & KJAER
New Sound Level Meter

The type 2236 is the first member of an entirely new range of sound level meters to be released by Bruel & Kjaer. The new precision integrating sound level meter has been launched in eight versions, each customised to the needs of a particular group of users in a particular country. It covers the relevant national standards for measuring environmental and industrial noise and comes in the local language. The meter features slow, fast, impulse, built in octave filters and logs Leq and Ln values.

Bruel & Kjaer new sound level meter type 2236

Multichannel Mic Pre Amplifier

The multichannel microphone preamplifier power supply input modules have dynamic and frequency ranges optimised for use with the portable battery operated Sony PC 204/208 DAT recorders. The type 5966 has 8 channels and the type 5968 has 4 channels.

Zwicker Loudness

The Zwicker loudness option, type 7638, is for use with the 2140 family of analysers. It works in single channel mode on the basis of 1/3 octave analysis and is based on the requirements of ISO 532 B.

Sound Level Calibrator

The type 4231 sound level calibrator is of robust pocket design for use with sound level meters and other sound measuring equipment. In addition to the 94 dB calibration it also has 114 dB calibration for use in noisy environments.

Further information: Bruel & Kjaer, 24 Tepko Rd, Terrey Hills, NSW 2084. Tel (02) 450 2066 Fax (02) 450 2379.

ACOUSTICS RESEARCH LABORATORIES
DAT Interface

A flexible remote control interface is now available which permits the ARL loggers to control a range of DAT recorders. The TRI-004 interface utilises established remote control standards to enable level triggered and/or timer controlled recordings to be obtained under the direction of a host Enviro-Logger. The post recording analysis software will allow for automatic processing of multiple DAT recordings which have been obtained using the TRI-004 remote control system.

Further information: Acoustic Research Laboratories, 169A Pacific Highway, Hornsby, NSW 2077. Tel (02)482 2866 Fax (02)476 4198

NIT
SYSNOISE

SYSNOISE is one of two new acoustic software products developed by Numerical Integration Technologies in Belgium. SYSNOISE is a comprehensive numerical acoustics software package which allows the designer to incorporate acoustic considerations right from the inception and well before a prototype has been constructed. The package allows the accurate modelling of both the complex acoustic and structural-acoustic behaviour. The acoustic Finite Element method (FEM) is used mostly to solve interior noise problems. When combined with the Wave Envelope Elements, exterior radiation patterns can also be predicted. Vibro-acoustic problems are treated by combining structural FEM data with the acoustic FEM or Boundary Element Methods (BEM). SYSNOISE provides a tool for a range of users including designers in automotive, aerospace, shipbuilding, household appliance and consumer electronics industries.

RAYNOISE

High quality acoustic performance can be provided by exploiting the power of simulations based on geometrical models. RAYNOISE is an advanced computer program that enables the assessment of any arbitrary enclosed or open space. Typical applications are in the analysis of room acoustics, industrial noise control as well as exterior and environmental noise. RAYNOISE embodies the conical beam method which combines the benefits of both ray tracing and mirror image source methods. Graphical display capabilities include echogram visualisation, top and side view sound rosettes, interactive selection of reflections and zoom options. Colour displays can be obtained for parameters such as pressure levels, definition, clarity index, early decay time, lateral efficiency and RASTI Index.

Further information: Acoustics and Vibration Centre, Australian Defence Force Academy, Canberra ACT 2600. Tel (06) 268 8241 Fax (06) 268 8276

DETECTSOUND

This software package has been designed for the analysis and selection of warning sounds, taking into account the background noise, the hearing status of workers and the use of hearing protectors.

Further information: Sonometric Inc.,5757 Deceles, Suite 514, Montreal, Que, Canada H3S 2C3. Fax (514) 345 8998.

ELECTRO CHEMICAL ENGINEERING
Lutron SL4001 Sound Level Meter

This meter provides top performance in an economical package. There are three ranges, dBA and dBC weightings, S or F response, peak hold feature, and an internal oscillator for calibration. The unit has DC and AC outputs, frequency response 30 Hz to 8 kHz, level accuracy approximately 0.7 dB, and weighs 250 grams.

Further information: Electro Chemical Engineering, 90 Calder Road, Rydalmere, NSW 2116.

LUCAS CEL
All-digital Sound Level Meter

The CEL-593 Sound Level Analyser is the first all-digital sound level meter. Signals from the microphone are converted immediately into digital form, and from this data broad band frequency weightings and time constants are calculated. Simultaneous real-time measurements can be made of 14 parameters selected to have two frequency weightings, two time constants and two amplitude weightings in any combination. Real-time octave and third-octave analysis is possible, and the analyser has an "event" mode for measurement of sources such as aircraft and road traffic. Preliminary processing is possible on the analyser, and results may be stored in internal memory or output via an RS-232 interface.

Environmental Noise Monitor

The CEL-268 Environmental Noise Meter is a hand-held type 1 instrument with a 10 to 140 dB measurement range in three sub-ranges. Measurement criteria and durations are menu-selected. Measurement results available include period Leq and Ln, short Leq, event profile and accumulative results. Results may be output to the LCD screen, stored in the 60,000 value non-volatile internal memory and output via a serial interface.

Further information: AWA Distribution, 112-118 Talavera Rd, North Ryde, NSW 2113.Tel (02)888 9000 Fax (02)888 9310.

NORSONIC

Real-Time Analyser 840

The Norsonic Real-Time Analyser 840 is a dual-channel type 1 precision instrument. It has a dynamic range of 80 dB and a frequency range of 1 Hz to 20 kHz in both channels, simultaneously. Its internal personal computer ensures that extensive postprocessing of data can be done even in the field. Data are presented on the instrument's 250 mm screen or on a VGA colour monitor, and can be stored in the internal memory, on a diskette, or on the internal 80 MB hard disk. The analyser has one IEEE-488 and two RS-232 interfaces.

Sound Level Meter 116

The Norsonic Sound Level Meter 116 measures both A- and C- weighted noise levels for both peak and rms values - all simultaneously. The instrument is type 1 according to IEC 651 and IEC 804 and has a dynamic range of 80 dB. Statistical analysis can be done with 8 Ln values. Data are presented numerically and graphically on the instrument's LCD screen, can be stored in the large internal memory, and output via the RS-232 interface.

Further information: RTA Technology Pty Ltd,1st floor, 160 Castlereagh St, Sydney, NSW 2000. Tel (02)267 5939 Fax (02)261 8294.

RTA SOFTWARE

Cassette Tape Logging Meter

This self-contained type 2 sound level measuring instrument features statistical processing capabilities, battery backed memory and incorporates a cassette recorder. The recorder may be programmed to turn on at selected times and/or days, or when the ambient sound level exceeds a preset level. Instantaneous A-weighted sound levels may be read on the 4-digit display, and Leq, Lmax, Lmin and 5 Ln values measured with F or S response may be stored in memory. Up to 2 weeks continuous recording is possible.

Further information: RTA Technology Pty Ltd,1st floor, 160 Castlereagh St, Sydney, NSW 2000. Tel (02)267 5939, Fax (02)261 8294.

ARO

Acoustical Diffusers

ARO Technology has recently introduced the 700 Series diffusion modules. Based on number theory, the 700 Series uses a quadratic residue formula and gives outstanding performance in both spatial and temporal diffusion. Incident sound at almost any angle is re-radiated over 180^{0}, eliminating sharp reflections and specularity, whilst preserving energy. The modules are ideal for any critical listening area, from studios through to auditoria, and greatly improve ambience and speech intelligibility.

Further information: ARO Technology, 4-6 Star Ave, Croyden Pk, SA 5008. Tel (08) 346 4199.

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AUSTRALIAN ACOUSTICAL SOCIETY ENQUIRIES

*** Notification of change of address**

*** Payment of annual subscription**

General Secretary
AAS– Science Centre Foundation
Private Bag 1, Darlinghurst 2010
Tel (02) 331 6920 Fax (02) 331 7296

Enquiries regarding membership and sustaining membership should be directed to the appropriate State Division Secretary as under:

AAS - NSW Division
Science Centre Foundation
Private Bag 1, DARLINGHURST 2010
Sec: Mr S Connolly
Tel (02) 922 4199 Fax (02) 923 1462

AAS - SA Division
C/–Department of Mech Eng
University of Adelaide
GPO Box 498, ADELAIDE 5001
Sec: Mr A C Zander
Tel (08) 228 5698 Fax (08) 224 0464

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27 Station St,
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Sec: Mr R H Rumble
Tel (07) 378 9211

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Sec: Mr R L Langford
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MELBOURNE 3000
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SOCIETY SUBSCRIPTION RATES

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Fellow and Member	$85
Affiliate and Subscriber	$68
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ANNUAL CONFERENCE

Copies of past conference proceedings may be ordered from:

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15 Taylors Road, DURAL 2158

ACOUSTICS AUSTRALIA INFORMATION

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The Editor
Acoustics Australia
Acoustics & Vibration Centre
ADFA
CANBERRA ACT 2600
Tel (06) 268 8241
Fax (06) 268 8276

SUBSCRIPTION RATES 1993

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ACOUSTICS AUSTRALIA EDITORIAL POLICY

Acoustics Australia is the house journal of the Australian Acoustical Society. It publishes general technical articles in all areas of acoustics of interest to members of the Society, together with relevant news and views. Review papers, covering particular fields of acoustics and addressed to a non-specialist acoustics readership, as well as papers of a "tutorial" nature dealing with important acoustical principles or techniques are most welcome.

Acoustics Australia does not aim to be a primary scientific journal, and therefore does not normally publish primary research papers, with the exception of those that apply specifically to Australia. Articles should generally not exceed five journal pages in length (i.e. about 6000 words, with each square single-column diagram being counted as 300 words, and pro-rata for diagrams of other shapes). Authors submitting longer articles may be asked to bear the extra publication costs involved. Shorter "Technical Notes", not exceeding one journal page in length, are also welcome. All articles will be submitted to independent review before being accepted for publication. Three copies of text and diagrams, together with originals of all drawings, should be submitted to the Editor. The drawings must be of publication quality and lettering must be of such a size that it will be no less than 2 mm high when the figure is reduced to single-column size (width 85 mm). In order to speed our production processes and save costs, authors are requested to submit papers, following their approval, in computer readable form using a standard word processing program such as Microsoft Word, Wordperfect, Lotus Manuscript, TeX or LaTeX, or in simple ASCII form. (Please consult the editor before using another format.) Three hard copies complete with copies of diagrams are however still required for the review process.

Diary ...

CONFERENCES and SEMINARS

* Indicates an Australian Activity

August 24-26, LEUVEN
INTER-NOISE 93
People Versus Noise
Details: INTER-NOISE 93, TI-K VIV, Desguinlei 214, B-2018 Antwerpen, Belgium, Tel (03) 216 09 96
Fax (03) 216 06 89

August 31-September 2, SENLIS
4th INTERNATIONAL CONFERENCE ON INTENSITY TECHNIQUES
Structural Intensity and Vibrational Energy Flow
Details: CETIM, BP 67, 60304, Senlis, France Tel (33) 44 58 34 15
Fax (33) 44 58 34 00

August 30-September 1, LEUVEN
INTERNATIONAL SEMINAR ON MODAL ANALYSIS
Details: ISMA, TI-K VIV, Desguinlei 214, B-2018 Antwerpen, Belgium,
Tel (32) 16 28 66 11
Fax (32) 16 22 23 45

September 2-3, WELLINGTON
Biennial Conference of the New Zealand Acoustical Society
Details: Malcolm Hunt, Secretary NZAS, Tel +64 4 384 6211, Fax +64 4 384 3306

September 15-17, BUCAREST
10th FASE
Details: Comm. d'Acoust. de L'Acad Roumaine, Calea Victoriei 125, 71 102 Bucarest, Romania

September 19-22, CARDIFF
7th International Symposium in Audiological Medicine
Details: Dr D Stephens, Welsh Hearing Institute, University Hospital of Wales, Cardiff CF4 4XW

October 4-8, DENVER
126th Meeting Acoustical Society of America
Details: Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury, NY 11797, USA,
Tel (516) 576 2360,
Fax (516) 349 7669

November 9-10, ADELAIDE
* AAS ANNUAL CONFERENCE
Progress in Acoustics Noise and Vibration Control
Details: 7 Hank St, Lockleys, SA 5032, Tel (08) 439 331, (08) 207 2080, (08) 390 3567 (ah)

December 6-10, PERTH
* INTERNATIONAL CONGRESS ON MODELLING AND SIMULATION
Modelling Change in Environmental and Socioeconomic Systems
Details: Anthony Jakeman, CRES, ANU, GPO Box 4 Canberra ACT 2601
Tel (06) 249 4742
Fax (06) 249 0757, email tony@cres.anu.edu.au

1994

February 27 - March 3, AMSTERDAM
96th AES
Details: Sec, AES Europe Office, Zevenbunderslaan 142/9, B-1190 Brussels, Belgium

May 15-19, PERTH
* MECH 94 - Resource Engineering including tri-annual Australian Vibration and Noise Conference
Details: Convention Manager,Mech 94, AE Conventions, Engineering House, 11 National Circuit, Barton, ACT 2600
Tel (06) 270 6530,
Fax (06) 273 2918

June 5-9, CAMBRIDGE
127th Meeting Acoustical Society of America
Details: Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury, NY 11797, USA

July 18-21, SOUTHAMPTON
5th International Conference on RECENT ADVANCES IN STRUCTURAL DYNAMICS
Details: ISVR Conference Secretariat, The University, Southampton, SO9 5NH, England.

August 23-25, SEOUL
WESTPRAC V
Details: Dr Il-Whan Cha, Yonsei University, Seoul, Korea

August 29-31, YOKOHAMA
INTERNOISE 94
Details: Yoiti Suzuki, Sone Lab, Riec, Tohoku Univ. 2-1-1 Katahira, Aoba-Ku, Sendai, 980 Japan.
Tel 81 22 266 4966,
Fax 81 22 263 9848, 81 22 224 7889 email: in94@riec.tohoku.ac.jp

November 28 - December 2, AUSTIN
128th Meeting Acoustical Society of America
Details: Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury, NY 11797, USA

1995

May 31 - June 4, WASHINGTON
129th Meeting Acoustical Society of America
Details: Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury, NY 11797, USA

July 10-12, NEWPORT BEACH, CALIF
INTERNOISE 95
Details: INCE/USA, PO Box 3206 Arlington Branch, Poughkeepsie, NY 12603 USA. Fax +1 914 473 9325

November 27 - December 1, ST LOUIS
130th Meeting Acoustical Society of America
Details: Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury, NY 11797, USA

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COURSES

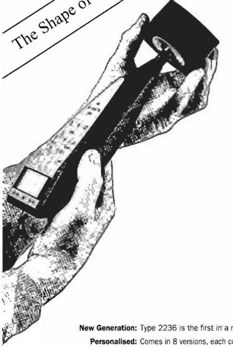
In accordance with the recognition of the importance of continuing education, details of courses held in Australia are included in this section at no charge. Additional details can be given in an advertisement at normal rates.

1993

CANBERRA
NOVEMBER 1-4
BASICS OF NOISE AND VIBRATION CONTROL
Details: Acoustics and Vibration Centre, Aust. Defence Force Acdemy, Canberra, ACT 2600.
Tel (06) 268 8241
Fax (06) 268 8276

SYDNEY
NOVEMBER 6-7
AUTOSOUND 2000
Details: Arena Distributors, PO Box 280, Victoria Park, WA 6100
Tel (09) 361 542
Fax (09) 470 1427

The Shape of things to come



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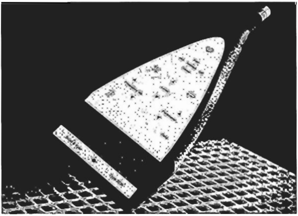

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- ★ 4/8 channels (0.5 HZ to 20 KHZ)
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- ★ Amplitude and phase matched channels (p pair)
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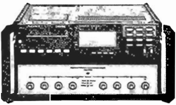

Type 5963

- ★ 8 channels
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Brüel & Kjær

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