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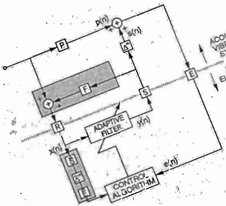

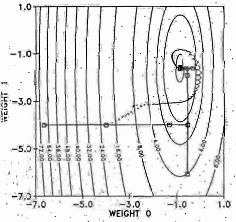

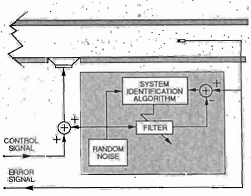

In this issue...

- **ACTIVE NOISE CONTROL**
- **CHINESE BELL**
- **VIOLIN**

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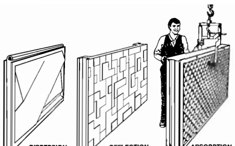

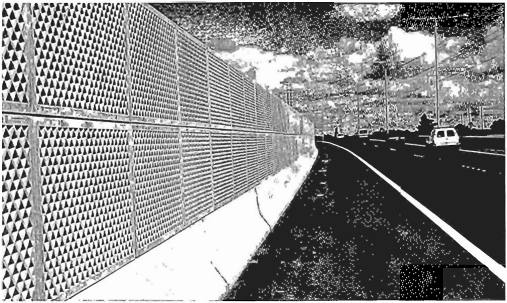

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COVER :
Figures from the article by Mackenzie and Hansen (see page 5)

Vol 20 No 1 April 1992

CONTENTS

ARTICLES

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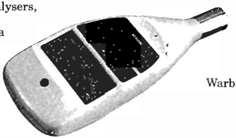

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FROM THE PRESIDENT

At the 48th Council meeting held in November last I received the honour of being elected President of the Society. I hope I can match the splendid examples set by previous Presidents.

Many Society members are basking in glory, perhaps just simply relaxing, after the double-header of International Conferences held last year - WESTPRAC IV in Brisbane and INTER-NOISE 91 in Sydney. Both seem to have been judged successful and have brought credit to the Society. Congratulations and thanks are due to all who took part in these and associated events.

A special word of greeting is proffered to new members of the Society.

New and old members can refer to reports elsewhere in this issue of Council Activities, particularly the award of the grade of Fellow to four members. One of the criteria for the award of Fellowship is that the nominee has made a sustained and outstanding contribution to acoustics and/or the Society. Acoustics in Australia has gained significant benefit from those who have attained the grade of Fellow in the Society.

On a number of occasions the question of a Code of Ethics has arisen in Council meetings. This seems to be an issue of growing importance - should we have a Code of Ethics, and if so, is the proposed draft the right way to go? As noted in the Council Activities report, this matter is being put before Divisions and members during 1992.

I may have a rare pleasure, namely, to announce that there will be no increase in subscription fees for 1992/93. What a note on which to end this message!

R.J. HOOKER

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A Review Of Controller Hardware And Control Algorithms For Active Noise And Vibration Control

Neil C. Mackenzie and Colin H. Hansen
Department of Mechanical Engineering,
University of Adelaide,
GPO Box 498, Adelaide,
South Australia, 5001.

Abstract: Development of the digital electronic controller component of an active noise and vibration control (ANVC) system is discussed with reference to the unique problems associated with the transfer of information from the acoustic to the digital electronic media.

1. INTRODUCTION

Active noise and vibration control (ANVC) was launched by Leug [1] in the 1930's, using a non-adaptive, open-loop feedforward model to control noise propagating in a duct, as shown in figure 1a. Such a model can achieve broadband cancellation of the primary disturbance provided high coherence exists between the reference signal and the primary disturbance. However the performance of a system like this in practice is very poor due to the inability of the system to cope with small changes in the duct acoustics

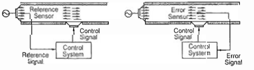


Figure 1(a). Feedforward control system.

Figure 1(b). Feedback control system.

(such as speed of sound changes). Thus there was limited interest in the technology due to an inability to demonstrate it convincingly. The fifties saw ANVC reintroduced independently by Olson [2] with a non-adaptive, closed-loop feedback model, as shown in figure 1b, which uses the error signal rather than a coherent reference signal to achieve narrowband noise cancellation. To achieve significant attenuation of the primary disturbance, such a system requires an amplifier with a high gain, which makes the system inherently unstable. The major difference between feedforward and feedback control is that the former modifies the zeroes of the plant transfer function (ie. it alters the impedance seen by the primary disturbance and/or absorbs the energy at the control source), thus achieving a more stable system, whereas the feedback control approach modifies the poles of the plant transfer function (ie. it cannot alter the impedance seen by the primary disturbance, thus it acts only as an absorber of energy at the control source), thus only affecting the transient response of the system [3].

Judicious arrangement of two or three control sources was used in the seventies in attempts to prevent the acoustic feedback (input contamination), from the control source, "contaminating" the reference signal used in Leug's feedforward model (monopole). Jessel and Mangiante [4], and Swinbanks [5] used three (tripole) and two (dipole) control sources respectively, in attempts to constrain the controlled disturbance to one direction in a duct. The alternative was to create a null in the control disturbance at the reference sensor location, as was attempted by Eghtesadi and Leventhall [6].

The introduction of digital electronics in the late seventies and early eighties saw dramatic advances in controller design. The first practical use of adaptive filters (adaptivity is required to account for changes in environmental conditions and ageing of the transducers) in ANVC systems was by Ross [7]. Chaplin [8,9] achieved limited success using the root mean square (RMS) value of the error signal to adaptively adjust the control transfer function parameters, in a frequency domain approach; however, he later used a time domain approach for random noise with, what one may purport from the referenced articles, Widrow's [10] well known Least Mean Squares (LMS) algorithm. This algorithm has since achieved widespread use for both periodic and random noise applications due to its simplicity, well known properties and ease of implementation. Burgess [11] applied Morgan's [12] analysis of the effect of the transfer function between the electrical output signal to the control source and the electrical signal from the error sensor (error path) on the control algorithm, to form the filtered-X algorithm. Eriksson [13] used random noise and an additional adaptive filter to provide an on-line estimate of the error path transfer function. The advent of digital electronics also enabled Eriksson [14] to account for acoustic feedback using a non-linear adaptive filter and non-linear (recursive) algorithm. Sommerfeldt and Tichy [15] later used the available signals with an additional adaptive filter and corresponding LMS type of system identification algorithm, to provide an alternative means of providing an on-line estimate of the error path transfer function. Elliott and Nelson [16] implemented the first practical multichannel system suitable for global control of sound, revealing the impact of the number and location of controllers (actuators) and error sensors on the amount of achievable noise or vibration attenuation.

It is the aim of this paper to use the common single channel model of an active noise control system as a basis for the discussion of the recent developments in digital electronic control systems, highlighting how the various problems have been overcome and how practical systems may be implemented using currently available software and hardware. It should be noted that at this time no multi-channel control system satisfying the general requirements of noise or vibration control has been implemented with proven reliability.

2. CONTROL ALGORITHMS

The widely accepted standard active control system is based upon the feedforward model of the physical system. A more detailed view of such a system is shown in figure 2, and consists of an adaptive filter and control algorithm. The capital letters in this figure represent the transfer functions for P the primary plant (the primary acoustic or vibration signal to be controlled), R the reference sensor, S the control source, F the feedback (input contamination) from the control source to the reference sensor, E the error sensor, Δ^m the number of samples equivalent to the time taken for the control signal to reach the error sensor, $\hat{S}$ the estimate for the control source, $\hat{E}$ the estimate for the error sensor and $\hat{\Delta}^m$ the estimate of the number of samples equivalent to the time taken for the control signal to reach the error sensor. For ANVC to be successful for a feedforward system, there must exist a reference signal that is correlated with the primary disturbance. After passing through an adaptive filter, the reference signal is convolved with the control source finite impulse response (time domain equivalent to the transfer function in the frequency domain) and then used to drive the control source. The adaptive filter is most often implemented as a transversal filter as shown in figure 3, where it can be seen that the filter output is a linear combination of delayed samples of the reference signal (the symbol Δ represents a delay of one sample). Note that the reference signal must pass through an analogue to digital converter before passing into the transversal filter and the filtered reference signal must pass through a digital to analogue converter before passing into the control source (as will be discussed in the next section).

The weights shown in the transversal filter of figure 3 (one weight for each stage in the filter) are adjusted in such a way as to minimise a cost function that is generally based on the expected value of the square of the error signal (obtained by passing the error signal through an analogue to digital converter) at sample n; that is $E[e^2(n)]$. To adjust the transversal filter weights so that the cost functionis minimised, a standard gradient descent algorithm such as the well known least mean squares (LMS) algorithm is used, resulting in the following weight update equation

$$W_N(n+1) = W_N(n) - 2\mu X_N(n)e(n) \qquad (1)$$

where, $X_N(n) = [x(n), ..., x(n-N+1)]$, with $x(n)$ the reference signal at sample n, $W_N(n) = [w_0(n), ..., w_{N-1}(n)]$, with $w(n)$ the individual weights at sample n, and μ the convergence coefficient or stability factor.

Acoustic feedback (input contamination), shown as F in figure 2, from the control source to the reference sensor can in some cases affect the stability of the controller. Non-linear feedback of this type was eliminated by Eriksson [14] using a non-linear (recursive) filter and the recursive least mean squares (RLMS) algorithm. This filter consists of a transversal filter feeding the reference signal forwards while another feeds the output of this backwards, as shown in figure 4. An alternative and simpler method which may not always be feasible is to use a reference sensor which isn't receptive to feedback such as a tachometer signal from a rotating shaft. However this will only enable the active control system to control noise which is harmonically related to the rotating shaft frequency.

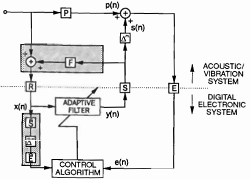


Figure 2. Block diagram of a single channel controller.

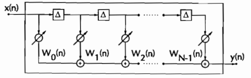


Figure 3. Transversal filter (with Finite Impulse Response [FIR] transfer function).

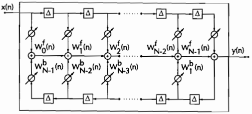


Figure 4. Recursive Filter (with Infinite Impulse Response [IIR] transfer function)

The preceding weight update equation does not account for problems associated with the electro-acoustic transfer functions of the control source and the error sensor, nor the time delay associated with the path of a signal between the two.

However, in 1981 Burgess [11] used the filtered-χ algorithm, originally defined by Morgan [12], to take this into account, resulting in the following weight update equation, with all variables defined as before.

$$W_N(n+1) = W_N(n) - 2\mu e(n)X_N(n-\hat{\Delta}^m)*\hat{S}*\hat{E} \qquad (2)$$

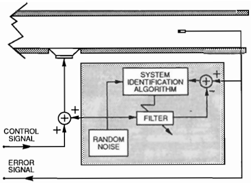


Figure 5. On-line estimation of error path transfer function using additional adaptive filter and random noise.

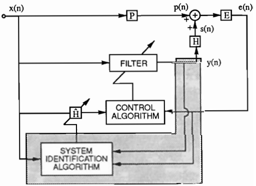


Figure 6. On-line estimation of error path transfer function using system identification algorithm and the available signals.

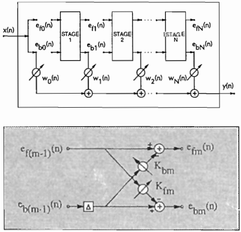
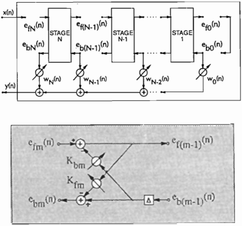


Figure 7. Tapped-Lattice filter structure (FIR form) with
= forward prediction errors,
= backward prediction errors,
= tap weights,
= input to filter, and
= output from filter.

Snyder and Hansen [17] found that errors in estimation of both the phase and magnitude of the error plant transfer function reduced the allowed bounds of the convergence coefficient for stability, and in some cases led to instability regardless of this coefficient. Similarly, if the weights of the adaptive filter are continuously updated at every sample (rather than every number of samples equivalent to the time taken for the control signal to reach the error sensor) the allowed bounds of the convergence coefficient for stability were found to be reduced by an amount dependent upon the number of samples equivalent to the time taken for the control signal to reach the error sensor. The net result is that the system will no converge any faster if the filter weights are updated at every sample rather than a intervals corresponding to the time taken for the control signal to reach the error sensor.

The problem of estimating the transducer transfer functions and control actuator-error sensor time delay may be eliminated by on-line measurement using an additional adaptive filter and random noise generator as was done by Eriksson [13] and is shown schematically in figure 5. The addition of random noise is clearly undesirable, as it reduces the amount of achievable noise or vibration control. However an alternative method of on-line estimation of these transfer functions and time delays, which does not involve the introduction of additional random noise into the system, was developed by Sommerfeldt and Tichy [15] as shown schematically in figure 6. In this figure H and Ĥ represent the transfer functions corresponding to the combined effect of the control source transfer function, the error sensor transfer function and the number of samples equivalent to the time taken for the control signal to reach the error sensor, and the combined effect of their estimates respectively. Their method uses the standard filtered-χ algorithm for control and a second adaptive filter with an associated system identification algorithm that is based on the projection algorithm developed by Goodwin and Sin [18]. However this method suffers from serious convergence problems when used to control random noise.

The above methods use the gradient of the cost function to adaptively adjust the weights of the control filter. The gradient approximation requires knowledge of the error path transfer function as discussed above. An alternative algorithm requiring no knowledge of this transfer function and thus offering more stable control has been developed by Mackenzie and Hansen [19], and is based on estimating the cost function, for three values of a particular independent weight, and then fitting these estimates to a parabolic curve, from which the optimum for the particular independent weight may be obtained. The disadvantages of this algorithm are its slow convergence rate and an optimal weightvalue that is dependent upon the number of samples taken to estimate the cost function and the spacing between the individual values for a particular independent weight. To enable efficient convergence to the optimum of the cost function, independent weights are required. This means that adjustment of one weight should not affect the optimum value of any other weight. This criterion can be attained using a lattice filter, as shown in figure 7, to orthogonalise the reference signal which, when tapped into a linear combiner, enables the linear combiner's weights to be independently adjusted. The elimination of input contamination of the reference signal, in this algorithm, is achieved using a non-linear form of the lattice filter, shown in figure 8.



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= input to filter, and
= output from filter.

The results obtained using these various algorithms are illustrated for a sinusoidal reference signal and a dual weight transversal filter in figures 9(a), 9(b) and 9(c). Figure 9(a) shows mean square error (MSE) contours, corresponding to the cost function discussed above, and the paths from the initial weight settings (weight 0 = -4, weight 1 = -4) to the optimal weight settings (weight 0 = -0.87, weight 1 = - 1.61), for the filtered-χ algorithm with Sommerfeldt and Tichy's method of on-line system identification, and the curve fit algorithm using a tapped-lattice filter. Figure 9(b) shows the error signal for the filtered-χ algorithm with Sommerfeldt and Tichy's method of on-line system identification, while figure 9(c) shows the error signal for the curve fit algorithm using a tapped-lattice filter. Figure 9(a) shows the differing stabilities of the two algorithms while figures 9(b) and 9(c) show the differing speeds of convergence .

3. HARDWARE AND SOFTWARE IMPLEMENTATION

Active adaptive noise and vibration control has only been practically realisable in the last decade due to the rapid advances in digital signal processing technology. Digital systems are used since analogue systems are inherently inflexible and thereby costly to modify, as well as sometimes possessing unpredictable and time varying qualities making them ill-suited to the crucial requirements of system stability.

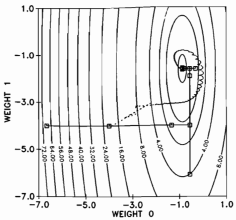

Figure 9(a). Comparison of Algorithms with Mean Square Error (MSE) Contours, Filtered -χ Algorithm with on-line system identification, and Curve Fit Algorithm.

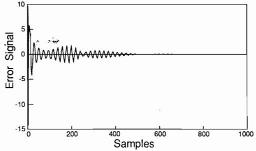

Figure 9(b). Error signal for the filtered -χ algorithm with Sommerfeldt and Tichy's method of on-line system identification.

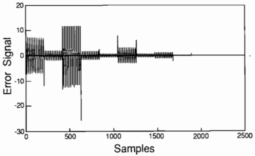

Figure 9(c). Error signal for the curve fit algorithm using a tapped-lattice filter.

A typical digital system architecture is shown in figure 10. The digital system communicates with the real (or continuous) environment via digital to analogue converters (DAC's) and analogue to digital converters (ADC's). The resolution of these "systems" determines the maximum amount of attenuation achievable; however, a side effect is to introduce quantisation errors into the algorithms thus adding a further source of instability. Both "systems" essentially consist of input/output amplifiers, anti-aliasing/reconstruction filters, and sample and hold circuitry which provide time for the ADC/DAC respectively, to convert a continuous signal to the digital domain or vice-versa. The components of such systems are synchronised by a master clock with a frequency of the order of a few MHz, which may be transformed down to a sampling frequency of the order of a few kHz.

The implementation of the three processes shown in the figure may be accomplished by using a hybrid combination of both software and hardware with either a serial or parallel computing architecture. The general system for performing each/all of these processes is shown in figure 11. In the figure the first-in first-out (FIFO) buffers are used to store data for the updating of the controller weights by the adaptive algorithm and indirectly the system identification algorithm on the microprocessor, while the special purpose unit (eg. INMOS A100 Cascadable Transversal Filter) enables adaptive filtering to be performed faster than may be performed on the microprocessor.

Depending upon the complexity of the calculations and the memory required for data storage, all three processes shown in figure 10 may be performed by the above system. Such systems commonly use a digital signal processing board (available from Texas Instruments, eg. TMS320C25) or Analogue Devices, eg. ADSP 2100) available in floating point or integer arithmetic form. The use of floating point arithmetic simplifies software development, as digital overflows are less of a problem, however operations of this type require more time to be performed than integer arithmetic operations. Digital signal processing boards currently have inefficient compilers; thus, to enable efficient programming of the processes, the programmer needs to know assembly language and the intricate details of the boards. Should a more flexible and sophisticated system be required, a parallel form of microprocessor known as a transputer can be used as shown in figure 12. The transputer developed by INMOS, uses a high-level programming language (OCCAM) that enables efficient and transparent implementation of parallel processes.

4. DIRECTIONS FOR FUTURE WORK AND CONCLUSIONS

Current research aims to increase the stability and convergence speed of control systems for complex environments which may be at odds with commercial requirements of flexible, reliable control systems able to improve sound quality as well as provide adequate noise reduction at minimum cost.

The use of a lattice filter eliminates the previously required knowledge of the error path transfer function, thus providing a more stable and reliable control system. It also substantially reduces the amount of control architecture required for multiple input/output systems, thus substantially minimising system cost. Future work on this type of control algorithm and architecture will aim to increase the rate of convergence and the accuracy of the calculated optimal

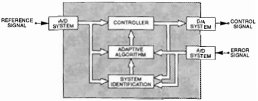

Figure 10. Overall system digital electronic architecture.

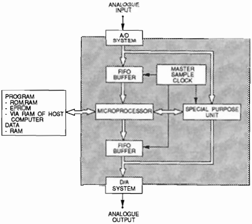

Figure 11. Specific process digital electronic architecture.

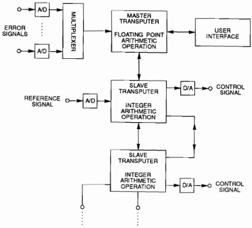

Figure 12. Multiple input/output control system using transputers.

weights. At present the use of a lattice filter in multiple input/output systems has been shown to achieve good attenuation. However, the algorithm concepts are currently under investigation, since the optimum of the cost function changes when the weights of each adaptive filter, corresponding to each control actuator, are optimised [20]. The system remains stable while the time for convergence to the achievable minimum MSE increases. The effect of random noise on the amount of attenuation and stability of the control algorithm is also presently under investigation.

The semi-conductor evolution is heading towards high performance and higher density circuit integration with the use of alternative materials (eg. Ga-As). Application of such technology to microprocessors will enable the development of computationally intensive but more robust algorithms and control architectures at lower cost.

Neural networks are now becoming increasingly attractive as alternatives to current control architectures [21]. They represent a parallel-processing architecture, similar to that of the lattice filter, with the ability to handle multiple inputs/outputs. Such networks have direct application to systems in which harmonic distortion is generated from non-linear control actuators. To increase the rate of convergence of the control algorithm updating the weights of the network, it is envisaged that lattice filters will be incorporated at the input to the network, providing the network with orthogonal rather than time delayed versions of the reference signal. The feasibility of using a combined feedforward and feedback control system with this type of control architecture is currently under investigation. This type of system will use algorithms such as the "model reference" form or the "self-tuning regulator" form detailed in "modern" control literature [22] and could link the stability advantages of the feedforward technique with the transient control advantages of the feedback technique.

It is evident that the rapid advances in microprocessor technology which has enabled the development of practical ANVC systems, has indirectly led to the introduction of further stability and control problems in the field of active noise and vibration control. With these problems on the verge of solution, one may envisage ANVC systems for complex environments becoming commercially viable within the next decade.

REFERENCES

1. Leug, P., 1933. "Process of Silencing Sound Oscillations", German Patent, DRP No. 655, 508.
2. Olson, H.F. and May, E.G., 1953. "Electronic Sound Absorber", Journal of the Acoustical Society of America,25(6):1130-1136.
3. Franklin, G.F., Powell, J.D. and Workman, M.L., 1990. "Digital Control of Dynamic Systems", Addison-Wesley, Reading, Mass..
4. Jessel, M. and Mangiante, G.A., 1972. "Active sound absorbers in an air duct", Journal of Sound and Vibration, 23:383-390.
5. Swinbanks, M.A., 1973. "The active control of sound propagation in long ducts", Journal of Sound and Vibration, 27:411-436.
6. Eghtesadi, Kh. and Leventhall, H.G., 1981. "Active attenuation of noise: The Chelsea dipole", Journal of Sound and Vibration, 75:127-134.
7. Ross, C.F., 1982. "An adaptive digital filter for broadband active sound control", Journal of Sound and Vibration, 80:381-388.
8. Chaplin, G.B.B., 1980. "The cancellation of repetitive noise and vibration", Proceedings of Inter-Noise 1980, 699-702.
9. Chaplin, G.B.B., 1983. "Anti-noise - The Essex breakthrough", Chart. Mech. Engr., 30:41-47.
10. Widrow, B. and Stearns, S.D., 1985. "Adaptive Signal Processing", Prentice-Hall, New Jersey.
11. Burgess, J., 1981. "Active Adaptive Sound Control in a Duct: A Computer Simulation", Journal of the Acoustical Society of America, 70(3):715-726.
12. Morgan, D.R., 1980. "An analysis of multiple correlation cancellation loops with a filter in the auxiliary path", IEEE Trans. Acoustics Speech and Signal Processing, ASSP-28:456-467.
13. Eriksson, L.J. and Allie, M.C., 1989. "Use of Random Noise for On-Line Transducer Modelling in an Adaptive Active Attenuation System", Journal of the Acoustical Society of America, 85 (2):797-802.
14. Eriksson, L.J., Allie, M.C. and R.A. Greiner, 1987. "The Selection and Application of an IIR Adaptive Filter for use in Active Sound Attenuation", IIEEE Trans. on Acoustics, Speech and Signal Processing, ASSP-35:433-437.
15. Sommerfeldt, S.D. and Tichy, J., 1990. "Adaptive Control of a Two-Stage Vibration Isolation Mount", Journal of the Acoustical Society of America, 88(2):938-944.
16. Elliott, S.J., Stothers, I.M. and Nelson, P.A., 1987. "A multiple error LMS algorithm and its application to the active control of sound and vibration", IEEE Trans. Acoustics, Speech and Signal Processing, ASSP-35:1423-1434.
17. Snyder, S.D. and Hansen, C.H., 1990. "The Influence of Transducer Transfer Functions and Acoustic Time Delays on the Implementation of the LMS algorithm in Active Noise Control Systems", Journal of Sound and Vibration, 140(3):409-424.
18. Goodwin, G.C. and Sin, K.S., 1984. "Adaptive Filtering, Prediction and Control", Prentice-Hall,Englewood Cliffs, NJ, chpt. 3.
19. Mackenzie, N.C. and Hansen, C.H., 1991. "The Implementation of a Lattice Filter Structure and Suitable Algorithm for an Adaptive Active Noise Control System", Proceedings of Recent Advances in Active Control of Sound and Vibration, Virginia Polytechnic and State University, Blacksburg, Virginia, USA, April 15-17, pp 372-388.
20. Mackenzie, N.C. and Hansen, C.H., 1991. "The Use of an Alternative Adaptive Algorithm with a Lattice Structured Filter for a Multi-Channel Active Noise or Vibration Control System", Proceedings of Inter-Noise 91, University of NSW, Sydney, Australia, December 2-4, pp 177-180.
21. Bozich, D.J. and MacKay, H.B., 1991. "Neurocontrollers Applied to Real-Time Vibration Cancellation at Multiple Locations", Proceedings of Recent Advances in Active Control of Sound and Vibration, Virginia Polytechnic and State University, Blacksburg, Virginia, April 15-17, 326-337.
22. Chalam, V.V., 1987. "Adaptive control systems : techniques and applications", M. Dekker, New York.

Acoustical Measurements of Quality Rated Violins and a New Measurement Method

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ABSTRACT: Quality rated violins from three amateur violin maker competitions have been diagnosed by acoustic measurements. At the first competition, Fiol75, long-time-average-spectra were measured. It was found that high levels at low and medium high frequencies are favourable, as well as low levels at high frequencies. At the second competition, Fiol80, vibration levels were measured at the violin bridge. It was found that high levels of three low frequency resonances as well as a "hump" in the bridge frequency region are favourable. At the last competition, Fiol90, a third method was tried. In previous experiments, the bridge vibrations gave less sensitive measures than the player's ears. Therefore the sound from a well-defined pulse excitation of the bridge is recorded at the position of the player's left ear. It is found that the recordings at "the left ear" and of the bridge vibrations generally exhibit the same properties. The new method is simple to use and has advantages when a FFT-analyser is available.

1. INTRODUCTION

In Stockholm the amateur violin makers have a club - the Stockholm Violin Makers' Club. They arrange combined exhibitions and competitions for amateur violin makers. Newly made "anonymous" violins are sent to the competition and are tested by two professional players. By means of tonal quality points awarded, a rating of the violins is established, and the best rated violins are given prizes of acknowledgement.

In cooperation with the club we receive an early copy of the ratings and can select violins of different qualities for our tests. The tests are made before the opening of the exhibition. We select the violins in three groups; best violins, some in the middle and poorer violins. By means of such a selection we hope to obtain a fair coverage of different qualities. In the selection we are not likely to find excellent violins. Therefore we have included such a violin as complement, an Andrea Guarneri violin owned by our expert test player, Lars Frydén. In addition our reference violin HS71 is included.

This report is limited to our findings. Very important contributions to the understanding of quality of violins have been made by Dr. Carleen Hutchins of the Catgut Acoustical Society and Dr. Heinrich Dünnwald (see [Hutchins 1981, 1989] and [Dünnwald 1990, 1991] for further references).

In Australia Graham Caldersmith has contributed to the understanding of the violin and its acoustics. Two reports on quality assessment by him have been published in previous issues of Acoustics Australia (Caldersmith, 1988 and 1989). Somewhat similar ways were used in the Swedish quality ratings (quality assessments) for Fiol75, Fiol80 and Fiol90. The ratings were, however, only made by two professional players, both as player and listener, and on a scale from not acceptable to very good.

2. QUALITY AND FIOL75

The competition and exhibition Fiol75 included 103 violins. The violins were given tonal quality ratings from 72 to 36 (80 being the best possible). Twenty-two violins were selected and represented ratings from the highest to the lowest [Gabrielsson and Jansson, 1979]. All violins were brought to a reverberation chamber, in which three whole tone scales over three octaves were recorded for each instrument. Thereafter long-time-average-spectra were made with a filter bank and a computer program, approximating the function of critical bands of hearing. Factor analyses were made of the spectra and examples are shown in Figure 1. In the figure, spectra for the violin scoring the best and worst in the three dominating factors are plotted. The three factors are a low frequency factor (high level is favourable), a high frequency factor (low level is favourable) and a medium high frequency factor (high level is favourable). The violin scoring most favourably in the third factor was the Guarneri violin, which is very interesting but may be accidental.

3. QUALITY AND FIOL80

In the exhibition and competition Fiol80 a total number of 77 violins had been tested and quality rated. Out of these violins 24 were selected to cover the full range of ratings. J. Alonso measured the input admittances perpendicular to the top plate on the bridge just outside the lowest and the highest string with a specially developed sond [Alonso and Jansson, 1982a].

The sond consists of two main parts. One part is built around a small accelerometer (B&K 8307 later 4374) fastened via a small plexiglass angle to the violin bridge and with a small but very strong magnet on top of the accelerometer. The parts are "glued together" with wax and also fastened to the violin bridge with wax. An electric coil is concentrically placed relative to the magnet and its current gives an excitation force without touching the first part or the violin.

Results of the measurements are shown in Figure 2. Analy-

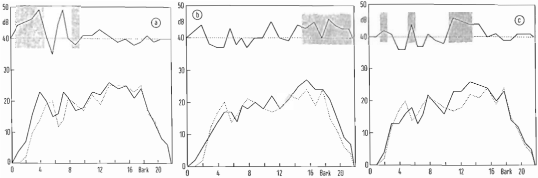

Figure 1. FIOL75 - Factor analysis of LTAS - showing that (a) high levels at low frequencies, (b) low levels at high frequencies, and (c) high levels at medium high frequencies are favourable. Lower curves for violins scoring maximum (full lines) and minimum (dotted lines) respectively in each factor with their frequency regions marked shadowed. Upper curve is difference (40 dB corresponds here to 0 dB) between the two violins (for reference: 4 Bark is 0.4 kHz, 8 Bark 0.92 kHz, 12 Bark 1.72 kHz, and 16 Bark 3.15 kHz from Gabrielsson and Jansson 1979).

sis of the measurements gave that the three peaks T1, C3 and C4 should be high and evenly high. Furthermore the "hump", the "bridge hill" around 2.5 kHz should be prominent.

4. NEW METHOD AND FIOL90

4.1 New Method

In experiments with violin bridges the method of measuring violin properties was modified [Jansson et al, 1990]. The bridge is excited with a blow at the bass side edge by a small impulse hammer arranged as a pendulum. The bridge vibrations are measured at the opposite edge by means of an attached small magnet and a coil via a short air gap. The method has been used much but seems to be too insensitive as perceived tonal quality changes could not be traced to changes in measured frequency responses.

Informally a number of violins newly made (by violin making students after a three year full time course) were tested in two different rooms. First the violins were tested in a small exhibition gallery and thereafter in a large concert hall (Berwaldhallen). In the small room it was easy to hear differences between the different instruments, especially for the player, but in the concert hall it was difficult, especially for the listeners. The tests indicated that measurement of the violin response in the position of the player's left ear (the one closest to the violin) can give the most valuable information. The short distance from violin to ear indicates further that such measurements should be possible to make in an ordinary room (without special damping).

The method and its possibilities were given preliminary tests in pilot experiments in the laboratory. Thereafter the main experimental series with the Fiol90-violins were conducted at the Music Museum. Finally the measurements were completed with two excellent violins in the laboratory. The results of the experiments are presented below. Answers to two questions were sought: Does the recorded response at the position of the left ear give information, which is missing in the response at the bridge? Do the measurements support the previous experimental findings?

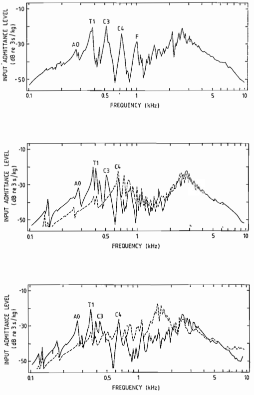

Figure 2. FIOL80 - Vibration level of bridge with high and evenly high peaks T1, C3, C4, and a marked "bridge-hill" is favourable: Top frequency response of the Guarneri violin, the best violin of FIOL80, and a not so good violin (full line for bass side and broken for treble, from Alonso & Jansson 1982a).

4.2 Reproducibility of the new method

In the new method the sound is measured in the position of the player's left ear, which results from a blow by a small hammer at the bridge.

The violin is laid horizontally on top of two felt covered supports, one under the lower edge of the bottom (2 cm wide and 13 cm long) and one under the scroll. The bridge is excited with a small impulse hammer (PCB 86M37) arranged in a pendulum of 120 mm length. The hammer head is initially displaced 45 mm from equilibrium and hits the bridge 15 mm after passing equilibrium. It hits the bridge horizontally perpendicular to the strings just below the bass corner of the bridge. A sound-level meter (B&K 2215 with 1/2 inch microphone) is placed with the centre of the microphone 14 cm above the supports and 10 cm beside the tailpiece button by means of a special template. No disturbing objects except table and sound-level meter are close to the violin. For comparison the small magnet (0.025 g) is fastened to the treble corner of the bridge and the coil core is adjusted to an air gap of 1 mm. The impulse response is analysed by means of an FFT-analyser (HP-3562A) and stored on a digital disk.

To begin with, the new way of measuring was tested for sensitivity to minor misadjustments, mainly in the microphone position. It was found that the position was moderately sensitive. A shift of 30 mm in all directions resulted in level shifts of ± 5 dB. The influence of the felt-covered supports was found to be minor compared to hanging in rubber bands (one measurement only though).

The change in excitation direction influences the result considerably. In the earlier measurements [Alonso & Jansson, 1982a] the violin bridge was excited perpendicular to the top plate. In the new method the excitation is in parallel with the plate, which results in differences (low C2-peak, less marked bridge-hill, no C4-peak, no resonance peaks in the range 500-700 Hz but new ones in the range 700-1500 Hz instead (for an explanation of the resonances see [Alonso & Jansson, 1982b]).

The small magnet as a vibration pickup works well. It influences the bridge properties little (< 3% on the bridge resonance frequency). The sond used in the Fiol80 experiments mass-loaded the bridge heavily (1 g). A comparison between the two methods shows, however, that the frequency of the maximum of the "bridge hill" coincides in the two cases, which is remarkable and fortunate (it is likely that the small amount of springiness of the wax attachment has preserved the peak frequency). The pickup direction in parallel with the top plate makes again a different weighting of the resonances (C3 and C4 are lost, the bridge-hill is less prominent, and some "new" resonances show up.) Mechanical excitation is necessary as no electromagnetic stray field is allowed to interfere with the vibration pickup of the coil-magnet sond.

4.3 Pilot experiments with four violins

A pilot series including four violins was conducted (see Table 1). Both the sound and the bridge vibration responses were measured.

Table 1. Violins in pilot experiments

HS71 - first time
W - (factory violin)
M - (modified factory violin)
G - (violin by Glass)
HS71, second time

Analysis of the measurements showed that the reproducibility (HS71 two times) was good for the sound response, say within ±2 dB, but somewhat less good in the bridge response, say ±5 dB. The high reproducibility of the sound response curves, says that the excitation pulse is well preserved but that the fastening and adjustment of the magnet-coil armature is more difficult to preserve. The sound radiation properties of the violin body should in principle be given by sound response curve divided by the bridge respone curve. The variations at single frequencies are, however, so large that hardly anything can be seen from such a curve.

Three of the violins are easily ranked after tonal quality, i.e. from best to worst: G, M and W. The measurements show that there is at least a tendency to have more energy collected at low frequencies for the best than for the worst violin. This is in agreement with the criterion that low frequency resonance peaks with high levels are favourable. The criterium for the bridge-hill does not show up so clearly. The violin W showed a clear bridge-hill, but violin G only a trend of bridge-hill in the sound response.

4.4 Main experiments with Fiol90

To the exhibition Fiol90 a total number of 52 violins had been submitted. After the quality judgements by the two professionals, the author selected 15 violins in three different quality groups: group I (ratings 72-54 and the five best violins), group II (ratings 45-43), and group III (ratings 33-31 i.e. low ratings). The measurements were made at the exhibition hall in three series. Each series began and ended with measurements on our reference violin HS71. The measurement records were stored digitally and were brought to the laboratory for analysis.

4.5 Reproducibility of measurements

Initially the reproducibility of the measurements were controlled with the repeated measurements of the reference violin (six times) (See table 2).

Table 2. Reproducibility of measurements

	0.2 - 3 kH	3 - 5 kHz
Sound response	± 1 dB	± 2 dB
Bridge vibrations	± 3 dB	± 5 dB

It was found that the reproducibility is good for the sound response, but somewhat less good for the bridge response. This means again that the variations because of misadjustment in the magnet-coil armature are larger than the variations in the blow (the impulse).

4.6 Sound response versus bridge response - all violins

The first question of Fiol90 investigation: Is there information in the sound response that is missing in the bridge response? To obtain a dependable (but insensitive) answer, the average of all 15 violins were investigated (see Figure 3).

In the lower frame the profiles of the sound response and the bridge response can be directly compared (not the absolute levels as two different quantities have been measured). It is easily seen that the curves follow each other, but that a peak in the sound response slightly below 300 Hz (AO - the air resonance) is missing in the bridge response. The bridge response shows three peaks (C2 just below 300 Hz, T1 between 400 and 500 Hz, and C3 between 500 and 600 Hz), but the sound response shows only the two higher ones. The peaks between 700 and 900 Hz are missing in the bridge curve which also shows a "bridge-hill" with a max-

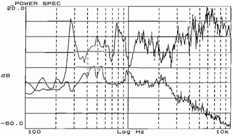

Figure 3. FIOL90 - Lower frame: Average for all 15 violins - sound response (upper curve) and vibration response (lower curve). Upper frame: "Sound" divided by "vibration" (upper curve) and vibration (lower curve).

imum just above 2 kHz, but there is only a hint in the sound response. Towards higher frequencies the sound curve gives a higher level than the bridge curve (peak labelling can in general not be made without additional information and has therefore not been pursued throughout this paper).

The differences are more easily seen in the upper frame of Figure 3, in which the difference between the sound and bridge curves have been plotted. The difference curve show a marked peak for the 300 Hz resonance, marked peaks between 700 and 900 Hz and a clearly increasing level at high frequencies. Furthermore a clear minimum slightly above 1 kHz is found as well as a less marked one at 2.1 kHz. The 1 kHz minimum shows that some resonances do not radiate well and that the bridge hill is less clear in the radiated sound. Thus it can be found that the bridge and the sound response give mainly the same information but there are differences. In conclusion the violin response seems mainly to be shaped by the air resonance, two or three resonances at 500 Hz, some resonances 800 to 1000 Hz and a bridge-hill around 2.2 kHz.

4.7 Measurements and tonal quality - groups of violins

The second question: What quality parameters of the violin do the measurements indicate? The collected material should at least give a hint – a large number of quality rated instruments have been measured – both on built-in properties and on sound radiated to the player. Let us again work with averages to obtain more reliable (but less sensitive) measures, i.e. averages over the groups the best (I) and the least good violins (III).

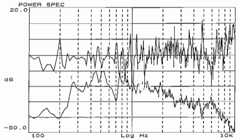

Figure 4. FIOL90 - Lower frame: Average sound response for group of best violins and group of least good violins, respectively (the absolute level is displaced +10 dB to clearly show differences in details between responses). Upper frame: Average level of group of best violins divided by the average level of group of least good violins ("equal" corresponds to -10 dB), and average level of group least good violins.

The lower frame of Figure 4 shows the average sound response for group I and group III. The response of group I violins shows a clear air resonance (AO), three approximately evenly high peaks around 500 Hz followed by a marked dip and several peaks around 1 kHz. The level is constant up to 2 kHz but drops thereafter approximately 20 dB to 10 kHz. A trend to a bridge-hill can be found at 2.5 kHz. The group III violins have approximately the same properties but a less broad and even grouping of peaks around 500 Hz (C2 is missing) and an evenly decreasing level past 2 kHz. Only a weak hint of a bridge-hill with maximum at 2 kHz can be found.

The difference curve between the two groups of violins is rather rugged and it is difficult to interpret differences between the two groups (Figure 4 upper frame). In spite of this difficulty the average level of group I compared to group III can be found to be approximately 5 dB higher in the range of the bridge-hill frequency (the sharp maxima at 3.8 and 4.8 kHz are likely to be the result of measurement "accidents").

Thus the peaks around 500 Hz and a bridge-hill are favoured candidates for quality measures, in agreement with earlier measurements [Gabrielsson & Jansson, 1979 and Alonso & Jansson, 1982a].

4.8 Single violins and quality

With the knowledge gained we can evaluate the response of certain violins, see Figure 5. It can be seen that the winning violin has several strong peaks around 500 Hz and that the

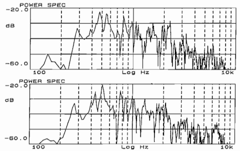

Figure 5. FIOL90 - Sound responses for single violins - from top to bottom: violin of average quality, less good, the best and the second best violin of FIOL90.

one at 500 Hz (probably C3) dominates. The second best violin has also this group of peaks in the 500 Hz range and a clear bridge-hill. The two less good violins have two well separated peaks in the 500 Hz region. The levels seem also to decrease considerably above 2 kHz. Thus the quality criteria found previously seem to have been verified again.

4.9 Two good old violins

In addition the responses of two excellent old Italian violins were measured, one Andrea Guarnerius and a Nicola Gagliano. The responses of these two violins are shown in Figure 6. Both violins show clear influence of a bridge-hill but a quite different picture in the 500 Hz range compared to the new violins. The old violins have a dominating peak at 600 Hz, probably the C3 resonance.

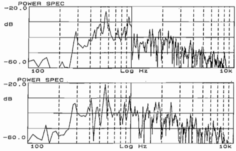

Figure 6. Sound responses for single good old Italian violins - upper frame N Gagliano and lower frame A Guarneri (note that the absolute levels are different in Figures 6a, 6b and 5).

5. CONCLUSIONS

In the laboratory a new method has been tried. The method measures the sound response in the position of the player's left ear (the one close to the violin). The method has shown to give very reproducible results and to be easy to use. Probably it can be further simplified by using only a mass as hammer head – it seems unnecessary to measure the excitation impulse. The measurements of sound response give essentially the same result as the bridge vibration response: the differences do not seem to be of major importance.

The measurements on the quality rated violins indicate that the properties around 500 Hz and in the bridge-hill range still are major candidates for quality. Additional measurements of two old excellent Italian violins indicate that a strong resonance at 600 kHz may be a mark of their excellence. The "bridge-hill" is partly governed by bridge properties [Jansson et al, 1990]. The findings are largely in agreement with those of Dünnwald [Dünnwald, 1990, 1991]. Investigation of a large number of different instruments by Carleen Hutchins indicates, however, that parameters not included here are of major importance [Hutchins, 1989, 1991]

ACKNOWLEDGEMENT

This paper was made possible by kind cooperation of many persons – violin makers, violin players and staff of the Music Museum. This help and support is gratefully acknowledged. The project work in financially supported by the Swedish Natural Science Council and the Royal Institute of Technology.

REFERENCES

1. Alonso, J. and Jansson, E. (1982a): Input admittance, eigenmodes and quality of violins, STL–QPSR 2-3 pp. 60-75.
2. Alonso, J. and Jansson, E. (1982b): Eigenmodes, input admittance and the function of the violin, Acustica **50**, 329-337.
3. Caldersmith, G. (1988): A Violin Quality Assessment Method: Pilot Study, Acoustics Australia **16**, pp. 84-86.
4. Caldersmith, G. (1989): A Violin Quality Assessment Method: Study II, Acoustics Australia, **17**, pp. 41-43.
5. Dünnwald, H. (1990): "Ein erweitertes Verfahren zur objektiven Bestimmung der Klangqualität von Violinen", Acustica **71**, 269-276.
6. Dünnwald, H. (1991): "Deduction of objective quality parameters on old and new Violins", CAS Journal, **1**, No. 7 (Series II) 1-5.
7. Gabrielsson, A. and Jansson, E. (1979): Long-time-average-spectra and rated qualities of twenty-two violins, Acustica **42**, 47-55.
8. Hutchins, C. (1981): "The acoustics of violin plates", Sci. Am. **245**, October, pp. 126-135 and 178.
9. Hutchins, C. (1989): "A measurable controlling factor in the tone and playing qualities of violins", Journal of the Catgut Acoust Soc. **1**, No. 4 (SeriesII), 10-15.
10. Hutchins, C. (1991): "Body length found to be the primary factor controlling tone quality between, violins, violas, cellos, and basses", CAS Journal, **1**, No. 7 (Series II), 36-38..
11. Jansson, E., Frydén, L. and Mattsson (1990): "On tuning of the violin bridge", CAS Journal, **1**, No. 6 (Series II) 11-15.

Claus and effect

Like many engineers I was brought up to question everyday happenings and phenomena. A result of this was my certain belief that the existence of Santa Claus was no more than mere mythology and that no self-respecting scientist could possibly treat it seriously. I have recently had to reconsider this position since my son is now of the age at which the concept of Santa Claus is very appealing. I have put some work into this and feel that I may be getting close to a solution. I have applied for an EC Science at Christmas grant but, due to an EC environmental initiative, there has been a massive organic growth in the amount of Administratium in Brussels sprouting to epidemic levels and, as a result, most grants are being delayed.

The scientific community has three main stumbling blocks over belief in Santa. These are: firstly, how does Santa manage to deliver presents to children all over the world in one night ? Obviously he takes advantage of global time differences but clearly this doesn't suffice. Secondly, why is it that Santa doesn't seem to age ? And, lastly, how can he continue to fund that entire operation, especially in these recessionary times ?

These are questions which, in isolation, are difficult to answer. It is only when we consider these questions simultaneously that a semblance of sense starts to emerge. The fact of the matter is that Santa makes use of Einsteinian relativity and travels close to the speed of light. Indeed he was using this principle of travel before Einstein developed the theory. So, with this explanation, can we satisfy the questions mooted above ?

The theory is clearly able to satisfy the first problem, in that travelling close to the speed of light enables Santa to visit all the world's children on the same night. It also satisfactorily explains why, from our perspective, he doesn't appear to age. Obviously his reindeers have seen him age over the centuries. To satisfy the issue of funding is a little more difficult to explain, but I believe relativity also plays its part in this.

Santa first began his role of providing children with free gifts when he was issued with a Union of Nations (predecessor to the UN) social arts grant. This was in the form of a fixed mass of gold which he could use towards funding this pilot scheme. When Santa started transporting this gold in his relativistic sleigh the mass increased: it is this additional mass which he uses to fund his gift giving. This phenomenon was copied in the 1980s by many Newtonian travellers in Britain and is commonly known as credit. However, Newtonian credit is subject to market forces and the intrinsic value of credit-based investments can go down as well as up, whereas Einsteinian mass resale is always a growth area. Furthermore, whereas science and arts funding has been decreasing in real terms in many areas, the Santa Fund (or SF for short) has maintained its value in absolute terms.

It, therefore, appears that the relativistic theory is able to answer the scientific sceptics who remain among us. This is very timely for me because I can now continue to relate the tales of Santa Claus to my son without compromising my scientific upbringing.

Campbell Airlie
Glasgow, UK (Letter to Physics World Feb 1992)

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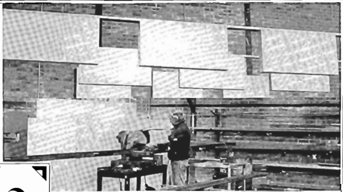

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TECHNICAL NOTE

Problem with a Column Loudspeaker

Roy Caddy

The problem: I have a ten year old column loudspeaker consisting of four 150 mm diameter driver units, at 250 mm centres. I may have to build another column loudspeaker to go with this one. The only similar sized driver units easily available are 5 dB lower in sensitivity. To build this second unit using four new driver units will mean the problem of matching loudspeaker sensitivities and power amplifier gains.

What will happen if the driver units are "mixed"?

If A represents the more sensitive driver unit and B the less sensitive, the theoretically obvious approach is ABAB along the column length. At the first minimum response each driver output lags a quarter wavelength out of phase behind the one above. Thus the A's and B's will be half a wavelength different from its similar driver. The first minimum will be at the same angle from the normal whether the drivers are mixed or not.

But a numerical investigation reveals that the power ratio of the first subsidiary maximum to that of the power radiated normally from the column is greater with this arrangement compared with the AAAA column. This subsidiary maximum will be the prime cause of acoustic feedback if a microphone is used.

What about the BAAB arrangement? This shows one advantage over the AAAA setup. The angular width of the primary lobe is widened by about one fifth. By that I mean the angular distance between the normal and first minimum of the column's radiation pattern. Instead of this minimum power being zero as with the AAAA setup it is down by 50 dB compared with the normal radiation, no great worry. BUT the secondary maximum is about 10 dB below that of the ABAB and the AAAA situations. (The ABBA and AABB setups are hopeless).

So the "mixture" of driver units has a worthwhile advantage, if used the right way.

NOTE: The standard column loudspeaker textbook approach is to treat the system as a single unit. I prefer a multiple source, diffraction grating, approach. The theoretical problem then becomes that of summing discrete vectors. This approach has been used in the above discussion.

Vibrational Modes of a Modern Chinese Two-Tone Bell

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ABSTRACT: The vibrational modes of an almond-shape bell from the Suzhou Musical Instrument Factory were studied using holographic interferometry. The non-circular shape results in mode pairs, one pair member having a mode at the xian or spine of the bell, the other an antinode. The two lowest modes have a frequency ratio of 1.188, close to that of a minor third (1.189), due in part to six tuning grooves cast into the bell.

Ancient Chinese bells with almond-shape cross sections have attracted the attention of acousticians [1-5] as well as musicologists and archaeologists [6-8]. Due to their non-circular cross sections, the normal modes of vibration of a circular bell are split into doublets, with each member of the pair having a slightly different frequency [9]. This results in the bells having two distinct tones, often referred to as the *sui* and *gu* tones.

The pitches of the two tones appear to be determined largely (but perhaps not entirely) by the frequencies of the two lowest modes of vibration. While the musical interval between the two tones varies rather widely in ancient Chinese bells, it is frequently about a minor third on the Western musical scale. (in 188 ancient bells from various sets known to us, a minor third was the nearest musical interval in 87 bells [46%] and a major third in 51 bells [27%] [10].

In our experiments, the bell was driven sinusoidally by means of a Bruel & Kjaer 4809 shaker, and the mode shapes were identified by scanning the surface with a small accelerometer and by time-average holographic interferometry [11]. The experimental arrangement for holographic interferometry was similar to that previously described [12].

Some 15 mode pairs are shown in Fig. 1. Modes are labelled (m,n) where *m* gives the number of complete nodal meridians and *n* the number of modal circles [13]. The *b*-mode, in each case, has a node at the sharp end of the bell *(xian)*, where the a-mode has an antinode. Some of the modes are distorted by simultaneous excitation of other modes having nearly the same frequencies; nevertheless, mode identification is reasonably certain.

A few additional modes are shown in Fig. 2. The (1,1) and (1,3) modes, having a single nodal meridian, may be described as "bending modes" of the bell. In the case of the $(2,4)_a$, $(3,4)_a$, and $(4,4)_a$ modes, the corresponding *b*-modes were not observed. Mode frequencies are shown as a function of *m* in Fig. 3.

The mode frequencies and ratios of the *b*-mode to the *a*-mode are given in Table 1. These ratios range from 0.89 to 1.19. In most cases the *b*-mode has a higher frequency than the *a*-mode, as in the Chinese two-tone bell previously studied [1]. The largest splittings occur in the (2,0) and (4,1) modes. No consistent pattern of mode splitting size has been noted, however.

The thickness of the bell varies from about 9 mm at the centre of the broad sides to 15 mm near the ends. The inner surface of the bell has six grooves, approximately 10 mm wide and 10 mm deep. Two grooves are at the ends of the bell, the other four about half way between the ends and the centre. On either side of these grooves, the wall is a few millimeters thicker.

Frequencies of bending modes in a uniform plate or shell are proportional to thickness. A groove at or near an antinode (where maximum bending takes place) will lower the modal frequency more than a groove near a node. Thus the two grooves at the ends would be expected to lower the fre-

Table 1. Mode frequencies and ratios of the *b*-mode to the *a*-mode

Mode Number	Frequency *a*-mode Hz	Frequency *b*-mode Hz	Ratio, *b*-mode to *a*-mode	%
2,0	494	587	1.188	19
3,0	1399	1535	1.097	10
4,0	2626	2705	1.030	2
5,0	4115	4198	1.020	2
2,1	1671	1493	0.893	-11
3,1	1886	1867	0.990	-1
4,1	2850	3381	1.186	19
5,1	4765	4879	1.024	2
2,2	3270	3240	0.991	-1
3,2	3062	3178	1.038	4
4,2	3775	3854	1.021	2
5,2	5774	5378	0.931	-7
2,3	4328	4441	1.026	3
3,3	4170	4076	0.977	-2
4,3	4964	5028	1.013	1

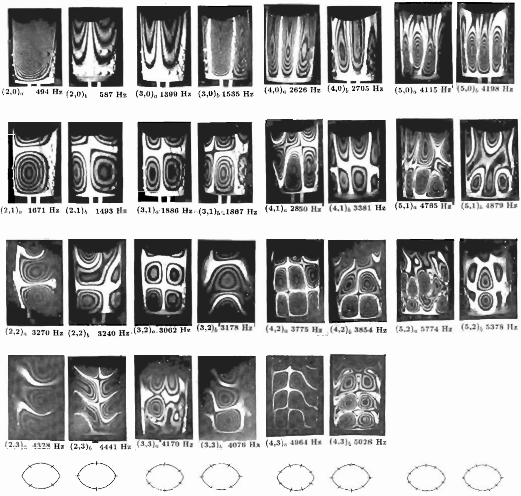

Figure 1. Holographic interferograms of 15 mode pairs: a-modes have antinodes at the ends, b-modes have nodes there.

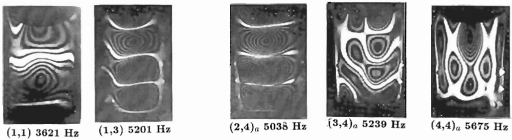

Figure 2. Holographic interferograms of some additional modes. The (l,n) modes may be called "bending" modes.

quencies of all the *b*-modes, while the four grooves half way to the centre would have their greatest lowering effect on the $(2,n)_b$ modes. The thinner area near the centre of each side would lower the frequencies of the $(2,n)_a$ modes and to a lesser extent the $(3,n)_b$ and $(4,n)_a$ modes which have antinodes there. However, it can be seen in Table 1 that the frequency ratios of the *b*-mode to the a-mode is different for the n=1, n=2, and n=3 mode families. The grooves are undoubtedly designed to give the desired frequency ratio of $(2,0)_b$ to $(2,0)_a$.

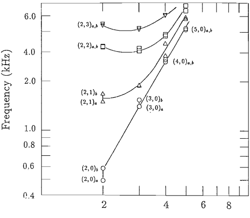

Figure 3. Mode frequencies as a function of the number of nodal meridians m. The modes are arranged into five groups according to the number n of nodal"circles" around the bell.

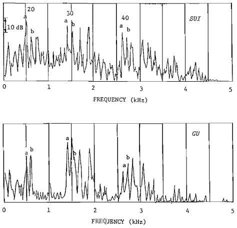

Figure 4. Sound spectra obtained by striking at the sui and gu strike points. Note that the $(2,0)_a$ mode is more strongly excited by striking at the sui strike point than is the $(2,0)_b$ mode. The same is true of the $(4,0)_a$ mode, but the $(3,0)_a$ mode is more strongly excited at the gu strike point, as expected.

REFERENCES:

1. T.D.Rossing, D.S. Hampton, B.E. Richardson and H.J. Sathoff, "Vibrational modes of Chinese two-tone bells," J. Acoust. Soc. Am. **83**, 369-373 (1988)

2. Chen Tong and Zheng Darui, "Acoustical properties of chime bells", Chinese J. Acoust. **4**, 1-9 (1985).

3. A.D. Fokker, "Acoustical analysis of a peal of thirteen Chinese bells", Proc. Konikl. Nederl. Akad. Wetenschappen **B74**, 257-262 (1971).

4. A. Lehr, "The tuning of the bells of Marquis Yi", Acustica **67**, 144-148, (1988)

5. J. Takahashi, "Size-frequency relation and tonal system in a set of ancient Chinese bells *Piao-shi bianzhong*", J. Acoust. Soc. Japan (E) **10**, 299-303, (1989).

6. Y-Y. Lee, "The music of the Zenghou zhong", Chinese Music, **3** (1), 3-15, (1980).

7. E.G. McClain, "The bronze chime bells of the Marquis of Zeng: Babylonian biophysics in Ancient China", J. Social Biol. Struct. **8**, 147-173, (1985).

8. L.A. von Falkenhausen, **Ritual Music in Bronze Age China: An Archaeological Perspective** (Doctoral dissertation, Harvard, 1988).

9. T.D. Rossing, "Acoustics of Eastern and Western bells, old and new," Acoust. Japan (E) **10**, 241-252 (1989).

10. T.D. Rossing, "Acoustical comparison of ancient Chinese bells with Western Bells", Proc. Conference on Ancient Chinese Science and Culture, Wuhan, China, November 1988 (in press).

11. R.L. Powell and K.A. Stetson, "Interferometric vibration analysis by wavefront reconstruction", J. Opt. Soc. Am. **55**, 1593-1598 (1965).

12. T.D. Rossing, R. Perrin, H.J. Sathoff and R.W. Peterson, "Vibrational modes of a tuned handbell," J. Acoust. Soc. Am. **76**, 1263-67 (1984).

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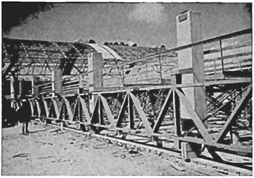
A major feature of the airport terminal's design is an unusual metal deck roof in the shape of a vaulted space frame. The vault, 50m long and 25m wide, creates a major concourse space in the centre of the building.

To provide an effective barrier against heat flow through the massive curved roof and to prevent noises caused by tropical rainstorms or air traffic, approximately 6,790 m2 of Anticon roofing blankets from Bradford Insulation were installed. Manufactured from glasswool and foil, Anticon is designed for efficient thermal insulation under metal deck as well as fibrous cement and tile roofs.

Condensation in metal roofs is another common problem which can dramatically reduce a building's lifespan. By incorporating a combination of ventilation and Anticon insulation into the building's design, the problem of condensation has been eliminated. And by stabilising the internal temperature, the insulation is placing less demand on the building's air-conditioning system, thus saving on energy costs.



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Available with a range of factory applied reinforced aluminium foil facings, Anticon eliminates the need to lay foil separately, so installation time and cost is reduced. With thickness ranging from 50mm to 100mm, Anticon can also be cut in non-standard lengths to fit the requirements of any job. At Mackay Airport, the rolls of Anticon were cut to specific sizes to suit the unusual roof configuration. The 75mm thick blankets were also manufactured with an overlap of foil on both the right and left sides to facilitate easier installation on the roof corners.

Higher Order Acoustic Modes in Ducts: Propagation Properties and Active Control

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Abstract: A brief survey of past and current research on the active control of higher order mode propagation in ducts is presented. This is followed by a discussion of the major problems encountered, solutions obtained thus far and suggested directions for future work.

1. INTRODUCTION

Active control of plane wave noise propagation in ducts has been shown to be feasible and commercial systems are now available. However, little headway has been made in controlling noise propagating at frequencies above the cut-on frequency of the first higher order mode. For large air conditioning ducts this frequency could be as low as 100 Hz. Thus, in many cases involving higher frequency noise, control of plane wave propagation only will not solve the problem. One solution is to partition the duct to reduce its effective cross-sectional size and apply active control in each partition. However, this is not always practical and a number of researchers are currently investigating alternative means to control higher order mode propagation.

Research in this area has been approached from different directions by various people, resulting in a number of research methodologies and active control systems. Neise and Koopmann [1] have conducted experiments using a system in which the control sources, namely two loudspeakers, were positioned in the cutoff of a centrifugal fan casing. Their aim was to attenuate the unwanted acoustic signal near, or at best directly in the source region to reduce the sound level for several or even all transmission paths simultaneously. Despite their previous success for excitation frequencies in the range where only plane waves could propagate, they found that their results were unsatisfactory when they attempted to actively control higher frequencies in the range where higher order modes could propagate. It was believed that the acoustic pressure distribution generated by the centrifugal fan was too complex to be adequately controlled by the simple arrangement of control sources used in their experiments. A more sophisticated control source arrangement consisting of a larger number of individually driven loudspeakers is intended to be used for future research.

Mazanikov, Tyutekin and Ukolov [2] have theoretically and experimentally investigated the active control of multimode sound fields. For a case in which there are N propagating acoustic modes, they proposed that 2N error sensors and 2N control sources are sufficient to suppress the propagating modes. For particular point measurement locations and excitation frequencies, they have reported up to 20 dB reduction in sound pressure levels.

Eriksson et al. [3] have approached the problem of higher order acoustic modes from a control system perspective because of a background in adaptive digital signal processing, and the success attained previously in actively reducing plane wave propagation in ducts using adaptive systems. In the system used to control higher order acoustic modes, multiple adaptive controllers are utilised with multiple error microphones. For the experimental system reported, one higher order acoustic mode propagates in a rectangular duct. A separate adaptive filter model is used for each positive and negative portion of the non-uniform pressure distribution associated with the higher order mode. Each filter model obtains error information from a separate error transducer and outputs a signal to a separate loudspeaker. An independent random noise source is used with each adaptive filter to model the transfer functions between the loudspeakers and the error microphones. The active control system was reported to reduce tonal noise by 20-25 dB at a single measurement location, and broadband noise, above the cut-on frequency of the higher order acoustic mode, by about 10-25 dB. System stability and convergence were found to be problematic and future research is focussed on improving these characteristics. No indication was given of a suitable system configuration to attenuate duct noise when more than one higher order acoustic mode propagates.

To determine why the development of systems to actively control higher order acoustic modes have not progressed as rapidly as those for controlling plane wave noise, examination of some differences between the two cases is necessary.

2. PROBLEMS ASSOCIATED WITH THE ACTIVE CONTROL OF HIGHER ORDER MODES

Each higher order acoustic mode has a specific cut-on frequency, above which the mode is able to propagate, which is a function of the duct geometry. For a rectangular cross-section duct, the first higher order cut-on frequency is given by $f_c = c/2L$ where c is the speed of sound in the acoustic medium within the duct, and L is the maximum transverse dimension of the duct. For excitation above this critical value one or more higher order acoustic modes may propagate, in addition to the plane wave mode which propagates at all frequencies.

In contrast to the plane wave mode, which has a uniform pressure distribution across a plane of the duct cross-section, higher order modes have a non-uniform pressure distribution consisting of regions of in-phase and in-quadrature acoustic pressure, introducing an added degree of complexity to the acoustic field for each propagating acoustic mode.

Generally, the aim of active control is to minimise the total acoustic power output of the system being controlled, and not to merely minimise the acoustic pressure at a point. To do this effectively, the active control system must be provided by its error sensors, a signal proportional to the total acoustic power. Active systems for the control of noise propagating as a plane wave have traditionally utilised single microphones as error sensors, measuring the acoustic pressure at a point. Inherent in the use of such sensors has been the assumption that the minimisation of the total acoustic pressure at the error sensor location is directly related to the minimisation of the total acoustic power flow. Generally, at large distances from the noise source and duct exit and at excitation frequencies well below the first higher order mode cut-on frequency, this assumption is valid. However, care should also be taken to ensure that there is no significant reflected energy travelling in the opposite direction to the acoustic power to be controlled, otherwise the application of active control could in some cases result in a local pressure minimum, with little associated reduction in power flow, even for only plane wave propagation. As mentioned previously for the case of higher order modes, both the amplitude and phase of the acoustic pressure are non-uniformly distributed over a plane of the duct cross-section. Hence, a point measurement of the acoustic pressure amplitude and phase will not necessarily provide data proportional to the total acoustic power flow, thus not enabling the active system to reliably minimise the total acoustic power of the duct system.

The use of an intensity probe as an error sensor is also unsuitable for a system intended to minimise the total acoustic power associated with higher order mode propagation, as the acoustic intensity in the direction along the duct length is non-uniformly distributed over a duct cross-sectional plane. This is because the acoustic intensity at each point on the duct cross-section includes cross-term contributions from products of the acoustic pressure in one acoustic mode with the acoustic particle velocity in another mode, or vice versa.

An additional problem arises for practical systems to actively control higher order acoustic modes because of the difference in phase velocity of each mode. In the majority of systems used to control duct noise, a reference, or input microphone, is located upstream of the control source and provides the controller with information regarding the undesired noise to be attenuated. A second microphone, usually known as the error sensor, is located downstream of the control source and provides a measure of the performance of the active control system. For the frequency range in which only the plane wave mode propagates, the pressure measured by these two microphones is linearly related, and hence a linear controller is suitable to achieve good reduction and stability characteristics, in a reasonable convergence time. For frequencies at which higher order modes propagate, the difference in phase velocity for each mode causes the relative modal pressure contributions to vary along the duct length. This results in the total pressures at the two microphone locations being non-linearly related. Hence a controller capable of handling non-linear signals, such as a neural network, is required for systems using this common arrangement of sensors and sources. This aspect of higher order mode propagation may explain the stability and convergence problems reported by Eriksson et al.3 for an active control system implemented at higher order mode frequencies which utilised a linear controller and a sensor / control source arrangement of this type.

The propagation of higher order acoustic modes not only introduces error sensing problems, but also makes the task of positioning the control sources more complex. It has been shown by the authors [4] that, provided the control source is able to achieve the required volume velocity, or source strength, it is possible to reduce the total mean acoustic power for plane wave propagation using a single control source located in any of the four walls of a rectangular duct. However, when higher order acoustic modes propagate within the duct, the placement of control sources has a great effect upon the levels of acoustic power reduction achieved. In addition, if the excitation frequency is such that higher order acoustic modes are generated by the primary source, they may also be generated by the control source. Hence the control source will generate both a plane wave and higher order modes, and the problem cannot be treated on a mode by mode basis, as one must consider the energy spill-over into these other modes.

3. SOME ANALYTICAL RESULTS

A theoretical investigation of the active control of higher order acoustic modes has been undertaken by the authors [4], using an analysis based upon the alteration of the acoustic impedance of each source by other sources, which is an extension of the work on plane wave active control undertaken by Snyder and Hansen [5]. This analysis differs from those mentioned previously, which supposed the active control mechanism to be "cancellation" or superposition of multiple acoustic fields.

A reduction in the total acoustic power flow may be achieved by two mechanisms - alteration of the acoustic radiation impedance of the primary source by the control sources, or absorption of the primary source acoustic power by the control sources, or a combination of both. Duct geometry, source location, and excitation frequency are major factors in determining the levels of acoustic power flow reduction achieved and the physical mechanism most responsible for control.

As an illustration of the influence of these variables, a rigid-walled duct of 2 m x 1 m rectangular section, containing a primary acoustic source mounted at a non-symmetric location in the cross-sectional plane of the duct, and a single control source in one of the four duct walls, will be considered. With the primary acoustic source excited at 100 Hz both the plane wave mode and one higher order mode, with a cut-on frequency of 86 Hz, can propagate. To determine the optimum location of the control source, a range of positions across the duct and along the duct length, need to be considered. For the purposes of illustration the calculated reduction in total acoustic power is shown in Figure 1, for a control source having the same lateral location as the primary source and for a range of primary and control source separation distances. For this case, the optimum power reduction occurs at a source separation distance of 6.8 m. This distance approximately corresponds to twice the plane wave mode wavelength and to a single wavelength of the higher order acoustic mode. At locations other than this optimum, it may be possible to attenuate either mode to a *Fig-*

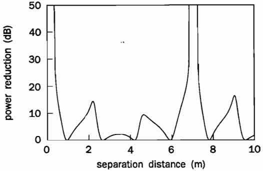

Figure 1. Total mean acoustic power reduction using a single control source at an equivalent lateral location to the primary source at 100 Hz.

greater extent; however, the other propagating mode will be reinforced, resulting in an overall reduction in the acoustic power of less than that achieved for the optimum source separation distance of 6.8 m.

It was found that the power reduction achieved is also a function of the modal wavelength of the propagating acoustic modes. Because the modal wavelength is dependent upon the excitation frequency, the optimum configuration of control sources will vary for different excitation frequencies. Hence the optimum arrangement for a particular excitation frequency may not be effective at other frequencies. Also, for higher order acoustic modes, the modal wavelength is a function of the duct geometry, and a configuration chosen for a particular duct may not be suitable for a differently sized duct. This is in contrast to the plane wave case for which the modal wavelength is independent of the duct geometry.

Introduction of an additional control source into the system increases the levels of power attenuation that can be achieved, and makes the active control system more robust by increasing the effective frequency range of operation. Thus to be effective over a reasonable frequency range, multiple control sources are necessary, even to control one higher order mode. As the mode order increases, so will the required number of control sources.

4. FUTURE WORK

In the results presented here, the analysis assumes the use of an error sensor capable of producing a signal proportional to the total acoustic power flow. The performance achieved in practice will depend upon the accuracy with which a particular sensor configuration can provide such a signal. Hence research towards this goal will improve the likelihood of the development of a practical system to actively control higher order acoustic modes in ducts. This might involve investigations into optimal multiple microphone configurations which provide a reasonable estimate of the residual power flow, and also the use of multi-channel controllers containing a sufficient number of channels to handle these error signals.

More work is also needed on the optimisation of control source placement and number to adequately control a number of higher order modes over a reasonable frequency bandwidth.

Development of controllers capable of managing signals which are non-linearly related, or system arrangements which eliminate the non-linearity associated with the commonly used arrangement, would be a major factor in speeding the realisation of an effective practical system for the control of duct noise characterised by propagation of modes other than the plane wave mode.

REFERENCES

1. W. Neise and G.H. Koopmann, "Active sources in the cutoff of centrifugal fans to reduce the blade tones at higher-order duct mode frequencies," ASME J. Vib. Acoust. 113, 123-131 (1991).
2. A.A. Mazanikov, V.V. Tyutekin and A.T. Ukolov, "An active system for the suppression of sound fields in a multimode wave - guide," Akust. Zh. 23, 485-487 (1977) [English transl.: Sov. Phys. Acoust. 23(3), 276-277 (1977)].
3. L.J. Eriksson, M.C. Allie, R.H. Hoops and J.V. Warner, "Higher order mode cancellation in ducts using active noise control," Proc. Inter-Noise 89, 495-500 (1989).
4. A.C. Zander and C.H. Hansen, "Active control of higher order acoustic modes in ducts," J. Acoust. Soc. Am., submitted for publication.
5. S.D. Snyder and C.H. Hansen, "Active noise control in ducts: some physical insights," J. Acoust. Soc. Am. 86(1), 184-194 (1989).

INTER-NOISE 91 CONFERENCE PROCEEDINGS

The COSTS OF NOISE was the theme of INTER-NOISE 91, the 1991 International Conference on Noise Control Engineering, held on the campus of the University of New South Wales in Sydney, Australia from 2-4 December 1991. The Proceedings of INTER-NOISE 91 are now available. Three hundred and eleven papers on a wide variety of topics have been published in the INTER-NOISE 91 Proceedings.

The texts of two Distinguished Lectures, "Fifty years of 'development' in the sound insulation of buildings" by Tor Kihlman, and "Frequency analysis - a stroboscopic approach" by Robert Randall are included in the Proceedings.

THE COSTS OF NOISE will be of interest to engineers concerned with noise control technology, educators, scientists, acoustical consultants, government researchers and regulators, public officials, architects, students and others concerned with the control of environmental noise.

Copies of the INTER-NOISE 91 Proceedings are available from Noise Control Foundation. The two-volume set of proceedings contains 1289 technical pages and is available for US$130.00. Shipped postpaid except that overseas orders must add US$45.00 if shipment overseas is to be by air. Payment must be in US Funds on a US bank or a bank that has a correspondent relationship in the United States. Order from Noise Control Foundation, P O Box 2469 Arlington Branch, Poughkeepsie, NY 12603, USA.

Cliff Winters

A Sketch

by Dennis Gibbings

When I went to see Cliff Winters at his Church Point home, he was smartly dressed, leaning on the railing of his deck, enjoying the splendid view over Pittwater. Had I gone unannounced, it is more likely that I would have found him in his working clothes, complete with goggles, dust mask and the hard hat that his wife Carolyn had insisted on from fear of what too frequent bruising might do to his brain, navvying away at his current project of enlarging the working space under his house; a picture of the retired executive who likes to get his hands dirty.

Cliff was born, in the mid-twenties was all he would say, in the ancient and bustling city of Bristol, and one can still detect traces of the English West Country accent in his speech. A scholarship took him to Cotham school, whence he emerged from secondary education into the world caught up in the struggle of World War II. Appropriately enough for the son of a great seaport that had seen John Cabot set out for the Americas in 1497, he joined the Navy. The Navy sent him first to the Robert Gordon College at Aberdeen to study Electronics and then to the Radio and Electronics School at Warrington, known, rather whimsically, as H.M.S. Ariel. Following training, he went into the Electrical Branch of the Fleet Air Arm and joined a real ship, the aircraft carrier Formidable.

After seeing much action the Formidable returned to the U.K. in 1946 and some word went round that the Australian Navy had plans for establishing its own Air Arm and was seeking volunteers from amongst Royal Navy personnel. Cliff, who had liked what he had seen of Australia, applied, was accepted, and sailed back to Sydney on the Esperance Bay. His job was to set up an Air Arm Section, largely with bits and pieces recovered from the store of spares abandoned by the Americans when they withdrew after the war. The routine was enlivened by the American habit of booby-trapping secret gear with detonators; failure to notice and remove them before working on something might have dire consequences.

In time, a small carrier, the Vengeance, was sent out to get Nowra started. Cliff joined the L.D.U. (naval acronymese for Electrical Development Unit) and moved to H.M.A.S. Watson, where he worked on such jobs as modifying acoustic detectors for the firing range at Nowra to discover whether pilots were actually hitting their targets, and developing sonar-buoy gear for detecting submarines and relaying the information to aircraft patrolling overhead. The group produced a training system which was installed in Navy Dakotas at Bankstown for use at Nowra.

After two years the L.D.U. moved to the main Electrical school, H.M.A.S. Cerberus on Mornington Peninsula, but someone had noticed that Cliff had not been to sea for more than four years, and he was sent on a number of "cruises". In 1960, he considered his options and decided to leave the Navy with the rank of Chief Petty Officer.

He does not regret his long time in the Service. Along the way he picked up a good deal educationally. His Navy courses in Administration have stood him in good stead in his business career, and the Navy fostered one of his great loves, navigation. As well as being a member of the Institute of Radio and Electronic Engineers, he continues to be a member of the Australian Institute of Management and the Australian Institute of Navigation.

In 1960/61 Australia was in Recession and there were no jobs so Cliff spent an enjoyable six months in Real Estate. Then the National Instrument Company offered him the position of Head of their Electronics Division. Bruel & Kjaer was one of their Agencies; the 2203 Sound Level Meter and the 2305 High Speed Level Recorder had just been released.

One of Cliff's first actions was to propose the then novel idea that Agents might have examples of the equipment they were selling to demonstrate to the clients. This meant spending money, and approval had to be sought from Head Office.

One of his worries was servicing the equipment. N.I.C. were well known in the Marine and Aeronautical fields and servicing demands in these areas tended to take preference over Acoustics. Repairmen were less familiar with the Acoustics equipment. One man might begin a job and be called away to attend to something more urgent, leaving his successor with a heap of bits that he was supposed to assemble and get going again. Not infrequently, to keep his customers happy, Cliff would do the repair himself.

Another problem was that, while Cliff knew something about Electronics, he knew rather less about Acoustics. The remedy was to talk to his customers, such as Ray Piesse at the Commonwealth Acoustic Laboratories and Ted Weston at the Experimental Building Station; see what gear they had and what they did with it. "Those days", says Cliff, "saw the beginning of a long association with some very nice people." Peter Knowland was another of his customers from this period. Peter, then of Norman Addicot, bought some gear and began testing in one of the disused ammunition bunkers at Chowder Bay. Peter was keen to form an Acoustical Society, and meetings of interested people , including Cliff, were held.

One of the highlights of the B & K agency was the annual visit by George Berg. George had a well-deserved reputation for being able to fix anything, and his visits were eagerly awaited. There are many stories about him, but two must suffice. One day George turned up at the Customs House to find Ray Piesse and Jack Rose ecstatic about the arrival of a wondrous new Neumann microphone, but despondent about the handbook which was entirely in German. A multi-lingual European was a gift from the gods. Of course George would translate, and he proceeded to do so with fluent ease, to the increasing mystification of his audience. It was some time before anyone realised what was happening. He was rendering the German not into English, but into Danish.

The second story concerns an occasion when George visited Sydney by way of South America. Cliff went to the Airport as usual to meet him, only to see George being shepherded out through a private door by two uniformed officials. Urgent enquiries revealed that George had arrived from South America with no record of vaccination against yellow fever in his little yellow book. Without option, he would spend a few days at North Head Quarantine Station, guarded by two Nursing Sisters, with Qantas footing the bill. The curious twist to the story is that while George was unable to visit Cliff, there seemed to be no objection at all to Cliff visiting George, so the two might have been seen chatting and sampling the provisions thoughtfully provided by Qantas, admiring Harbour Views.

After some time as head of its Electronics Division, Cliff had become Sales Manager for the whole of N.I.C., but N.I.C. belonged to the Ansett conglomerate, and Ansett had ideas of making it part of Ansett Transport Industries. When Ansett proposed that Cliff should move to Melbourne, he decided that the time to part had come and took a job with Jacoby Mitchell. Ironically, the year that he spent with Jacoby Mitchell, and no longer associated with Acoustics, was the very year in which the Acoustical Society was founded.

The move had another equally unforeseen result. No longer inhibited by ethical scruples against poaching an employee from their own agent, B & K approached Cliff to set up an Australian Branch company. Fresh from completing a 4 year course in Management, Cliff grabbed the opportunity. There would be offices in both Sydney and Melbourne. When B & K acquired the Sydney Office it was a little more than a shell with a quaintly old-world frontage. Cliff fitted it out, making all the workshop benches himself, with Carolyn helping with the painting. The founding staff all came from N.I.C. and included Maggie Mooy (Secretary), Eric Pedersen (Maintenance) and Ray Wilcox (Stores). Prior to moving in during March 1974, Cliff and Maggie dealt with the letters in Maggie's kitchen. After her husband had left for work, Cliff would arrive to attend to the correspondence, doubtless to much twitching of the neighbourhood lace curtains.

The Melbourne operation was run by Daryl Bowker with secretarial help. N.I.C. continued to act as agents in Queensland, South Australia and Western Australia, but withdrew after two years. The agencies were replaced in S.A. and W.A. by one-man operations from private homes. Queensland needs were attended to from Sydney, Tasmanian from Melbourne. All repairs were sent to Sydney. The first priority was to establish a high class service system handling only B & K equipment, and it was believed that quality and economy were most likely to be achieved by concentrating service at one location where the greater throughout would engender greater expertise. Every item imported came first to Sydney where it was unpacked and tested, then returned to its box and forwarded to the customer.

When he opened B & K (Australia) in 1974, Cliff set out for himself a 15 year plan in which he would get his own B & K building, built to his own specifications with display rooms and classrooms and with service facilities recognised by N.A.T.A. The goal of N.A.T.A. registration was reached by 1979. By that time, Vibration, which in the beginning had accounted for only 30% of a relatively small turnover, represented 70% of a much larger budget. By 1987, the annual turnover was around $4 million.

The dream of a home of its own was finally realised in February 1987 when B & K (Australia) opened its Terrey Hills offices. They almost managed to arrange that the Queen of Denmark, who was visiting Australia, should do the honours, but worry about fitting a journey up and down Mona Vale Road into a very tight schedule made it necessary to settle for the Danish Foreign Minister.

Any close association with the firm of B & K inevitably meant an association with Dr Per V. Bruel, its co-founder, and with his passion for flying. He was reputedly at one time the only private pilot, or at least one of very few private pilots, permitted to fly into the Soviet Union, where he went frequently on business. Amongst other planes, B & K owned a small red aerobatics plane of Italian design which had originally been bought for model testing as part of the contract with the developers of Concorde, and Dr Bruel flew it like a test pilot. Rumour had it that a flight with him in the little red plane was part of the selection procedure for entry into the higher echelons of the company.

By 1988, Cliff was beginning to feel that B & K was no longer the firm he had joined. Dr Bruel was still active, indeed still flying, but control of the company was passing to the younger Bruel and others who did things differently. He decided to retire and take a year to look around Australia. For an ex-seaman, he had a curious enthusiasm for the deserts of the inland. Two and a half years later, he is still not finished.

For many men, the demands of his business career would have been enough, but Cliff has found the energy for many voluntary activities connected with Acoustics. He chaired the S.A.A. committee on Vocabulary and has been a member of three others, representing the Confederation of Australian Industries. He was on the S.A.A. Executive Board for Acoustics and Vibration, but finds that the S.A.A. too is doing things differently and it takes up less of his time.

Possibly his most notable contribution to the Acoustical Society was the job he did as Treasurer for the Tenth International Congress on Acoustics, held in Sydney in 1980.

Not surprisingly, his success in 1980 resulted in his being roped in again as Treasurer for Internoise '91.

Asked to what he attributes his success, Cliff modestly gives two answers. First, he has enjoyed the unswerving understanding and support of his wife, Carolyn. Second, he has had to deal with a bunch of people who, by and large, have been a pretty decent lot. My guess is that, in both cases, it has had a little to do with the fact that he is not a bad sort of a bloke himself.

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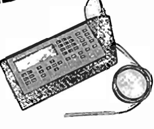

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News & Notes . . .

SOUNDS FISHY

With the development of a commercial krill fishery has come the responsibility of monitoring and managing this resource which is pivotal in the Antarctic food chain. Acoustic techniques are recognised as one of the main tools available to scientists for fish stock abundance estimations. Fundamental to these techniques is knowledge of the "target strength" (TS) of the species, ie the proportion of incident energy reflected by the fish.

At the August meeting of the WA Division, **Tim Pauly**, a research associate in the Centre for Marine Science and Technology (CMST) at Curtin University, presented a description of the acoustics data acquisition system he has developed for determining the TS of krill. He also showed some interesting results from a trip to the Antarctic when he and Assoc Professor **John Penrose** deployed the system in an effort to determine the TS of krill "in situ". (Wondering what krill look like? - small prawns about 20 mm long!)

John Macpherson

* * *

STARTING WITH A BANG

Impulse Sounds, such as gunshots, have been used as a probe for investigating a number of physical phenomena. Because of their short duration, the direct impulse can often be time isolated from reflected and diffracted components while the wide frequency range inherent in an impulse means that most of the acoustical spectrum is being simultaneously investigated.

At the February meeting of the ACT group, held jointly with the Institute of Physics, **Assoc Prof Charles Don** from Monash University, explained the methods he has used for the production of impulse sounds (see paper in Acoust. Aust **19**, 3). The application to soil impedance measurements showed clear "resonance" effects where the frequency spectrum of the reflected sound changed dramatically with changes in the moisture content of the soil. He suggested that these changes were due mainly to the layering introduced by the addition of water to the top surface. Studies on barriers were conducted on full size samples in the laboratory; for the tests the barrier samples could be positioned vertically and the implications of the shape of the edge of the barrier investigated. The investigations of the propagation of sound through an atmosphere showed a form of shadow boundary but the reduction in sound levels was not in full agreement with the theories. These results prompted many interesting questions from the Institute of Physics attendees who work in the area of fluid flow and shock waves.

Marion Burgess

* * *

EXCELLENCE IN ACOUSTICS - NSW

Submissions for the 1992 Excellence Awards are welcome from all persons and organisations presently or having recently been engaged in design, research or manufacture and installation of products, materials or systems in projects involving acoustics and vibration. Entries are open to all individuals and organisations who consider their work, no matter what its scale, is deserving of recognition by their peers and the public at large and serves as an example of the pursuit of excellence. The work must have been carried out either in design, study or execution within NSW.

Closing date for submissions is 31 July 1992. Entry forms and conditions of entry are available from: *Excellence in Acoustics Awards, Australian Acoustical Society, NSW Division, Science Centre Foundation, Private Bag 1, DARLINGHURST, NSW 2010 Tel (02) 331 6920, Fax (02) 3317296.*

* * *

QUESTIONS TO MEMBERS - VICTORIA

In an attempt to determine the future direction of the Society, the Committee of the Victoria Division sought the opinion of members on a variety of topics. Perhaps it was the pledge by the Committee to donate $2 to the Deafness Foundation for each reply that gave rise to the very high, 50%, return of questionnaires (ie 63 responses) - although one member did query whether it was constitutional for the Committee to use members' funds for such a purpose.

While several of the questions and answers are specific to Victoria, some of the responses may prove interesting to those in other States. The Victorian technical meetings held throughout the past year have proved to be very interesting and informative, however, the Committee was often disappointed by the overall attendance, typically about 20. So, many of the questions sought to help the Committee to plan future meetings. 62% of the respondents had attended a meeting in the past year. The major reasons for not attending were time pressure (45%) and location (19%). Of those listed on the questionnaire, the most preferred topic was industrial noise, which scored 34% of first preferences and 75% of responses when adding first, second and third choices together. Using the latter criteria, noise measurement (56%) and mechanical service noise (41%) were the next most popular topics while auditoria design, vibration isolation, hearing and instrumentation all scored in the low twenties. Underwater acoustics and a workshop were least popular, recording only 2% of the votes in the first three preferences.

The replies were equally divided about the usefulness of having a local division newsletter, although 70% agreed to occasionally contribute news items to such a production. Acoustics Australia was considered good by 71%, excellent by 10% and average by 19% of respondents. A strong vote (79%) was recorded for Acoustics Australia to feature more news of members while other suggestions included the need for more practical articles and an increase in the number of issues per year.

A common interest (31%) and the gaining of knowledge (24%) were considered to be the main reasons for joining the Society with 17% each claiming that the technical meetings and affiliation recognition were their principle reason. Acoustics Australia was the lure for 8% while the conference attracted only 2% of respondents. One person noted the support received since retirement as being a reason for continued membership. The majority of members (72%) were happy with the perceived academic level of the Society, with the remainder being equally divided about increasing or decreasing the level. One suggestion was that there should be a stronger applied emphasis within the Society to meet the needs of industrially based members.

Other comments included encouraging student members by awarding scholarships and reducing their fees. Joint technical meetings with other learned societies and running the annual conference in parallel with another industry association were suggested as a way of increasing attendance. It was pointed out that companies cannot afford to exhibit at six or seven conferences per year. Elevation of more members to fellow, creating a higher profile for the Society, possibly, by hiring a professional publicity officer, promoting greater public awareness of community noise and how it can be prevented, were other suggestions. In particular, material could be prepared for students in the areas of acoustics, hearing loss and noise control.

Many of the above suggestions and responses will act as a guide for the planning of the Victoria Division activities over the following years. One of the major concerns of the Society must be to maintain and preferably encourage growth in the membership numbers. Some 27% of the respondents indicated they knew of additional people who were eligible for and likely to become new members. If this holds true nationally, then the potential growth of the Society is good. If you are one of the 27%, go and enrol a new member today. (Don't forget our 33% discount on new subscriptions - Ed).

* * *

COUNCIL ACTIVITIES

Report of 47th meeting of Council, 25th November 1991.

Membership of the Society again increased slightly during the year to 411 with the elevation of 27 applicants to member, 4 to Affiliate and 9 to Student grade. The grade of fellow was awarded to 1 South Australia and 3 New South Wales Division members. Council welcomed 3 new Sustaining members and appreciated the high level of support from existing members.

1991/92 Budget: Although council estimated to spend about $47,000 it now appears likely the final expenditure for the year will be closer to $40,000 due to a lower than expected cost of supporting the International Standards meetings in Sydney held at the time of Inter-Noise 91 and lower costs of producing "Acoustics Australia".

1992/93 Budget Estimates: Council expenditure is expected to be about $38,000. This includes an amount of $12,000 to support "Acoustics Australia", $3,000 for the publication of the directory of members and some increase in general expenditure. In view of the generally lower expenditure and a low increase in the c.p.i. to June last year Council decided not to increase annual subscriptions.

Acoustics Australia: Council expressed appreciation of the work of Howard Pollard, the Chief editor, and all those who assisted in the publication of the journal. In particular, it commended them for the high standard of the special issue associated with Inter-noise 91.

Code of ethics: A draft code together with a note on the procedure for handling complaints will be forwarded to the Divisions for comment prior to its publication in the August edition of "Acoustics Australia". It is anticipated that members will be asked to vote on its adoption at the AGM in November this year.

Conferences: The South Australian Division has been asked to explore the possibility of organising the 1993 Annual Conference.

Careers information: Council has established a small sub-committee to prepare a brochure and has appealed to Divisions to supply suitable material.

History of Acoustics: Little progress has been made with the suggestion from Fergus Fricke to document the experiences and memories of people who have retired from Acoustics. Members are urged to assist this project by offering any ideas they may have on how an interesting account of the history can be assembled.

Liaison: Council considered joining the Australian Foundation for Science but decided to seek the approval of members at the next Annual General meeting before committing Society Funds.

The Society continues to support the Federation of Australian Scientific and Technological Societies and Marion Burgess has agreed to liaise with them. Neville Fletcher continues to represent the Society on the National Committee for Physics and the National Committee for the Environment. Charles Don is involved in closer co-operation with the Australian Institute of Physics.

Appreciation: Council is fully aware that many members make significant contributions to the Society and acoustics generally. Those contributions are much appreciated.

R.A Piesse - Acting General Secretary

* * *

STANDARDS

A Draft **American** National Standard on *Evaluating the Effectiveness of Hearing Conservation Programs*, (ANSI S12.13-1991) has recently been released for trial use, comment and criticism. After three years a revised text of the draft standard will be submitted for approval as an American National Standard. The standard defines the methods for evaluating the effectiveness of hearing conservation programs in preventing occupational noise-induced hearing loss by using techniques for audiometric data-base analysis. *Details: ASA Standards Secretariat, 335 East 45th St, New York, New York 10017-3483, USA.*

* * *

ISO MEETINGS

Immediately following Internoise 91, Standards Australia hosted a number of ISO plenary and working group meetings.The factor dominating many of the committees is the need to produce standards rapidly for adoption by the European Community which has its own Standards Technical Committee (CEN). The CEN committee has agreed that the technical work should be undertaken by ISO and that voting on drafts should take place in parallel provided that the stringent target dates can be met. This will mean that Working Drafts should be prepared within 18 months (2 year target at present), Committee Drafts within 24 months (5 years at present) and Draft International Standards within 36 months (7 years now). These new targets are placing great demands on the Secretariats and committee members. The previously perceived pro-European bias of ISO is even more pronounced, however the very fact that the ISO meetings were held in Sydney demonstrates the commitment of ISO to being a worldwide organisation. It is Standards Australia's policy to adopt International Standards as Australian Standards, without alteration wherever possible, so it is most important that we have inputs at the working group stage. There is also a possibility that Standards Australia may be able to assist with partial funding for delegates to attend overseas meetings considering standards of importance to Australia, if industry funding is not available.

SC1 produced 26 resolutions including approval of a number of Committee Drafts - these include specification of the test surface for road vehicle noise measurements, a series relating to measurement of emission sound pressure levels from machinery and equipment at the workstation, determination of sound insulation performance of enclosures, measurements of insertion loss of ducted silencers without flow and recommended practice for the design of low noise workplaces.

SC2 agreed to prepare a proposal for short test methods for measurement of impact sound insulation and the working group is to enlarge its work program to include measurements of reverberation time in rooms other than auditoria.

The main **TC 43** committee approved 4 new work items - reference hearing thresholds for acoustic test signals of short duration, for pure tones in range 8 Hz - 16 kHz, evaluation of the effectiveness of hearing conservation programs and determination of noise emmissions from sources placed at the ears.

from report by Anita Lawrence

* * *

INTERNOISE 91

Internoise 91 was organised by the Australian Acoustical Society and held on the Kensington campus of the University of New South Wales, December 2-4, 1991. Some 500 delegates attended with approx 50 accompanying persons; in addition there were 70 representatives of the 31 trade exhibitors.

The first of two plenary lectures was given by **Tor Kihlman** from Sweden on "Fifty years of Development in sound insulation of dwellings" and the second by **Bob Randall**, from the University of NSW on "Frequency analysis - a stroboscopic approach". The eight "special sessions" and the technical contributions meant that delegates could choose from approximately 300 papers in up to nine parallel sessions. All the papers are available in the two volume proceedings.

A number of Technical tours were arranged. Internoise 91 was not all work and delegates were invited to an "Australian Barbeque" at the Rocks hosted by Vipac and Ono Sokki. The Conference banquet was held at the Argyle Centre and the participants were particularly intrigued by the Australian flavour of the entertainment - including the shearing of a sheep on stage. The closing ceremony included an invitation by **Dr Tony Embleton** to participate in Internoise 92 in Toronto, Canada, July 20-22.

The Secretariat was provided by IPACE at NSW University and **Christine Bourke** in particular was responsible for the smooth running of the meeting. I would like to express my sincere appreciation to the members of the local organising committee who spent many hours over the three year preparatory period; they were – **Ray Piesse, Ferg Fricke, Renzo Tonin, Cliff Winters, Richard Heggie and Roy Caddy.**

Anita Lawrence - General Chairman

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WESTPRAC IV

The IV Western Pacific Regional Acoustics Conference was held in Brisbane, 26 - 28 November, 1991. This timing was selected to allow delegates to attend Internoise in Sydney the following week. The Conference was co-sponsored by the Queensland Division of the Australian Acoustical Society and the Department of Environment and Heritage. Griffith University was selected as the venue and the University also kindly donated $250 towards hosting the Conference.

The four **key note speakers** were: • Prof. Toshio Sone (Japan), • Prof. Yu Wann (Korea), • Prof. Wang Ji-Qing (China) and • Prof. Ma Yuan Liang (China). Eighty-eight **contributed papers** were received. The break up of authors by country was: Japan(18), China (17), Korea (7), Australia (28), United States (2), New Zealand (1), Germany (1), Hong Kong (2), Italy (2), France (3), UK (2), Singapore (1), India (1), Canada (1), Denmark (2).

The **papers** ranged across the fields of Architectural Acoustics, Bio Acoustics, Underwater Acoustics, , Measurement, Management of the Acoustic Environment and Specialist which included acoustic theory, electroacoustics, signal processing and ultrasonics. **Workshops** on Architectural Acoustics, Bio Acoustics, Education, Measurement, Underwater Acoustics and Planning Controls were held.

One hundred and fifty **delegates** attended the Conference. Countries represented included: Japan (24), Korea (15), China (15), Australia (65), New Zealand (3), Poland (2), Norway (3), Belgium(1), Philippines (1), Singapore (1), UK (3), USA (3), Canada (1), Denmark(2), Sweden(1), Italy (2), France (3), Germany (2), India (1), Hong Kong (2).

The main **social events** for the Conference commenced on Tuesday evening, at a barbeque on the lawns at Griffith University. A demonstration of didgeridoo playing provided entertainment. A number of delegates even joined the artists and tried their skill at aboriginal dancing. The Conference Dinner was held at the Beenleigh Rum Distillery. The smorgasbord and the company were delightful and many an unsuspecting delegate lost some personal item to the roving magician.

Conference Proceedings are for sale at $A50 per copy from: *The Australian Acoustical Society (Queensland Division), c/- Mr Greg Lee-Manwar, Division of Environment, 160 Ann Street, BRISBANE 4000 Qld. Tel (07) 227 6436.*

Noela Eddington, Conference Convenor

* * *

NOISE WORKSHOP

In the week prior to WESTPRAC IV, the Division of Environment sponsored a Noise Workshop on behalf of the World Health Organisation. The Division is a Reference Centre for Noise Control in the Western Pacific Region.

Approximately 16 delegates attended the Workshop. WHO sponsored one delegate from China and one from the Philippines. At the end of the week, students presented reports on noise impact assessments of various developments. A panel of experts commented on these reports and was most impressed with the standard of work. Dr Lex Brown from Griffith University undertook some specialised work with the overseas students at the University for 2 days during the Workshop. **Greg Lee-Manwar** did an excellent job in his single handed organisation of the Workshop.

* * *

DESIGN AWARD FOR SHIPPING CONTAINER

A Sydney company, **Environmental Noise Control Pty Ltd**, has earned the prestigious Australian Design Award for its acoustic shipping container for diesel generators. Known as 'Enco Containerised Power', the innovative container is a complete diesel generator power package in an approved shipping container - designed to supply auxilliary power for refrigeration and other purposes.

"We had to build a complete acoustic power package which met the requirements of Lloyd's container certification scheme. The result is a durable unit with flexible interior space able to accommodate a range of generators," the Technical Director at Environmental Noise Control, **Ram Krishnaswamy** said. The Commercial Director of Environmental Noise Control, **Roy Mammone**, emphasised the fact that the Enco Containerised Power unit needs minimum maintenance, and comes with a five year unlimited warranty.

General Manager of the Australian Design Award program, **Keith Jordan**, said that the Enco Containerised Power module is a major improvement to the current technology for providing containerised power generators for shipping and other industrial situations. "A product is only granted an Australian Design Award after a rigorous assessment by an independent panel of experts, who take account of market demands, the use of appropriate materials and technology, the capabilities and quality systems of the production facilities, ergonomic design, and safety," Mr Jordan said.

* * *

QUIET TILES

Anechoic tiles were first developed by German scientists during World War II to reduce the reflections of underwater sound from submarines. While there have been improvements in these types of tiles, they need to be tailored for the temperature of the sea water in which they will be deployed. The Laboratory of the Defence Science and Technology Organisation has been conducting a program of research and development on anechoic tiles. **Dr. David Oldfield** has been awarded the 1991 Minister's Achievement Award for his work on developing anechoic tiles for the Collins class submarine.

FOR SALE

ANECHOIC CHAMBER

The Civil Aviation Authority has an Anechoic Chamber for sale by Tender. The Chamber is presently installed at the CAA Environment Laboratory, 14 Wales Street Belconnen, ACT.

Tenders are being called for the purchase and the removal of the Chamber from the above premises. Prior inspection is welcome.

Tenders close: 15th May 1992

Manufacturer: G & H Montage
Modular Construction
inside Free Size: 3.8 X 3.4 X 3.4
(2.4m above grid floor)
Cut off frequency: 1000Hz
Wedge Material: ACI Fibreglass
Spare (new) wedges included
Trampoline Floor
Original Installation: 1988

Further details or inspection contact
Alan North
CAA Environmental Laboratory
14 Wales St. Belconnen, ACT, 2617

Tel: **(06) 251-4877**
Fax: **(06) 253-1719**

FIBRE HEALTH HAZARD

A half day seminar was held at the National Acoustic Laboratories on "The Use of Synthetic Mineral Fibres in the Construction & Other Industries. Is There a Potential Health Hazard?". Speakers were **Dr. Eva Francis**, Co-ordinator of the Inhalable Particulates Unit, Work Cover; **Mr. Ray Thompson**, Marketing Manager - Health, Bradford Insulation Group, and at short notice (due to the non-appearance of Mr. John Parkin, of the Metal & Engineering Workers Union) **Dr. James Leigh**, Head of the Epidermiology & Serveillance Unit of Worksafe Australia.

Dr. Francis dealt with the size of synthetic mineral fibres in relation to their potential for inhalation and Dr. Leigh discussed the results of overseas investigations carried out over a 20 year period showing that no relation can be shown between lung disease and time of employment, time of exposure and fibre dose. Mr. Thompson stated that the studies are being continuously monitored and, to date, animal inhalation studies have given no evidence of fibrosis, lung cancer or mesathelioma in association with insulation wools. He also commented that Worksafe Australia's National Standard and Code of Practice is now the most stringent in the world. The seminar concluded with a short talk by Peter Knowland on his experience with alternative materials for sound absorption purposes.

Further to the meeting, the fibreglass issue has been raised in the media and in Federal Parliament resulting in a letter being sent from the Australian Council of Trade Unions to the Secretaries of affected Unions stating that the ACTU considers any risks are eliminated by following the Worksafe Standard and Code. Copies of background documents circulated at the meeting are available.

Contact Valerie Bray (02) 498 8188

Valerie Bray

People...

NEW MEMBERS

• Interim Admissions

We have pleasure in velcoming the following who have been admitted to the grade of Subscriber while awaiting grading by the Council Standing Committee on Membership.

New South Wales
Mr R J Sleeman

• Graded

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

Student
New South Wales
Mr P J Knott
Victoria
Mr D K Cahill, Mr P McMullen, Mr Y L E Tan

Subscriber
New South Wales
Dr J D Quirt (Canada)

Member
New South Wales
Mr B J Clarke, Mr T Markiewicz, Mr G P Veale, Mr J Zie
Victoria
Mr C J D'Rozario, Mr S J King, Dr K Legge, Dr E A Lindqvist
Western Australia
Mr L J Storer

* * *

● Congratulations to the following firms who gained ACEA Engineering Awards for 1991:

Renzo Tonin & Associates Pty Ltd, Highly Commended for their noise impact study in relation to expansion of the Tomago Aluminium Smelter.

Sinclair Knight & Partners, Highly Commended for their noise and traffic studies in relation to expansion of the Scrumlo Feedlot.

Challis & Associates Pty Ltd, Award of Merit for their work on engine and run up facilities, Tindal RAAF Base.

* * *

● Congratulations to Doug Cato of DSTO, Sydney on his recent elevation to Fellow of the Acoustical Society of America " for research in ambient noise mechanisms in the sea".

NEW FELLOWS

Councillors are deeply aware of the debt that the profession of Acoustics and the Society owe to earlier Councils, Office-bearers and the body of membership. In recognition of their contributions, Council at its meeting on 25th November 1991 invited the following to become Fellows of the Society.

David A. Bies – Anita B. Lawrence – Raymond A. Piesse – Jack A. Rose

Each has accepted the invitation and accordingly the grade of Fellow is conferred. The citations presented to Council are as follows . . .

David Allan Bies

The grade of Fellow is conferred on David Allan Bies in recognition of his notable contribution to education and research in the field of Acoustics and of his sustained support of the South Australian Division of the Society.

Anita Barbara Lawrence

The grade of Fellow is conferred on Anita Barbara Lawrence for her meritorius contributions to teaching and research in Architectural and Building Acoustics; for her outstanding service to the Society since its formation; and in recognition of her important contributions to Standards Australia and other public bodies

Raymond Alfred Piesse

The grade of Fellow is conferred on Raymond Alfred Piesse for his outstanding contribution to Acoustics especially in the development of the National Acoustic Laboratories; his substantial work with Standards Australia and the National Association of Testing Authorities; and his faithful service to the Society as foundation member, President, Registrar and General Secretary.

Jack Anthony Rose

The grade of Fellow is conferred on Jack Anthony Rose for his significant contributions to promotion and practice of hearing conservation and control of noise, particularly aircraft noise, and the building of new laboratories for the National Acoustic Laboratories; in recognition of his service to the International Commission on Acoustics and his enthusiastic support of the society since its inception.

● As General Chairman of Internoise 91, **Anita Lawrence** has been elected a member of the Board of I-INCE for a period of six years. Ferg Fricke is a delegate alternative.

● **Ron Barden** provided an entertaining after dinner talk to the end-of-year dinner for the Victoria Division. His topic "Oscillatory Humans - Incidents and Interactions" was based on reminiscences from his long acoustical career.

● A talk by **Glen Harries** on "Fan Noise" commenced the Victoria Division programme for 1992. This was followed by a workshop discussion, led by **Dave Watkins**, on a draft of the revised Environmental Noise Standard.

FOR SALE

B & K 2221 TYPE 1 SLM

SURPLUS TO REQUIREMENTS

ANY OFFER CONSIDERED

Ph / Fax Bob Russell

0064 7 5443038

New Zealand

● Preceding the WA Division AGM, **Rob Woodcock** explained and demonstrated his system for reading music from a score into a computer then playing it back through an electronic keyboard with MIDI (musical instrument digital interface). Rod is an electronics student at University of WA and he also showed how the system could be used for composition/ editing with a demonstration of one of his own works.

● The end-of-year dinner for the WA Division featured a talk and demonstration of the didgeridoo and relevant aspects of aboriginal culture by **Robert Walker**.

● The WA Division arranged a breakfast to meet with **Harry Lester** who is a specialist noise inspector with the UK Health and Safety Executive. Harry outlined the huge workload being undertaken by ISO and CEN Standards Committees in their runup to the Dec 1992 deadline for the EEC Countries as they move to a single market. It was clear that this work will have a significant impact on Australian markets in terms of noise declaration and noise labelling of goods in the future.

● **Flakt-Richardson** has closed down its sound insulation materials factory at Mordialloc, Vic, as part of a general rationalisation of its operations. Though the demand for acoustical materials for use in industry has been maintained, the slump in the building industry has meant significantly reduced demand for them in new buildings.

● **Company Name Change** - Amatek Ltd and GRC Composites have been trading under various names for a number of years. Since late 1991, while the office locations and telephone numbers remain the same, all the businesses are united under the name ROCLA. Thus the noise attenuation barrier systems, made from glass fibre reinforced concrete, are now available from Rocla Composite Products.

● **Styrofoam Distribution** - Bradford Insulation has been appointed distributor for Dow Chemical Styrofoam. The insulating material is made of extruded polystyrene foam with a completely closed cellular structure. The combination of Dow technology with the existing Bradford range will be a benefit to the building industry.

● **Public Company** - Cirrus Research Ltd ceased to exist on 14 Feb when formalities were completed in order for it to become a public company. The name is now Cirrus Research plc.

❑ ❑ ❑

Books...

PSYCHOACOUSTICS - FACTS AND MODELS

E. Zwicker and H. Fastl.

Springer Verlag, 1990, pp 350 , Hard cover, ISBN 3-540-52600-5. Australian Distributor: DA Books, PO Box 163, Mitcham, Vic 3132. Price A$81.75

This book is a summary of research in psychoacoustics carried out in the research departments of the Institute of Telecommunications in Stuttgart from 1952 to 1967, and the Institute of Electronics in Munich since 1967.

This book contains a wealth of material on psychoacoustics from two front rank laboratories, and is highly recommended to all acousticians. While the authors did not set out to write a textbook of psychoacoustics, the book is organised somewhat like one. The first chapter (Stimuli and Procedures) has some interesting material on signal analysis, presenting stimuli with earphones and loudspeakers, and averaging results. Its treatment of psychophysical methods is rather perfunctory, however, and for students could be rather misleading, since no mention is made of signal detection theory, which some have considered makes the notion of threshold itself questionable. The second chapter, "Hearing Area", is also disappointing. The empirical basis for threshold curves (hearing levels of otologically normal young people) is not described, and the presumption that, because exposure to loud music on one day exceeds the levels and trade offs for daily occupational noise exposure then pure tone thresholds must also be permanently affected, is asserted uncritically. The absence of references from the text is noticeable here, e.g. the source of the curves given for the pure tone thresholds of young people who listen "frequently" to loud music is not given, and is not obvious from the references at the back of the book. Presbycusis is described briefly but no curves are given.

In the third chapter the book begins to get into its stride. Preprocessing of stimuli in the outer, middle and inner ear is discussed, with interesting sections on the roles of the outer and inner hair cells, and on otoacoustic emissions and their relation to pure tone thresholds. Preprocessing in the inner ear is modelled in a block diagram.

The fourth chapter, on masking, is also far more comprehensive than the early chapters. This chapter establishes the pattern followed throughout the remainder of the book, characterised by numerous (but never superfluous) and well labelled diagrams, "connections" made between data (e.g. tuning curves are related to the masking pattern), and theoretical models which summarise the relations between the data. The chapter on pitch also makes rewarding reading, covering a variety of phenomena including virtual pitch (are these illusions?) and pitch "strength". The material on critical bands is also very valuable, as befits Zwicker's seminal contributions to the literature on this topic. One interesting section of this chapter shows that critical band number (for some unknown reason called "critical band rate" in this book), number of JNDs for pitch, the ratio pitch scale in mels, the number of hair cells, and distance along the basilar membrane are all linearly related to each other, but not to sound frequency.

Chapter 7, on just noticeable changes, is again good value, but the omission of data on JNDs for duration illustrates the point that this book is not to be taken as a handbook of the field. Chapter 8, on loudness, covers the basic phenomena, including the loudness function, spectral effects, and the "recruiting' effect of partial masking on the loudness function, although the similar effect of noise-induced temporary threshold shift (NITTS) on the loudness function is ignored. A model of loudness, the Zwicker method of calculating loudness, and loudness meters are treated in detail, but again it is noticeable that these methods are not related to other loudness computation methods (e.g. Stevens' methods). There is also no discussion of the loudness of impulse noise, or of the possibility of impulse noise loudness meters.

Some of the most interesting reading is found in the results of research aimed at giving the term 'timbre' more specific meaning. The authors refer to these as the "sensations" of sharpness or "Density", and "Sensory Pleasantness", which is inversely related to sharpness but "also depends on other sensations such as roughness, tonalness and loudness", perceptual qualities which are investigated in separate chapters. While it is clear that these variables are important in the characterisation of hearing, the question of definition is glossed over and there is no discussion of whether or not these "sensations" are thought to be the only ones of importance. Details of the basic experiments, including the instructions given to subjects, would have been helpful here. The short chapter on rhythm, and its relation to the temporal envelope of the sound and its loudness is well worth reading, as are the following ones on the ears nonlinear distortion, and binaural hearing. The books limitation to the research of these two laboratories is again evident in Chapter 15, where the only discussion in the book on auditory localisation does not mention monaural localisation.

The final chapter is devoted to Applications. This also makes very interesting reading, but again the authors discussion of some issues is limited, by restricting attention to their own work. Thus loudness is regarded as the only "unbiased" estimate of the acoustical determinants of annoyance due to environmental noise, neglecting the experimental foundations of Kryter's 'equal noisiness contours', which were the bases for the scale of effective perceived noise decibels (EPNDB) and, ultimately, the Noise Exposure Forecast (NEF) method of assessing the impact of aircraft noise on the community.

Psychoacoustic variables such as loudness, pitch and the authors' "roughness" etc are as real as any other scientific measure. If they weren't there would be no point to a science of hearing, since science consists of propositions in which the terms used in the conclusion must appear in the premises. One feature of this book that the reviewer personally appreciated, therefore, was that the word 'subjective', with its connotations in English of variability and unverifiability, was used sparingly (albeit once in a chapter heading). In fact, it need not have been used at all.

In summary, this is an excellent book which should occupy a unique place in the literature on psychoacoustics. Its occasional limitations of scope can be made up by wider reading.

Norm Carter

Norm Carter is head of the Human Effects Group at the National Acoustic Laboratories in Sydney. His past research includes studies of TTS due to impulse noise in the laboratory and in the field, scaling the loudness of impulse noise and assessing the effectiveness of earplugs as protection against impulse noise. He has also studied the permanent effects of amplified music on young people's hearing thresholds and the effects of noise on the cardiovascular system during task performance and sleep.

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FIVE LECTURES ON THE ACOUSTICS OF THE PIANO

Anders Askenfelt (Editor)

Royal Swedish Academy of Music, Stockholm, 1990, pp.105, Soft Cover, plus CD. ISBN 91-85428-62-0. Available directly from publisher at Blasieholmstorg 8, S 111 48, Stockhol;m, Sweden. Price US$23.00 plus postage.

The Royal Institute of Technology in Stockholm is one of the world's best known centres for the study of the acoustics of speech and music, and has a regular stream of distinguished visitors from other parts of the world, as well as its own resident researchers. This volume contains the text, figures, and musical examples for five lectures on the piano given at the Institute in May 1988, and follows several other publications of similar type.

The first lecture, by Harold Conklin, outlines the design principles of the piano, makes comparisons between early and modern instruments, and presents some striking recorded illustrations of the effects of hammer hardness and the unexpected influence of longitudinal string modes on piano tone. Next Anders Askenfelt and Erik Jansson present a detailed description and careful experimental analysis of the operation of the piano action between the players finger touch and the impact of the hammer on the string, giving some new insights into the extent to which a player can influence tone quality. The third lecture, by Donald Hall examines in detail the impact of the hammer on the string and the nonlinear elasticity of the hammer felt, while in the fourth, Gabriel Weinreich discusses the way in which multiple strings with slightly spread individual tuning lead to a sharp initial decay but long sustain in piano tone. Finally Klaus Wogram examines in detail the vibration modes of the soundboard and the influence of the ribs.

All the authors are experts in their fields, and the lectures convey a great deal of information in readily readable form with virtually no mathematics, but a good number of quantitative figures. They make interesting reading for musically inclined scientists or students, and would also be most valuable to technically minded pianists and to piano technicians.

The CD that accompanies the book provides sound examples to illustrate the first two lectures, and then goes on to present recorded excerpts from a concert, which followed the lectures, in which music of appropriate period is expertly played on a harpsichord and on five pianos dating between 1813 and 1980. The playing is excellent, and the fine recording of these instruments all in the same hall makes comparison easy. My only regret is that the concert excerpt runs for less than 15 minutes and that some tracks are faded out, rather than concluding musically. This certainly facilitates comparison, but rather makes one wish for the complete version.

The production of this short book is excellent, and the price very reasonable, considering the included CD. I recommend it to anyone with an interest in the piano.

Neville Fletcher

Neville Fletcher is a Chief Research scientist with CSIRO. He has written widely on musical acoustics, among other topics, and has recently published (with T Rossing) a book on the "Physics of Musical Instruments" reviewed in the last issue of Acoustics Australia.

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UNDERWATER ACOUSTIC MODELLING : PRINCIPLES, TECHNIQUES AND APPLICATIONS

Paul C Etter

Elsevier Applied Science, 1991, pp 305, Hard cover, ISBN 1 85166 528 5. Australian Distributor: DA Books, PO Box 163, Mitcham, Vic 3132. Price A$144.25

In the authors words, "the scientific discipline of underwater acoustics is transitioning from a stage of observation to a stage of understanding and prediction." The tool of prediction is the mathematical model. Whereas the basic concepts of underwater acoustics are covered in several existing textbooks, accounts of recent advances in modelling often remain scattered through scientific journals, conference proceedings and the so-called "grey" literature of unpublished reports. With this new book, Etter succeeds in providing a concise, up-to-date review of those models which are applicable to "in-the-field" sonar and, ultimately, the solving of sonar performance problems. Its scope doesn't extend to analogue modelling (scaled acoustics experiments in controlled tank environments) or to developments in low frequency seismology (unless applicable to sonar modelling). For these aspects of the field, the reader is referred to reviews elsewhere in the literature. Nor does the author claim to offer detailed mathematical derivations of the theoretical expressions employed in the models. Rather, he maps out the physical and mathematical origins of representative models and indicates their domains of applicability. An extensive list of 443 references (including relevant "grey" literature) enables the reader to "fill in the details".

The order of presentation of the material follows the structure suggested by a hierarchical method of sonar model construction described in the introductory chapter. Specifically, all models are divided into the three broad categories of ENVIRONMENTAL MODELS ("Acoustical Oceanography"), BASIC ACOUSTIC MODELS (with subcategories of "Propagation", "Noise" and "Reverberation") and SONAR PERFORMANCE MODELS. Reverberation is sound scattered back to the hydrophone and differs from noise in that it is produced by the sonar itself. As one progresses from the first category to the third, the models necessarily become less universal in application and more system-specific. The author rightly claims *This book is unique in that it treats the entire spectrum of underwater acoustic models .....* Nevertheless, 7 out of the 11 chapters (representing 60% of the body of the book) are devoted to the second category which is, in fact, the book's primary focus. The approach is to deal firstly with the physical models of a particular category (or subcategory) and then with the mathematical models of that category. Physical models offer conceptual representations of the physical processes involved whereas mathematical models offer formulations suitable for computation. A further distinction is made between numerical mathematical models which are based on the knowledge of the governing physics and empirical mathematical models which involve the matching of mathematical expressions to experimental observations.

The chapters dealing with acoustical oceanography and physical propagation models offer a useful summary of what is treated more didactically in existing texts such as those of Clay & Medwin or Urick. In fact the reader will recognise many of the figures which have been borrowed from Urick's earlier texts. From a physicist's point of view, there is some pleasing modernisation of the terminology such as the use of sound "speed" (versus "velocity") and the adherence to SI-related units. The chapters dealing with the mathematical models of propagation, noise, reverberation and sonar performance are well written and each finishes with a tabulation of current models and their applicability. A separate chapter treats mathematical models for special propagation paths such as surface ducts, shallow water and Arctic half-channels tomography and chaos, references to more extensive sources of information are provided. The book concludes with a chapter on model evaluation.

It is evident from the referencing in the introductory chapter that the author was a key participant in the inaugural U.S. Navy review of the availability of numerical models (including supporting data bases) and has published four subsequent literature review updates, the most recent being in 1990. In addition to its extensive reference list, the book includes an author index (449 entries), a glossary of 290 terms and an appendix of 193 abbreviations and acronyms (you will be reassured to learn that "RAP" is an acronym for "Reliable Acoustic Path"). Although the book arose out of the author's lecture notes for a series of intensive short courses, it is likely to be useful as a student textbook only for advanced, highly specialised courses. However, it constitutes an authoritative overview and reference source for those already active in the field and an excellent guide to the literature and terminology for those who have a solid background in the physical concepts of underwater acoustics but wish to gain further insight into their practical application.

Glen Stewart

Glen Stewart is a Senior Lecturer in the School of Physics at the Australian Defence Force Academy and is responsible for the courses in Marine Acoustics and Optics

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NOISE BARRIERS AND CATALOGUE OF SELECTION POSSIBILITIES

Graphic Services, Roads and Traffic Authority, PO Box K198, Haymarket, NSW 2000, Tel (02) 218 6833. Price: A$ 60

This 170 Page document has been prepared by Wilkinson, Murray, Griffiths in conjunction with Bruce Mackenzie and Assoc. for the NSW Roads and Traffic Authority (RTA). It is intended, not as a comprehensive handbook, but as a guide for planners, designers and construction personnel.

The guidelines for road traffic noise in NSW were published in 1987 and included a brief section on barriers as a form of control. This document provides a more comprehensive explanation of the principles for the reduction of sound by barriers and gives details of the various types of barriers which are available.

Part 1 comprises 10 Sections on the theory and design aspects of barriers. These cover such aspects as heights of barriers, attenuation, design considerations, cost effectiveness and the selection process. In the technical sections there are very clear simple diagrams showing the principles of reflection, diffraction, effective height etc. This simplified approach is contrasted by details in other sections. For example; the sound transmission loss (STL) of 25 types of wall materials is given even though it is acknowledged that the typical barrier attenuation achieved by diffraction is about 10 dB so an STL of at least 20 should be suitable. Only 9 of the 25 types listed have values less than 20. Two graphs are given for the potential barrier correction as a function of path length difference - one sourced to the UK , the other to the USA. As the values obtained from each graph are slightly different, this could cause confusion.

The sections on design aspects are supplemented with diagrams and photographs showing the particular features. The importance of the view of the barrier from both sides is discussed. The flow diagram identifying the important factors in the section process shows public involvement as an important feature at many of the steps.

Part 2 comprises a catalogue of 18 barrier types. A summary table gives the cost per linear metre at 1990. For each barrier type there is a description, examples of applications and other comments plus cost and contact details. A small sketch or photograph would be of advantage in this section. The Appendix has 36 photographs of various barriers from around the world but it is difficult to compare those with the types listed in the catalogue.

Planners, designers and construction personnel would find the document useful. The many photographs and diagrams make it a particularly worthwhile addition to the office library.

Marion Burgess

Marion Burgess is currently a research officer at the Acoustics and Vibration Centre of the Australian Defence Force Academy. She has been involved with the measurement and control of road traffic noise for many years.

* * *

CONFERENCE PROCEEDINGS

NOISE-CON 91: Twenty Years of Progress and Future Trends

Noise Control Foundation, PO Box 2469 Arlington Branch, Poughkeepsie, NY 12603, USA Price: US$75 (plus US$25 for air mail)

NOISE-CON 91, the 11th National Conference on Noise Control Engineering, was held at Tarrytown New York on 14-16 July 1991. The proceedings comprise the five distinguished lectures and 82 contributed papers.

The distinguished papers were by:

- Leo Beranek "Fifty years of noise control; A personal history"
- Per Bruel "Practical use of acoustical technology for the measurement of energy flow, holography and wavelets"
- Karl Kryter "Perception of noisiness"
- Richard Lyon "Designing products to sound good"
- Istvan Ver "Proposal for a long-range noise control policy: Cooperation between government, industry and the research community"

The subjects for the contributed papers include product design, fan noise, active noise control, electrical utility noise modelling, binaural measurement systems, loudness of noise, boundary element methods and noise control regulations. The proceedings will be of interest to those wishing to keep informed on the progress and future trends in noise control.

New Products...

CIRRUS

Integrating Sound Level Meter

CRL 254 has been designed to satisfy the EEC directives for noise in the workplace and to meet the requirements of the UK Armed Services. It is based on the successful CRL 222 and has a single analogue display range going from 80 to 120 dB. Measurements can be made in dB(A) or dB(C) to allow for the selection of the best ear defenders. It is available as a complete measurement kit including calibrator, windshield etc.

Screening Audiometer

CRL 602 is a binaural screening audiometer complying with IEC 645 specifications for Class 4 units. It provides a simple means of establishing hearing levels at an employee's initial medical check and for routine screening. It is "user friendly: with coloured LED's to show battery power, test signal and external power.
Further information: Davidson, 17 Roberna St, Moorabbin, Vic 3189, Tel: (03) 555 7277 Fax: (03) 555 7956

BRUEL & KJAER

Mapping and Sound Power Analysis

The software BZ7021 is uniquely designed to directly load into Real Time Analysers, type 2123 and 2133. The analysers' post-processing abilities are combined with a comprehensive range of mapping facilities which cover both spatial and sequential multispectra. Five map types can be displayed on screen; landscape, outline, shaded, number and vector. The software also contains user-defined functions for sound power ranking. It is also possible to use the software to map data from Analysers type 2143 and 2144 by transferring the data to a type 2123/2133.

VXI Test System

A family of audio range analogue modules and Digital Signal Processing (DSP)-based virtual instruments have been released and all use VXI bus technology. The measurement software includes, in addition to standard measurement functions, a comprehensive package of spectrum analysis hardware and software. The virtual instruments are software packages running on an embedded VXI computer. In conjunction with only three hardware modules - and A/D converter, a D/A converter and a DSP

- these software packages cover the majority of analogue measurement functions.

FFT Option

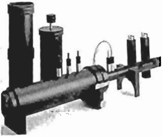
The 7637 is a single channel FFT option for use with Real-Time Analysers Type 2143. It comes on 3.5in disk and is loaded using the built-in disk drive. The FFT Option greatly increases the range of applications for the analyser.

Statistical Data Logger

Long term environmental noise measurements can be made with the Sound Level Meter type 2231 programmed with the Statistical Analysis Module BZ7115. The memory is large enough to store more than one month's worth of 15 minute records. After measurements, the results can be displayed, printed or transferred to a computer for further processing. The results can be printed or sent to a computer and the meter itself can be controlled by a computer.

Impedance Tube

The Two Microphone Impedance Tube, type 4206, offers quick and easy calculation of the acoustic absorption coefficient, acoustic reflection coefficient and normalised impedance of small test samples over a frequency range from 50 Hz to 6.4K Hz. Results can be displayed as magnitude, phase, real and imaginary part, Nyquist or Nichols plots. The measurement setup comprises the Impedance Tube, Applications Software BZ 5051, Multichannel Analysis System type 3550 and Power Amplifier type 2706. The 4206 is also supplied with Application Software BZ 5050 for use with a PC so that the measurements can be controlled with Analysers types 3550, 2032 or 2034.



Bruel & Kjaer's New Impedance Measurement Tube Leaves Standing Waves Standing

Human Vibration Unit

Human-vibration Unit Type 2522 and Human-vibration Module BZ7116 combine with Sound Level Meter Type 2231 to form a dedicated and portable human-vibration analysis set which can measure simultaneously in up to three channels. It is ideally suited for the monitoring of human-vibration for the assessment for health risk such as Raynaud's phenomenon (vibration-induced white finger).

A digital data store allows storage of measurement data in up to 99 records, either automatically at user-defined intervals, or manually. Analogue outputs are also available—data can be simultaneously recorded on a level recorder. Frequency weightings comply with standards for hand-arm measurements, whole-body measurements and whole-body combined measurements (designed for measurements of vibrations in buildings). The set also has a facility for linearly weighting the signal over the specified frequency ranges for future analysis.

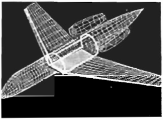
Human-vibration Unit Type 2522 & Human-vibration Module BZ7116 – for modular Precision Sound Level Meter Type 2231

Further information: B&K, PO Box 177, Terrey Hills NSW 2084 Tel: (02) 450 2066 Fax: (02) 450 2379

VIBRO-ACOUSTIC

Auto-SEA Software

Auto SEA is a new software tool designed to enable accurate predictions of the noise and vibration behaviour while products are still on the drawing board. It is a fully graphical, object oriented implementation of the acoustic design methodology, Statistical Energy Analysis (SEA). It is particularly, when there are a number of noise paths through structures,



SEA Aircraft Geometry

Further information: Paul Bremner, Vibro-Acoustic Sciences Ltd, 5/15 Orion Rd, Lane Cove, NSW 2066, Tel: (02) 418 6577, Fax: (02) 418 8038

ACOUSTIC RESEARCH LABORATORIES

These items are repeated from the last issue due to publication errors

Environmental Noise/Vibration Loggers

Designed and manufactured in Australia, the Enviro-Log range has been specifically developed to meet the needs of medium to long term, outdoor monitoring applications where rugged, inconspicuous design and low cost are paramount.

The **EL-015,** a type II Lin/A weighted statistical noise logger which captures 16 samples/second with a 90 dB dynamic range capability. 2048 statistical results may be stored on the basic instrument, allowing for a maximum logging period of 84 days if an external trickle source is provided or more than 3 weeks using the internal battery.

The **EL-035**, a triaxial statistical vibration logger which stores statistical linear rms, AS 2670 human sensitivity weighted and peak hold levels. It is intended for logging structural vibration in occupied buildings and the frequency range is 1Hz to 1 kHz and can operate for up to 14 days.

Spatial Sound Field Monitor

The **SFM-16** is a 16 channel 1/3 octave sound level meter for measurement of sound pressure level and spectrum (from 50 to 10kHz) at discrete locations. The parallel sound level meter circuits and filters are designed to comply with the requirements of AS 1259 and AS Z41. Control is via a front panel 'qwerty' style keyboard and results may be displayed in either text or graphics on a liquid crystal display. The system, fully programable, permits RS 232 communication with MS DOS computers for long term data storage and analysis. An internal, rechargable battery permits operation for up to 24 hours when mains power is not available.

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

New Publications

REPORTS

NPL Report RSA (EXT) 14
"Noise levels of military aircraft at low altitude: Exercise 'Luce Belle'"
B F Berry, R C Payne and A L Harris

NPL Report RSA (EXT) 16
"Noise levels of USAF aircraft in Exercise 'Luce Belle'"

Copies available from Bernard Berry, National Physical Laboratory, Acoustics Branch, Teddington, Middlesex, TW11 0LW, UK
Fax 081-943-6161

* * *

Institute of Sound and Vibration Research, University of Southampton, SO95NH, UK.
ISVR Technical Reports
No. 194, "Risk to hearing from overflight noise of military aircraft".
B W Lawton and D W Robinson

No. 196, "A frequency domain least squares method for modelling acoustic fields".
M Anciant, P A Nelson and J K Hammond

No. 204, "Realistic models for predicting sound propagation in flow duct systems".
P O A L Davies

* * *

Department of Speech Communication & Music Acoustics, Royal Institute of Technology,
P O Box 70014, S-10044 Stockholm

Annual report 1990
Quarterly Progress & Status Report 15 Oct 1991

* * *

JOURNALS

Applied Acoustics, Vol 34 No 3 1991
Contents include : 'An empirical study of comfort afforded by various hearing protection devices: laboratory versus field results' by Min-Yong PARK & John G CASALI; 'On the study of the active attenuation of noise in an L-formed duct' by Jiluo ZHOU, Tielsin SHI & Shuqi LU; 'Transmission of structure-borne sound in buildings above railways' by S LJUNGGREN; 'Prediction of sound fields in rooms using statistical energy analysis' by Ren WENTANG & Keith ATTENBOROUGH.

Applied Acoustics, Vol 34 No 4 1991

Contents include: 'Statistical analysis of noise levels in urban areas' by A GARCIA & L J FAUS; 'A theoretical study of sound transmission through aerogel glazing systems' by P P NARANG.

Australian J of Audiology, Vol 13 No 2, Nov 1991

Canadian Acoustics, Vol 19 No 5 1991

Contents include: 'Noise in rural recreational environments' by Herbert G KARIEL; 'Bottom loss in areas with ice-rafted sediments' by Francine DESHARNAIS; 'Attenuations from hearing protectors and the ABC classification system' by Alberto BEHAR.

Catgut Acoustical Society, Vol 1 No 8 (Series II) 1991

Contents include: 'Anatomical features and anisotropy in spruce wood with indented rings' by Antonio PACE; 'The dynamics of musical strings' by Maurice HANCOCK.

Chinese J of Acoustics, Vol 10 No 4 1991

Contents include: 'Acoustics of Chinese bowed string instruments Jinghu and Erhu' by CHEN Tong, ZHENG Minhua & CAI Xiulan; 'Rotational character of sound intensity and surface sound intensity' by JIANG Zhe & GUO Hua; 'Active anti-noise transmitters and receivers' by TIAN Jing, SHA Jiazheng & LI Ningrong; 'Complex eigenvalues and group velocities of normal modes in shallow water with a lossy bottom' by ZHANG Renhe & WANG Qin.

IINCE Newsletter Nos 63, 64 1991

Shock and Vibration Digest Vol 24 Nos 1,2,3 1992

INDEX

VOLUME 19 1991

A - ARTICLES

B - REPORTS

C – AUTHOR INDEX

D – LETTERS

Diary ...

CONFERENCES and SEMINARS

• Indicates an Australian Activity

1992

• April 30 - May 3, BAROSSA VALLEY
10th NATIONAL CONFERENCE
Audiological Society of Australia
Details: 1992 Conference, 50 Hutt St, Adelaide, SA 5000, Australia

May 5-8, RIO DE JANEIRO
IV INTERNATIONAL SEMINAR ON NOISE CONTROL
Details: Meta marketing e Eventos Ltda, PO Box 347, 20010, Rio de Janeiro, Brazil..

May 11-15, SALT LAKE CITY
MEETING OF ACOUSTICAL SOCIETY OF AMERICA
Details: Acoustical Society of America, 500 Sunnyside Blvd, Woodbury, NY 11797, USA.

May 18, BIRMINGHAM
ACOUSTICS ARCHITECTURE & AUDITORIA
Details: R. Orlowski, Arup Acoustics, St. Giles Hall, Pound Hill, Cambridge CB3 OAE, U.K.A

May 25-29, GDANSK
5th SPRING SCHOOL ON ACOUSTO-OPTICS AND ITS APPLICATIONS
Details: A.Sliwinski, Institute of Experimental Physics, University of Gdansk, Wita Stwosza 57, 80-952 Gdansk, Poland.

June 16-19, EGER
7th HUNGARIAN SEMINAR & EXHIBITION ON NOISE CONTROL
Details: OPAKFI Secretariat, H-1027, Budapest Fo u 68, Hungary

June 17, LONDON
HEALTH EFFECTS OF NOISE & VIBRATION
Details: B Berry, Acoustics, Div. Rad. Sciences, N.P.L., Teddington, MDDX ,TWII OLW, U.K.

June 23-25, PRAGUE
AIMS FOR NOISE CONTROL IN EUROPE OF THE FUTURE
17 th International Congress AICB
Details: 17 AICB, Czech Technical University, Faculty Civil Engineering, Thakurova 7, CS 166 29, Prague, Czechoslovakia

July 20-22, TORONTO
INTERNOISE 92
Details: Congress Secretariat, PO Box 2469, Arlington Branch, Poughkeepsie, NY 12603,USA

Aug 28 - Sept 1, TOKYO
INTERNATIONAL SYMPOSIUM ON MUSICAL ACOUSTICS
Details: ISMA 92 Tokyo Secretariat, c/ Acoustics Laboratory, Ono Sokki Co, 1-16-1 Hakusan Midoiku, Yokohama 226,Japan

September 1-3, SENLIS
FAN NOISE
Details: J Tourret, CETIM BP 67 - 60304, Senlis, France

September 3-10, BEIJING
14th ICA
Details: 14 th ICA Secretariat, Institute of Acoustics, P.O. Box 2712, Beijing 100080, China

September 12-14, NANJING
INTERNATIONAL SYMPOSIUM ON ACOUSTICAL IMAGING
Details: 14 th ICA Secretariat, Institute of Acoustics, P.O. Box 2712, Beijing 100080, China

September 14-18, LONDON
EURONOISE 92
Details: Institute of Acoustics, PO Box 320, St Albans, Herts, AL1 1PL, England

October 12-16, ALBERTA
1992 INTERNATIONAL CONFERENCE ON SPOKEN LANGUAGE PROCESSING
Details: ICSLP-92, Catering and Conference Services, University of Alberta, 103 Lister Hall, Edmonton, Alberta, Canada T6G 2H6

October 27-28, SENLIS
RECENT ADVANCES IN SURVEILLANCE
Using Acoustical and Vibratory Methods
Details: Mme F Chapelon, Revue Pratique de Controle Industriel, Editions Ampere, 25 rue Dagorno, 75012 Paris, France.

• November 26-27, BALLARAT
PRACTICAL ACOUSTICAL SOLUTIONS
AAS Annual Conference
Details: AAS Annual Conf, PO Box 233,Moonee Ponds,Vic 3039 Australia

• December 14-18, HOBART
11th AUSTRALASIAN FLUID MECHANICS CONFERENCE
Details: 11 AFMC Secretariat, Dept Civil & Mech Eng, University of Tasmania, GPO Box 252C, Hobart 7001

1993

April 4-7, SYDNEY
• INTERNATIONAL CONFERENCE & EXHIBITION
Australian Institute Refrigeration, Air Conditioning and Heating.
Details: AIRAH 1993 Conf, 191 Royal Parade, Parkville, Vic 3052 Tel (03) 347-4941/347-3786 Fax (03) 347-8571

May 31 - June 3, ST PETERSBURG
NOISE 93
International Noise and Vibration Control Conference
Details: c/-Malcolm Crocker, Mech Eng, 210 Ross Hall, Auburn University, Auburn, AL 36849-3501, USA

June 26 - July 2, BERGEN
13th INTERNATIONAL SYMPOSIUM ON NONLINEAR ACOUSTICS
Details: Prof Halvor Hobaek, Dept Physics, University Bergen, Allegt 55, Bergen, Norway 5007

July 6-9, NICE
NOISE & MAN
6th International Congress on Noise as a Public Health Problem
Details: Noise & Man 93, INRETS LEN, Case 24, F 69675, Bron Cedex, France

August 24-26, LEUVEN
INTER-NOISE 93
Details: INTER-NOISE 93, TI-K VIV, Desguinlei 214, B-2018 Antwerpen, Belgium

1994

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

COURSES

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

1992

July 13-17, LAUNCESTON
UNDERWATER ACOUSTICS
Details: Heather Strutt, AMC Search, PO Box 9487, Launceston, TAS, 7250. Tel (003) 260 703, Fax (003) 263 790

Oct 26-29, CANBERRA
BASICS OF NOISE AND VIBRATION CONTROL
Details: Acoustics and Vibration Centre, Aust Defence Force Academy, Canberra, ACT 2600. Tel (06) 268 8241, Fax (06) 268 8276

ADVERTISER INDEX

The Scientific Solution to Sound Control...

For almost 30 years, Flakt Richardson's Sound Control Division has used Research and Development to create new solutions in noise abatement. Today we are recognised as a leader in noise control technology. Utilising its internal development team and valuable links with Sound Attenuators U.K. and Kinetics Noise Control U.S.A., Flakt Richardson Sound Control have manufactured and installed numerous noise control solutions, both in Australia and Overseas.

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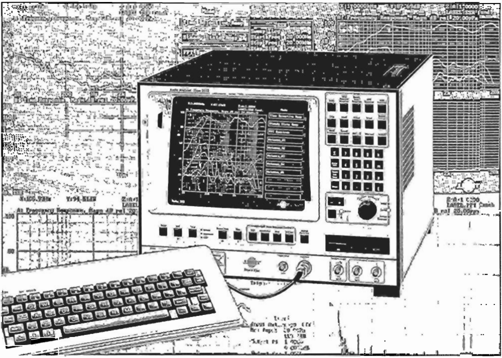

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