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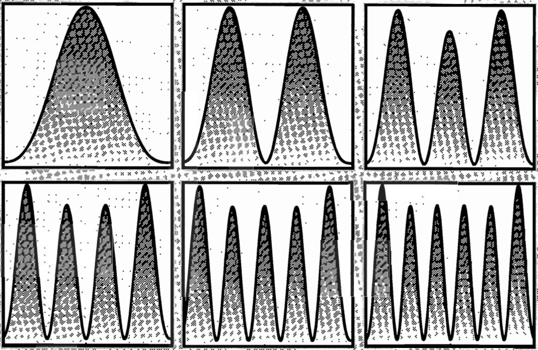

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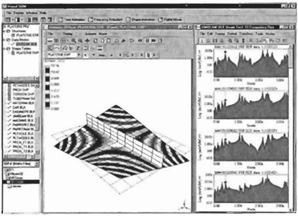

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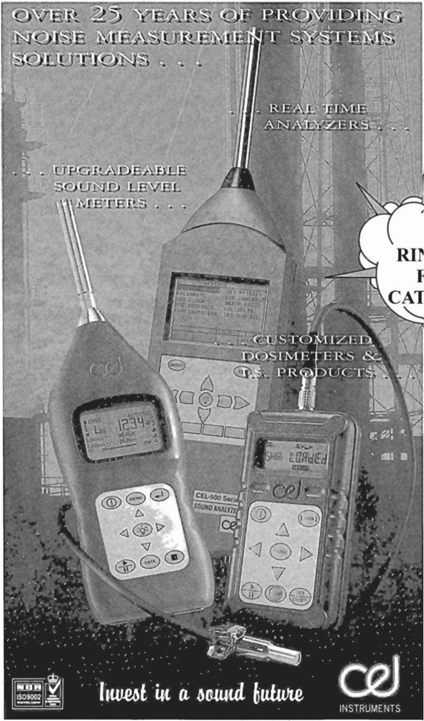
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INSTRUMENTS

From the President

Ethics

Perhaps it's a sign of the times, or perhaps it's just coincidence. Ethics is not a subject which occupies a lot of my thinking, but two cases involving members of the Australian Acoustical Society have been brought to my attention recently and the general issue of ethical behaviour has been raised by others. I had thought it was not a major concern for us, given our various backgrounds and areas of acoustical practice, but as I considered it more I became less certain. It's a clear enough conflict when the consultant is pressured by a commercial client to modify his report just a little, or to choose an atypical time to carry out long-term monitoring, but there are other, less obvious examples. The bottle of scotch as a Christmas present to the EPA officer is harmless enough, and an invitation to the developer's office party may be alright, but where is the line to be drawn? When does a gift become an inducement?

Other situations sprang to mind. The engineer who benefits directly from sales might find it easy to justify a more expensive option than is strictly necessary, or to overspecify a solution for a client. A council noise officer might be pressured by his council secretary to 'reconsider' noise measurements which affect a big commercial development in the area. Even in my own field there are ethical implications in academic research: I have a responsibility to see that public grant money is ethically spent on pertinent and efficiently undertaken research, and I have a responsibility to my students to see that they are not exploited as they learn and work in my laboratory. Of course, I'm not suggesting for an instant that we frequently give into such temptations, but we are all exposed to the pressures of time and money.

And how do we withstand these pressures? Our primary line of defence is our sense of integrity, our general idea of what is right and wrong. This can be relied upon in the most obvious cases of unethical pressures and should sustain us most of the time, but the only effective way of being certain of our ethical behaviour is to remain aware of the issues and to discuss them with our colleagues. Ethical behaviour is an instinct for professionals but, like all instincts, it can be subverted by dubious logical arguments when the proper course of action is not in our personal interests. So these arguments must be tested on our peers.

We have a Code of Ethics. Perhaps it is time to review it? Or perhaps to take even greater steps? The Code of Ethics is reproduced in this issue of the Journal so please take the time to read through it and forward any comments to Council.

Graeme Yates

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MATERIALS FOR MUSICAL INSTRUMENTS

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ABSTRACT: The relation between musical instruments and the materials from which they are made is discussed. In most cases the particular material used was originally dictated by availability or by technological necessity – only wood was suitable for the bodies of stringed instruments, only tin-lead alloys could be made into organ pipes, only bronze could be cast into bells – but this fact then determined the way in which these instruments evolved. Today the choice of materials is almost limitless, but often nothing better than the traditional materials has been found. The technological and, where appropriate, the acoustical basis for this situation is discussed.

1. INTRODUCTION

Those of you who play musical instruments will probably be convinced, if you have thought about it, that the materials from which they are made have an important effect upon their tone and general response. The top plates of violins and cellos, for example, are always made from sitka spruce and the backs from curly maple, and the special varnish used was one of the secrets of Stradivarius. Clarinets are made from African blackwood, recorders from apple or pear wood, and flutes from silver or, if you can afford it, gold. Trumpets and trombones are made from brass, plated with silver. Bells are made from bronze, and organ pipes from a tin-lead alloy.

In a spirit of inquiry, it makes sense to ask how well founded these traditions are. Why not a bassoon made from plastic, a flute of glass, or a violin of fibre-reinforced epoxy resin? Why not bells of aluminium and trumpets of stainless steel? Would it make any difference to the sound? In this short article I shall examine these questions in the light of both tradition and acoustics, and try to come to some appropriate conclusions.

2. STRINGED INSTRUMENTS

Vibrating strings are too thin to radiate any appreciable amount of acoustic energy, and it is therefore essential that they be coupled to some sort of radiating structure – a taut diaphragm in the case of a banjo, a flat soundboard in a harpsichord or piano, and a vented box in a violin or guitar. Since any structure like this will have its own mechanical resonances, and these depend both on shape and material, it is an inescapable conclusion that such details will affect the sound and response of the instrument. The important material parameters are the speed of vibrational waves, which is proportional to $(E/\rho)^{1/2}$ where E is the Young's modulus of elasticity of the material and r its density, the mechanical impedance which is proportional to $(E\rho)^{1/2}$, and the mechanical damping contributed by losses within the material itself. In wood, the Young's modulus is very different along the grain and across the grain, the ratio being as high as 20:1 for spruce and as low as 3:1 for some other woods, which means that, even if average properties are matched by some other material, the frequencies of the vibrational modes will be quite different. Because of this anisotropy, the wood in violin and guitar tops always has its grain running along the length of the instrument, and something similar is built into pianos and harpsichords.

The effect of these body modes is clearly heard in the sound of a violin or cello – they are what makes one instrument different from another and one note different from another – and they show up clearly in the spectrum, as can be seen if a cellist bows a steady low note and we examine the sound with a spectrum analyser. For a featureless resonator the bowed-string spectrum should decline at a steady 6dB/octave, but a real cello body will introduce peaks and valleys of as much as 20dB. The internal damping of the wood has a rather different effect, since it becomes most important at high frequencies, and again differs considerably from one timber to another, and even from one tree to another of the same timber. If the high-frequency damping losses are very low, then the sound will be bright and clear, while if they are larger the sound will be smooth and mellow.

Can these properties of wood be duplicated by any other material? The answer is that perhaps they can. The elastic anisotropy can be introduced by using fibre-reinforced material, which has, indeed, a structure quite like that of wood. The density can be matched fairly well, and adjustments made by small changes in the plate thickness. Internal damping can similarly be controlled by adjustments in composition. All these things have been done with moderate success as a sort of scientific tour de force, but while suitable timber can be procured it is difficult to match its suitability and appearance for making traditional stringed instruments.

Of course the strings of the instrument are important too, but we return to consider these later.

3. ORGAN PIPES

Pipe organs have a history going back 2000 years, and organ pipes have changed little for more than a millennium. Why is the traditional material a lead-tin alloy similar to pewter, and why is it still used? How does it effect the sound quality?

To answer these questions we need to examine how organ pipes are made, since this is still the same today as it was 1000 years ago. Pipes of many different lengths and diameters have to be made for each pipe rank, and the first step is to produce the metal sheet. This is done by melting suitable metal in a wooden box with an exit slit at the foot of one side. The box is then slid along a flat stone table covered with cloth and this casts a uniform metal sheet 1 to 2mm in thickness, perhaps 500mm wide, and 5 to 10 m long. This sheet is rolled up and used to make the pipes. We can see immediately that the choice of suitable metals is very limited. In the middle ages all that were available were lead, tin, copper, zinc, precious metals such as silver and gold, and a little iron. Copper-tin alloys produced hard bronze for armour, copper-zinc produced brass for ornaments, and tin-zinc or tin-lead produced low-melting pewter alloys. Silver and gold were too expensive to use commonly, and iron was too difficult to work. Of these, then, only the pewter alloys were suitable for low-temperature casting, and the lead-tin eutectic at about 62% tin with melting point 183°C was ideal. It was strong enough to form self-supporting pipes, provided they were not too large – impurities in the metals helped with this – and soft enough that the pipes could be easily fabricated and adjusted. The only option that was reasonably available to the organ builder was to vary the composition slightly.

So does the alloy composition – or even the choice of metal, since with modern techniques we can now use any metal we choose – affect the tone of the pipe? Most organ builders believe the answer to this question is "Yes", but most acousticians disagree. Certainly the walls of the pipe do vibrate a little, particularly during the onset transient of the sound, though they are so stiff relative to the air column that their vibration level is around 40dB below the air motion. They may therefore influence the relative levels of harmonics in the sound by 1dB or so, and may contribute inharmonic partials at a very low level during the onset transient. But is this influenced by the pipe material? The answer is certainly that the main variable that could influence these wall effects is not the pipe material but the wall thickness.

Most organs do, of course, also have wooden pipes, particularly for flute stops, and these do sound different from metal pipes. Is this the effect of wall material? Once again, the answer is "No". What is different about a wooden pipe, apart from scaling variables such as pipe diameter, is the geometry of the mouth – not particularly because the pipe is square in section, but rather because the wooden walls are typically about 20mm thick, compared with 1 to 2mm for metal pipes. If, however, large bass pipes were made from thin plywood, then we would indeed be able to hear the vibrations of the pipe walls, but no organ builder would contemplate this!

4. WOODWIND INSTRUMENTS

The conclusions reached above for organ pipes apply also to woodwind instruments, though their history is very different. Most woodwinds were initially made from hollow "found" objects with little modification. Examples are the panpipes made from lengths of bamboo with one end open and the other sealed by a septum in the plant stem, the gemshorn, made for a goat's horn, and then various flutes made from bamboo or cane with added finger holes, such as the Japanese shakuhachi and the flutes of South America.

As the instruments were refined, the obvious choice of material was wood, since it could be easily drilled and turned on a simple lathe. In this case, again, the initial requirement was for workability – a fine smooth grain that would take a polished finish and resist the damaging influence of condensation from the player's breath which was liable to cause cracking. Fruit woods such as apple and pear were good for this purpose, and later rainforest timbers such as ebony or blackwood from Africa. Appearance is also important, though many instruments are actually stained and oiled or varnished – bassoons made of white maple and stained red or brown are a typical example.

The only properties of the wood that are of acoustic significance in woodwinds are the smoothness and porosity of the bore and the sharpness with which the edges of the tone holes can be cut. The thickness of the walls is, of course, also important, but only from a geometrical viewpoint. The importance of surface finish arises from its relation to viscous losses from the vibrating air column and, since the viscous boundary layer is typically only about 0.1mm in thickness, structure down to this level is relevant. Thermal conductivity in the wall material is only of borderline significance, because almost any solid has a conductivity that is high compared with that of air, but if anything it argues for walls with low conductivity.

In all cases the bore of the instrument is rather small, rarely exceeding 20mm except in the case of bassoons, and the walls, if the instrument is made of wood, are at least 5mm thick so that the tube is quite rigid. Wall vibrations, even at the level encountered in organ pipes, scarcely come into consideration. Good quality plastic is clearly a possible substitute for wood in this case, and has the advantage of durability, though lacking the good appearance of wood. The often poor reputation of instruments made from plastic rather than wood arises from the fact that they are usually cheap student instruments from large makers, though some plastic-bodied clarinets of excellent quality are made. An exception occurs in the case of bassoons, which are never inexpensive. All top-quality bassoons have the upper half of their bore lined with plastic or with metal to overcome the ravages of breath condensation, and at least one top quality maker also produces expensive bassoons made entirely from plastic material.

When we come to flutes, the situation is different, perhaps because of their relationship to flue organ pipes. Until the middle nineteenth century, flutes were made of wood like other instruments, with a few exceptions made from ivory. About 150 years ago, however, the German silversmith and flute player Theobald Boehm completely redesigned the flute. His initial modification involved making the tone holes much larger and using a system of coupled padded keys to close them. This flute, like its predecessors, had a cylindrical head joint and tapering main bore. Boehm's second modification to the flute gave it a tapered head joint and a cylindrical body, with tone holes nearly as wide as the body diameter and closed by padded keys. Boehm's original flutes were still of wood, but he soon changed the material to thin-walled silver tubing, with the tone holes and embouchure hole built up to mimic the thickness of the original wood. This design is still used today with very little alteration.

If we ask whether a modern Boehm-pattern silver flute sounds different from an early eighteenth century wooden flute or from an Irish folk instrument, then the answer is certainly "Yes", but the reason does not lie with the change from wood to silver, but principally with the change from small finger holes to large tone holes closed by pads. This modification raises the efficiency in the upper part of the spectrum and gives the instruments a much brighter and more open sound. The change from a tapered to a cylindrical bore has a smaller effect, and indeed orchestral piccolo players generally prefer wooden instruments with the old tapered bore, while band players use cylindrical metal piccolos. Another minor effect of the change from wood to metal relates to the smoothness of the bore and the sharpness of the edges of the tone holes, both of which have a small but strictly geometrical effect on the sound.

Silver (actually sterling silver, which contains about 7.5% of copper and is much harder than the pure metal) was Boehm's material of choice for the flute, again by reason of the ease with which it can be worked and also its fine appearance. From there it is possible to go in one of two directions: either to the use of gold (usually a 12 to 18 carat alloy with 30 to 50% of added copper, silver or nickel) or even platinum, or to the use of cheap metals that are later plated. Both courses have been followed, but at opposite ends of the price spectrum. Gold flutes are superior to flutes made of silver in two ways: firstly the gold is nearly free from tarnish, which gives the flute a better appearance, and secondly a gold flute is always made by a top craftsman in a flute company and is therefore an example of its best instruments. "If gold is good, then platinum should be better," and some fine flutes now have the tubing made from this metal, though the keys are usually of white gold. There is even a well-known solo flute piece called Density 21.5 written by Edgar Varese for the platinum flute! Most of the superiority is, however, illusory, and there is more difference between silver flutes by different makers than between a gold and a silver flute by the same craftsman. There is no way in which the properties of the metal itself can influence the sound, except indirectly through the psychology of the player!

Flutes made of cheap alloys, generally cupro-nickel, and then plated with silver, on the other hand, are generally mass-produced for student use. Their tone again can be excellent and their mechanism reliable, but they lack the refinement that comes from hand-work on the delicate edges of the embouchure hole, and the silver plating is sometimes not very durable.

The family of saxophones, developed by Adolphe Sax in Brussels in the middle nineteenth century, also belongs to the woodwind family, though they are always made from metal, usually brass. Again the choice of material was dictated by manufacturing requirements because of the large flaring bore, but the typical sound of a saxophone can also be heard in the Hungarian tarogato, which has a similar bore shape but is straight and made from wood. It is this wide conical bore and the geometry of the mouthpiece and reed that are responsible for the tone quality.

5. BRASS INSTRUMENTS

In this category we include all forms of lip-blown instruments, from the didjeridu of the Australian aboriginal people and the conch shell of Egypt, through the trumpets of the Roman legions to the refined trumpets and trombones of today. Setting aside the didjeridu and the conch shell, which are essentially "found" instruments, the choice of construction materials was limited by the nature of the instruments themselves. Wood was generally out of the question because of the complicated geometry of the instruments, but there were a few exceptions among the conical lip-blown instruments with finger holes, such as the cornett and the serpent. Cornetts were generally made of wood, and serpents either of wood or of varnished papier-maché covered with leather. Trumpets and trombones (originally sackbuts), however, were always made of metal. The tin-lead alloys were too soft for this purpose, and bronze too hard, so the copper-zinc alloy brass was the material of choice, and remains so. Brass can be easily formed into tubes and these, even now, are bent to final shape by filling them with water and freezing it to ice, to prevent tube collapse during the forming operation. Brass sheet or wider tube can also be formed into sections for the flaring horn by spinning it against a former in a lathe. In all cases the sound of the instrument is determined by the detailed profile of the bore and the exact proportions of the mouthpiece cup.

Once again, the stiffness of the walls of the instrument is so great that they can contribute little or nothing to the sound production. The exception is perhaps the flaring bell of instruments such as French horns but, once again, the effect is controlled not by material but by wall thickness. Only if one goes so far as to make the flaring horn of the instrument from some sort of rubber-like material can one measure any significant acoustic effects.

6. BELLS, GONGS AND CYMBALS

When we come to discuss instruments that are impulsively excited and act to radiate their own sound – idiophones in the terminology of musicologists – we find a situation in which construction materials can have a significant influence on sound quality. In Western cultures, the most notable of such instruments is the bell, as found in churches and in carillons and, in some countries such as the United States, in handbell choirs.

Western church bells and their relatives are all tuned to nearly a common pattern that is dictated by their general shape. As many as six of the lowest vibrational modes of the bell are tuned, initially in the design and finally by turning material off the inside of the bell on a vertical lathe, so that their frequencies are in harmonic relationship – that is, they are integer multiples of a common fundamental. The one exception to this simple rule is the third mode or tierce, which is tuned to a minor third (6:5) in this progression. It is this mode that gives western church bells their characteristic sound, and a bell designed to have a major third for this mode (which requires a peculiar bulgy shape) sounds entirely different. Eastern European and Asian bells, which all have shapes quite different from those of Western bells, have very different sounds.

Bells have always been made by casting metal, and again this limited the options available to medieval bell-founders. Since bells have metal clappers, the tin-lead alloys were too soft, and the options were essentially brass (copper-zinc) or bronze (copper-tin). Bronze was found to be harder and to give better sound and has been used nearly universally. The casting technology was also well advanced, since it was essentially the same as used for casting cannon!

Since the shape of the bell is fixed by the tuning requirements, its size for a given frequency is determined by the velocity of sound, which is proportional to $(E/\rho)^{1/2}$ as discussed before. If the sound velocity is low, then the bell will be relatively small, which means that it will not be as loud but will sustain its tone longer, although this latter statement depends upon the balance between internal losses in the material and radiation losses. Both are actually of comparable importance in bronze.

If bells are made from cast iron, which has the benefit of being a good deal cheaper than bronze, then, because the sound velocity in cast iron is about 30% greater than in bronze, the bell must be made larger by the same amount for a given pitch. The situation is even more extreme in aluminium, where the sound velocity is 50% greater than in bronze. These larger bells can produce a louder sound, if appropriately struck, but radiate their sound away more rapidly. Aluminium is favoured, however, for large handbells.

Gongs and cymbals differ from bells in that their walls are thinner, so that their sound often exhibits nonlinear effects. Some of them are cast and some either spun or beaten from an initial flat plate. Bronze and brass are both suitable for this purpose, and work harden to give strong structures that will resist the impact of the hammer or stick used to excite the instrument. Hardness, workability and low internal losses are the main requirements for such gong and cymbal materials, though internal losses are generally less important since losses to the air tend to dominate.

7. OTHER PERCUSSION INSTRUMENTS

The variety of percussion instruments used in various parts of the world is very large. Apart from the bells, gongs and cymbals discussed above, we can recognise other "tuned idiophones" such as marimbas and xylophones, untuned idiophones such as Aboriginal music sticks and log drums, and then the whole family of "membranophones" which we ordinarily call drums.

In the tuned instruments the vibrating element is usually a wooden or metal bar, sometimes shaped in thickness to tune its second mode to a harmonic of the fundamental. Apart from necessary mechanical hardness and durability, the main acoustic features desired are high density, so that considerably vibrational energy can be stored, and low internal losses, so that the sound rings for a relatively long time. Many metals are suitable for the metal instruments, and the low damping of metals at high frequencies gives a bright tone. Instruments with wooden bars, on the other hand, have a mellow tone and shorter ring time because of the greater internal losses of wood, particularly at high frequencies. Fine-grained rainforest hardwoods are ideal for such instruments, and are actually nearly the same woods sought for woodwinds. Wood anisotropy is not important in these instruments, for the bars bend only across their narrow dimension, so that synthetic materials could be used, provided they have adequate hardness and density and that their internal damping has a frequency dependence similar to that of wood.

The membranes of drums were traditionally made from animal skins, for want of any alternative, and these suffered from uneven thickness, only modest strength, and sensitivity to both temperature and humidity. Synthetic polymers overcome these problems and are used nearly universally in modern instruments. The damping of a drumhead is almost entirely caused by viscous losses to the air and by sound radiation, so that the requirements on the membrane are almost purely mechanical.

8. ACOUSTIC LOSSES IN MATERIALS

Since minimising internal losses is important in all idiophones, and the frequency dependence of internal losses influences the response of the bodies of stringed instruments, it is interesting to see how these losses arise. There are essentially just two processes involved – atomic or molecular rearrangement, and thermal conductivity – and their relative importance varies from material to material.

In natural materials such as wood, and also in plastics, the thermal conductivity is low and the material is rather soft. Thermal conductivity losses can therefore be ignored compared with losses from molecular rearrangement. In wood, some of this rearrangement may be associated with water absorbed within the structure, but the dominant mechanism is the rearrangement of weak inter-molecular bonds. Some of these rearrangements are slow, leading to gradual distortion of the material, but those that vary over only intermolecular distances may have relaxation times of the order of a millisecond, leading to loss peaks within the high audio range. It is these losses, generally characteristic of the material but perhaps even varying from specimen to specimen, that are important in choosing materials for stringed instruments and percussion idiophones. The instruments tend to be a little "temperamental" because the magnitude and frequency of the internal loss peaks depend upon both temperature and absorbed atmospheric moisture.

Metals can also suffer slow creep and atomic rearrangement, generally described in terms of the movement of dislocations, particularly if they have low melting point, as in the case of tin and lead. Quite small quantities of other metals added to form an alloy can, however, pin these dislocations and harden the metal. Pure metals are therefore very little used in any application requiring mechanical strength and stability. Among the harder alloys used for musical instruments, the main cause of internal loss is by thermal conductivity, the heat flowing between parts of the metal that are compressed and those that are stretched during a cycle of the vibration. The frequency at which these losses are large generally depends upon the dimensions of the vibrating element. This frequency is low for large metal objects such as bells, but may range up to several kilohertz in the case of thin metal wires.

9. STRINGS AND WIRES

We return now to consider the other essential component of a stringed instrument – the strings. In early times these were made from biological sources such as the tendons or twisted gut of animals, but now these materials have been largely superseded by the use of synthetic plastics, such as nylon, or by metals.

In a bowed-string instrument there is a steady source of energy in the moving bow, and the main requirement placed upon the strings are that they support adequate tension stress σ to give an appropriate vibrational frequency $(\sigma/\rho)^{1/2}/2L$, where ρ is the density of the string material and L the string length. Strings of gut, or later of twisted nylon, were generally adequate for this purpose, though over the past century or so the lower-pitched strings have been overwound with metal to give extra mass, and the highest pitched strings replaced with metal to give added brilliance. Indeed, twisted strings, whether of gut or of nylon, tend to have large internal losses at high frequencies because of dry friction between the separate strands.

In plucked or hammered string instruments, internal losses in the strings are of great importance, because the string must store all the mechanical energy from the exciting impulse. This argues for the use of monofilament nylon strings or of solid metal strings to reduce internal frictional losses. The metal gives lower damping at high frequencies, and higher initial energy storage because of its greater material density. A change in string material from gut or nylon to metal, as happens in the transition from a classical to a popular guitar, changes the character of the instrument by increasing the energy content at high frequencies, and may be resisted for aesthetic reasons because the sound becomes too bright or even "hard" in addition to being louder.

The harpsichord and the piano, however, were both developed after metal wires became available, so that their natural sound is based upon metal, although the plucking and hammering mechanism is non-metallic. Only in the clavichord is the exciting tangent of metal, but the sound is in any case very gentle. While piano stringing is universally of steel, though the lower strings are overwrapped with copper or brass for added mass without excessive stiffness, harpsichord stringing is traditionally with iron or steel in the treble and solid brass in the bass. This is in part because the shorter-than-proportional length of these strings requires reduced tension, and the added density of brass counteracts this to some extent, thereby reducing inharmonicity due to string stiffness. There are also more subtle effects because of the different thermal loss frequency of the brass strings. The piano avoids excessive brightness, while introducing a change in sound quality from mellow to bright with increasingly vigorous playing, through the use of graded felt in its hammers

10. CONCLUSION

Throughout history there has been a close connection between musical instruments and the materials from which they are made. Some of this connection is aesthetic – what could be more repulsive than a harpsichord covered in Laminex or a violin made from painted tin-plate? – but much of it has shaped the whole evolution of the instrument concerned. Bells are a prime example, since they could hardly have been developed without knowledge of the casting of bronze, a craft also of importance for the making of cannon. Woodwind instruments required initially the existence of natural hollow plant stems, and then the availability of dimensionally stable but easily worked wood. Pipe organs depended upon the discovery and ready availability of the stable, soft and low-melting alloys of tin and lead, hardened with a little antimony. Brass instrument development relied upon readily rolled and bent brass and upon the techniques of soldering tube and spinning horns.

Over the years a great mystique has grown up around the use of some of these materials. Some of the mystique is supported by modern acoustics – there are indeed good and poor timbers for stringed instruments, and even good and poor trees; there are appropriate and inappropriate metals for casting bells and gongs, and no superior modern substitutes have been found for many traditional materials such as tin-lead alloys for organ pipes and brass tubing for trumpets. But some of the mystique is unfounded, or at least wrongly founded – gold is excellent for making flutes, but not because it produces a superior sound; cocus wood is excellent for oboes and maple for bassoons, but the reasons are mechanical rather than acoustic.

But progress in understanding thrives on controversy, and our knowledge of what is important and what is possible continues to expand.

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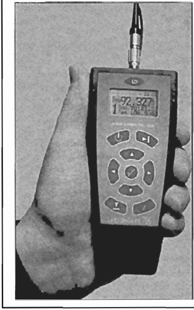

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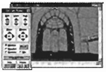

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DESIGN OF CHIMES TO PRODUCE CONSONANT, NON-HARMONIC SCALES

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ABSTRACT : Thin, cylindrical metal chimes can be used to play in a variety of scales requiring non-harmonic spectra. The spectrum required for the chimes to have consonant intervals in a given non-harmonic scale can be determined according to a method developed by Sethares, based on the theory of dissonance proposed by Plomp and Levelt. First order perturbation theory was applied to control the frequencies of the first six modes of a thin, cylindrical metal chime by perturbations to the chime radius. The resultant chime profile was then refined using finite element methods. Two aluminium chimes manufactured with this optimised profile demonstrated superior musical performance compared with unperturbed thin cylinders.

1. INTRODUCTION

The majority of non-percussive musical instruments currently used in the West produce spectra consisting of harmonically related frequencies. That is to say, notes played using these instruments have partials that are nearly integer multiples of some fundamental frequency f_0. Such harmonic spectra are caused by a control oscillator (such as a reed, lip reed or air jet in wind instruments, or a bow in string instruments), or by the intrinsic properties of the vibrating elements used in these musical instruments, whose natural frequencies are almost exactly harmonic. Examples of the latter are long, thin, uniform, flexible strings.

When two notes produced by a harmonic musical instrument are played together, the sound produced can be either consonant, meaning pleasant and relaxed, or dissonant, meaning discordant and tense. Although there is still speculation regarding the quantitative measurement of dissonance, Plomp and Levelt [1] have proposed that the perceived dissonance between two notes is exclusively a function of the location and amplitude of the partials making up these notes. This theory of dissonance is widely accepted.

Various scales have been developed that make use of the dissonance properties of the harmonic spectrum to ensure that a fairly large range of intervals sound reasonably consonant. The 12 tone equal temperament (12-tet) scale has been widely adopted so that free modulation from one key to another is possible.

Many objects that are used, or could potentially be used to produce music, however, do not have harmonic spectra. Thus they sound discordant when played in chords using notes in a scale designed for harmonic instruments, such as the 12-tet scale. In addition, many modern composers are interested in writing music for scales other than 12-tet, which require spectra that no readily available, non-electronic musical instrument is able to produce. An approach to designing spectra for non-harmonic scales was formulated by Sethares in [2,3].

One class of non-harmonic objects with potential for wider musical applications are thin cylindrical metal chimes. In this project, a design process was developed that can be used to create a set of such chimes that have a range of consonant intervals for a given non-harmonic scale. Sethares' approach was used to determine the chime spectrum for the non-harmonic scale under consideration.

Previous work in the design of musical instruments with non-harmonic spectra includes the Pentangle by Fletcher [4]. The Pentangle consists of a pentagonal gong tuned to produce a bell-like spectrum, using a combination of analytic and finite element methods. A similar approach was followed in this study, in that analytic methods were used for basic chime design, and the chime profile was then refined using the finite element analysis package STRAND 6. Such an approach differs from the method used by Petrolito and Legge [5], who applied finite element methods alone to tune the first three modes of xylophone bars with rectangular cross sections. Thus while the approach adopted by Petrolito and Legge was to constrain the finite element optimisation process using criteria such as the minimisation of material to be removed, the approach of this work and of Fletcher was to limit the finite element based optimisation to solutions close to results obtained using simplified theoretical models of the system. As far as we are aware, however, this study is the first attempt to produce a non-electronic musical instrument that implements Sethares' method of selecting a spectrum for a scale.

2. CHIME FREQUENCY SHIFT CALCULATION USING PERTURBATION THEORY

The theoretical model that was used to obtain a chime profile that produces a close approximation to the desired spectrum is described. Equations are given for the bending modes of a thin, cylindrical rod, and then a general theory is introduced to describe the frequency shifts caused by perturbations to a vibrating object. Next, this theory is used to predict the shifts to rod frequencies when small changes are made to the radius of a rod.

Finally, this theory is applied to the specific problem of controlling the frequencies of a cylindrical metal chime. The problem of achieving the chime goal frequencies while minimising the changes to chime radius is also addressed, since the perturbation theory predictions will only be accurate for small changes to the rod profile.

2.1 Bending wave equation for a rod

The general wave equation for bending waves in a uniform rod is [6]

$$\frac{\partial^2}{\partial x^2}\left(-ES\kappa^2\frac{\partial^2\Psi}{\partial x^2}\right)=\rho S\frac{\partial^2\Psi}{\partial t^2}\,, \tag{1}$$

where E is the Young's modulus, S is the cross sectional area ($S=\pi r^2$ for a cylindrical rod), κ is the radius of gyration about the neutral axis ($\kappa = r/2$ for a cylindrical rod), ρ is the density, x is the position along the rod as measured from the middle, t is time, and $\Psi(x,t)$ is the displacement of the rod from equilibrium.

Equation (1) is a "thin beam" approximation that neglects such effects as shear and rotary inertia, and only models bending modes. For this approximation to be true, the wavelength of the modes must be large compared with the rod diameter, since otherwise shear distortion is non-negligible in comparison with bending. Since we only consider the first six modes of the rod (the most audible modes), this translates as a requirement that the length to dimeter ratio for the rod should be around 60:1 or greater. In practice, this requirement may be relaxed a little.

The solutions to (1) take the form of sums of members of the series

$$\Psi_n=\psi_n(x)\cos(\omega_n t), \tag{2}$$

where

$$\psi_n = A_n\cosh\frac{\omega_n x}{v_n}+C_n\cos\frac{\omega_n x}{v_n}+B_n\sinh\frac{\omega_n x}{v_n}+D_n\sin\frac{\omega_n x}{v_n} \tag{3}$$

Here $v_n=\left(\omega_n^2\kappa_n^2 e/\rho\right)^{1/4}$ is the wave velocity of mode n with angular frequency ω_n, and A_n, B_n, C_n and D_n are constants.

For a rod with both ends free, the solutions to equation (1) have $A_n=C_n=0$ for even n and $B_n=D_n=0$ for odd n, since ψ_n is even for odd n and odd for even n. Bending oscillations in a rod of constant radius with both ends free occur at frequencies f_n, given by

$$f_n\approx\frac{\pi\kappa}{8L^2}\sqrt{\frac{E}{\rho}}(2n+1)^2 \tag{4}$$

2.2 Frequency shifts to a cylindrical rod due to changes in rod radius

A general perturbation theory that can be used to determine the effect on rod frequencies of perturbations to the rod radius is now described. This theory takes a form similar to that proposed by Tse, Morse and Hinkle [7]. Only first order perturbations will be taken into account, which means that the frequency shifts predicted are approximate. As a starting point, it is possible to write (1) in the form

$$-\omega_n^2\psi_n=\Im\psi_n\,, \tag{5}$$

where $\Im$ is a linear differential operator, given by

$$\Im=-\frac{E}{\rho}\cdot\frac{1}{S}\cdot\frac{\partial^2}{\partial x^2}\left(S\kappa^2\frac{\partial^2}{\partial x^2}\right) \tag{6}$$

for the rod, and we take the functions ψ_n to be normalised so that $\int_{-L/2}^{L/2}\psi_n^2 dx=1$. We now consider the effect of making the perturbations

$$\omega_n^2\to\omega_n^2+\delta\left(\omega_n^2\right),\quad \Im\to\Im+\delta\Im,\quad \psi_n\to\psi_n+\delta\psi_n \tag{7}$$

in (5). Expanding (5), and retaining only first order or lower terms, gives

$$\frac{\delta\omega_n}{\omega_n}=-1+\sqrt{1-\omega_n^{-2}\int_{-L/2}^{L/2}\psi_n\delta\Im\psi_n\,dx}=-1+\sqrt{1-\zeta_n} \tag{8}$$

where we have written $\zeta_n=\omega_n^{-2}\int_{-L/2}^{L/2}\psi_n\delta\Im\psi_n dx$ for ease of reference.

We now derive a formula for the ζ_n due to perturbations in the rod radius. The expression for $\Im$ in the case of the rod is given by (6). Making the changes $r\to r+\delta r(x)$ and $\Im\to\Im+\delta\Im$ in (6), retaining only first order and lower terms in the resulting expansion, and then substituting this expression for $\delta\Im$ into (8), gives

$$\zeta_n=\int_{-L/2}^{L/2}\left(\frac{\delta r(x)}{r}\psi_n^2\right)dx-\frac{32L^4}{\pi^4 Q_n}\int_{-L/2}^{L/2}\left[\frac{\partial^2}{\partial x^2}\left(\frac{\delta r(x)}{r}\frac{\partial^2(\psi_n)}{\partial x^2}\right)\right]\psi_n dx, \tag{9}$$

where

$$Q_n\approx(2n+1)^4 \tag{10}$$

2.3 Design of a chime with a specified set of frequencies

Equations (9) and (8) may now be used to obtain a cylindrical metal chime whose frequencies of bending oscillation can be assigned specified values. Given that N mode frequencies are to be controlled, the perturbation to the chime radius will take the form of a sum of N terms,

$$\delta r(x)=\sum_{m=1}^{N}b_m\delta r_m(x) \tag{11}$$

where the $\delta r_m(x)$ represent perturbations to the chime radius as functions of longitudinal coordinate x, and each constant b_m scales the perturbation m. A set of functions for the $\delta r_m(x)$ is now chosen, with the intention that each perturbing function should have as large an effect as possible on only one modal frequency, and a minimum effect on all other frequencies.

For a given increase in chime radius δr, the stiffness will increase by a factor $1+4\delta r$ while the mass will increase by $1+2\delta r$. In addition, for all modes, regions of high lateral displacement from equilibrium correspond to regions of large curvature over most of the chime (the exception being near the ends, where the displacement is significant but the curvature approaches zero). Therefore if the chime radius is increased in regions where a given mode has a large curvature, then the frequency increase for this mode due to the higher stiffness will be greater than the drop in frequency due to the increased mass, and the net effect will be an increase in mode frequency.

From this property, it seems likely that the perturbing functions $\delta r_m(x)$ will have larger effects on unique mode frequencies if each perturbing function only has a large amplitude where the mode that it targets has large curvature. Thus the set of perturbing functions adopted is

$$\delta r_m(x) = \left(\frac{\partial^2\psi_m}{\partial x^2}\right)^2 - \frac{1}{L}\int_{-L/2}^{L/2}\left(\frac{\partial^2\psi_m}{\partial x^2}\right)^2 dx \qquad (12)$$

The purpose of the integral is to avoid applying an upwards shift on all modes when the radius is perturbed. Substituting (11) into (9) allows (9) to be rewritten as

$$\zeta_n = \sum_{m=1}^{N} b_m U_{n,m}, \qquad (13)$$

where

$$U_{n,m} = \int_{-L/2}^{L/2}\left(\frac{\delta r_m(x)}{r}\psi_n^2\right)dx - \frac{32L^4}{\pi^4 Q_n}\int_{-L/2}^{L/2}\left[\frac{\partial^2}{\partial x^2}\left(\frac{\delta r_m(x)}{r}\frac{\partial^2\psi_n}{\partial x^2}\right)\right]\psi_n dx \qquad (14)$$

Once the N desired frequency shifts $\delta\omega_n$ have been specified, (8) may be solved to obtain the N quantities ζ_n. The set of linear equations (13) can then be solved to give the amplitudes of the perturbing functions in (11).

3. CHOOSING A TARGET SPECTRUM

Now that an approximate process for controlling the frequencies of a cylindrical chime has been illustrated, the chime goal spectrum that was used to test this procedure is described. Given that the object of this project was to find a design process that can be used to create chimes for a given scale, we decided to test this process by selecting a genuinely arbitrary scale and working towards a set of chimes with appropriate spectra.

The scale that was chosen for the chimes is an unequally stretched, Pythagorean major scale. The unstretched Pythagorean major scale sounds quite similar to the 12-tet major scale, but with slightly sharper major thirds and slightly flatter minor thirds [3]. The steps of the Pythagorean scale, whether stretched or unstretched, can be written

$$\left(1,\ a,\ a^2,\ a^2b,\ a^3b,\ a^4b,\ a^5b,\ a^5b^2\right)\times f_0\ , \qquad (15)$$

where f_0 represents the frequency of the first note in the scale and a and b are the two basic frequency step ratios. The notation in (15) means that the first note in the scale has frequency $1\times f_0$, the second note has frequency $a\times f_0$, and so on. The unstretched Pythagorean scale has a=9/8 and b=256/243. Our stretched scale had a=6/5 and b=16/15. This means that the "octave" (literally the eighth note) occurs at 1,990,656 / 703,125 ≈ 2.83 times the frequency of the lowest note in this scale, rather than the usual factor of 2 for unstretched scales. For this reason, the term *pseudo-octave* will be used to designate the stretched "octave" interval.

One possible chime spectrum for the scale described in (15), as determined using the procedure outlined by Sethares [2,3], is

$$T = \left(1,\ a^5b^2,\ a^8b^3,\ a^{11}b^4,\ a^{13}b^5,\ a^{15}b^5\right)\times f_0\ , \qquad (16)$$

where the notation of equation (15) has been used, and the number of partials is N = 6. The required frequency shifts to the modes of the unperturbed chime, as fractions of the unperturbed mode frequencies, vary from -8% to 9%.

To see why the target spectrum in equation (16) represents a good spectrum for the scale in (15), it is necessary to introduce the concept of the *dissonance curve* for a spectrum. This is a plot of the dissonance (as defined by Plomp and Levelt [1]) perceived when two notes are played simultaneously, where the frequencies of the partials of the higher note are increased by a factor R with respect to the partials of the lower note. Plomp and Levelt found that when these two notes are pure sinusoids, the dissonance $d(a_1, a_2, f_1, f_2)$ between them is a function of the amplitudes a_1 and a_2 of the sinusoids, and their frequencies f_1 and f_2. The dissonance between the sinusoids is zero when their frequencies are equal, rises rapidly as the frequency difference increases, and then drops slowly upon further increase in the frequency difference. A plot of the dissonance $d(a_1, a_2, f_1, f_2)$ between two sinusoids is given in Figure 1, where $a_1 = a_2 = 1$ and $f_2 = R \times f_1$. Plomp and Levelt found that this function $d(a_1, a_2, f_1, f_2)$ closely approximated the average dissonance measured in a series of tests involving 90 musically untrained volunteers.

The dissonance $g(R)$ of a spectrum containing partials at several frequencies is obtained by adding the dissonance of every pair of partials, so that

$$g(R) = \sum_{i=1}^{N}\sum_{j=1}^{N} d(f_i, Rf_j, a_i, a_j)\ , \qquad (17)$$

where a_i and a_j are the amplitudes of the partials with frequencies f_i and f_j respectively. The dissonance curve for a given spectrum is a plot of $g(R)$ for that spectrum.

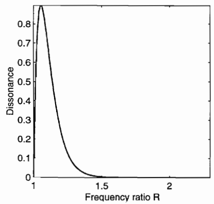

Figure 1 : dissonance between two sinusoids with frequencies f_1 and f_2, where f_2 = R × f_1. The sinusoids have equal amplitude.

The dissonance curve for the spectrum in (16) is illustrated in Figure 2, where stems are used to show the location of the steps of the scale described in (15). We see from this plot that dissonance is low at most of the scale steps, indicating that chords played using these intervals will sound pleasant.

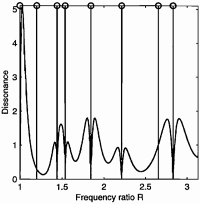

Figure 2 : Dissonance curve of a the stretched Pythagorean scale, a=6/5, b=16/15, for the spectrum defined in (16). The stems represent the intervals defined in (15). Amplitudes of all partials are assumed equal to one.

4. DESIGN OF THE CHIME

The approximate chime design procedure described in section 2 was applied to design a chime to play in the goal spectrum. A finite element model of the chime was used as a fast and inexpensive means of testing and refining the results obtained using perturbation theory. The finite element model was formulated using the STRAND 6 finite element analysis package.

4.1 Chime profile obtained using perturbation theory

The profile for a chime that produces the spectrum given by (16) was generated in accordance with section 2.3. The unperturbed cylinder on which the chime was based has length L=0.5215m and diameter 6.02mm. These dimensions satisfy the thin rod approximation for the first six modes as described in section 2.1. The six perturbing functions for the chime, determined in accordance with equation (12) of section 2.3, are illustrated in Figure 3.

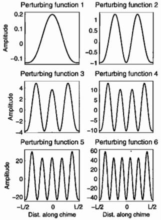

Figure 3 : The six perturbing functions for the chime.

The solid profile in Figure 4 illustrates the chime obtained by summing the scaled perturbing functions and adding the result to the unperturbed cylindrical chime. It was not possible to manufacture the smooth profile illustrated in Figure 4, since the chimes were too long and thin to be machinable using a computer controlled lathe, and the sinusoidal shape was too difficult to reproduce by hand. For this reason, a step approximation to the profile, as illustrated by the dashed curve in Figure 4, was designed. Although this step approximation caused slight shifts to the goal frequencies, these remained small (0.7% of the original goal frequencies at most, when calculated using perturbation theory), and were in any case reduced by the refinement process to be described in the following section.

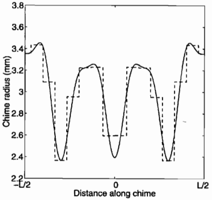

Figure 4 : Profile obtained using first order perturbation theory, and manufacturable step approximation to this profile. ——— : ideal profile. .... : step profile.

4.2 Refinement of chime profile using finite element methods

The finite element analysis package STRAND 6 was used to model the chime shown in the step approximation from Figure 4. The natural frequencies calculated by the finite element model for this chime profile differed from the goal frequencies by amounts ranging from 2.0% to -2.4%. of the goal frequencies. An improvement in the musical performance of the chimes, however, is deemed to occur when the differences between the goal frequencies and the STRAND 6 simulation frequencies drop below 1%, since our experience (based on a computer simulation of "chime-like" chords) was that perceptible improvements in consonance occur once the error in the partial frequencies falls below 1%.

For this reason, an optimisation process was undertaken using STRAND 6. Small changes to the profile of the finite element model were made, and the changes to the natural frequencies calculated by the model were observed. This data was used to make small changes to the chime profile that improved the agreement of the calculated chime frequencies with the goal frequencies. Simulation of the optimised profile in STRAND 6 resulted in frequency differences between the simulation and goal frequencies of 0.89% of the goal frequencies or less, which is below the level of 1% mentioned above. The optimised profile is illustrated in Figure 5.

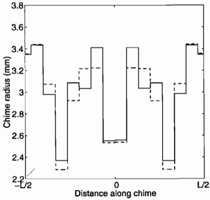

Figure 5 : Chime profile obtained using STRAND 6 based optimisation vs profile obtained using perturbation theory. ——: STRAND 6 optimised. ......: perturbation theory only.

5. MANUFACTURING AND TESTING THE CHIMES

The chime design arrived at using STRAND 6 optimisation was tested experimentally by manufacturing two chimes, and measuring their frequencies of oscillation. The results of these measurements are summarised, and explanations are proposed for the differences between the measured results and the STRAND 6 frequencies.

5.1 Chime dimension selection

Since funds were only available to make two chimes, these chimes were designed so that one plays a "pseudo-octave" above the other. The reason for this choice is that this interval represents the limits of the scale in which the chimes are to be played. Thus the interval gives a good indication of whether these limits are attainable using the chimes. Another advantage of using this interval is that unperturbed chimes sound dissonant when played in the same interval. Finally, the octave is usually judged the most consonant interval in the commonly used temperaments, and so it is especially interesting to improve its consonance in new timbre/tuning combinations.

A fundamental of around 170Hz was chosen for the chime that plays the tonic in the interval. This ensures that the first six partials of both chimes are audible. When scaling the chimes to produce these two notes, a constant average radius was maintained and only the chime lengths were varied. This causes the radiated sound volume from both chimes to be fairly similar.

A disadvantage of this scaling method is that the length to diameter ratio for the octave chime is at most 35:1, which is below the ratio required for the thin rod approximation to hold for the fourth to sixth modes. The frequencies predicted by STRAND 6 for these modes, especially for the fifth and sixth modes, may therefore be inaccurate. This effect could be countered using thinner chimes, however such chimes would become too difficult to machine. The dimensions of the two chimes manufactured are given in Table 1. Both chimes were turned from an aluminium rod using a manually controlled lathe.

Table 1 : Dimensions of the tonic and pseudo-octave chimes

Dimension	Tonic chime	Octave chime
Length L (mm)	372.8	221.7
Mean diameter (mm)	5.83	5.83

5.2 Measurement of manufactured chime frequencies, comparison with STRAND 6 model.

The chime frequencies were measured using a microphone attached to a computer. Sound from the microphone output was sampled for 2 seconds at 44.1kHz, and the frequency spectrum was obtained by taking the FFT of this signal. Chimes were suspended using cotton to simulate the boundary conditions (the chime must be free at both ends).

Table 2 contains a comparison between the spectra of the manufactured chimes and the goal spectrum in equation (16). The partials of the goal spectrum are expressed as ratios with respect to the goal fundamental. The measured partial frequencies are expressed as ratios of the scaled fundamental f_s, which is equal to

$$f_s = Nf\left(\sum_{n=1}^{N} r_{G,n}/r_{M,n}\right)^{-1}, \tag{18}$$

where f is the measured fundamental frequency, $r_{G,n}$ is the ratio of the nth goal frequency to the goal fundamental, and $r_{M,n}$ is the ratio of the nth measured frequency to the measured fundamental. This scaled fundamental is used so that the measured frequencies are compared with the pitch centroid of the goal frequencies.

Table 2 : Results of the measurement of tonic and pseudo-octave chime frequencies

Mode	Goalfrequency ratio with respect to fundamental frequency	Measured frequency ratio with respect to scaled fundamental frequency	
		Tonic	Pseudo-octave
1	1.00	1.01	1.02
2	2.83	2.82	2.85
3	5.22	5.26	5.29
4	9.62	9.58	9.58
5	14.77	14.84	14.73
6	21.27	20.91	20.63

As was noted previously, a significant reduction in dissonance occurs once the errors in the partial frequencies drop below 1% (approximately 1/6th of a semitone in the 12-tet scale). In the right hand column of Table 2, we note that the errors in the ratios of four of the partials for the chime at the tonic, and three of the partials for the chime at the pseudo-octave, are less than 1%. Thus consonance will be improved for at least some of the chords playable in the scale proposed in (15), when comparing chimes manufactured with the STRAND 6 optimised profile to unperturbed chimes.

There are a number of factors contributing to the errors in the STRAND 6 predictions of the perturbed chime frequencies. These include differences in segment length and chime radius when comparing the manufactured chimes to the finite element model, and the uncertainty in the location of the measured partials due to the resolution of the recording equipment. These effects, however, are less important than the consequences of inaccuracies in our finite element model. The STRAND 6 simulation used to predict the chime frequencies made use of a thin rod approximation that neglects shear effects, as well as being slightly inaccurate in its treatment of the forces between adjacent cylindrical segments. These effects cause our simulation to yield higher frequencies than expected for higher modes, hence the downward trend in the measured frequency ratios when comparing to the goal frequency ratios.

6. CONCLUSION

The results obtained in this study are encouraging, since they indicate that the musical performance of chimes designed using the method proposed is perceptibly superior to the performance of unperturbed cylindrical rods, for the stretched Pythagorean scale. Error with respect to the goal spectrum in the partials of the manufactured chimes was mainly due to shear effects not modelled by our finite element simulation, and/or the incorrect assumptions made in this simulation when joining thin beam elements end to end.

There are a number of ways to further improve the performance of these chimes. The chimes could be tuned by hand, or by changing the goal frequencies used in the finite element optimisation of the profile derived using perturbation theory. Another approach would be to use a more sophisticated finite element model of the chimes. Alternatively, the chime profile could be designed by perturbing the Timoshenko beam equations [7], which take shear effects into account and do not require a thin beam approximation to hold. This would allow the diameter of the chimes to be greatly increased, thus increasing both manufacturability and acoustic radiation efficiency. Once a single such chime has been produced with a satisfactory spectrum, a set of chimes could easily be manufactured by linearly scaling the length and diameter of the successful design.

Perhaps the most exciting outcome of this research is that these chimes represent, to our knowledge, the first attempt at applying Sethares' method [2,3] of creating a spectrum for a musical scale in a non-electronic instrument. Musical instrument design methods such as the one proposed in this study have the possibility of opening up vast new realms of musical potential to composers. The evolution of these design methods, both for cylindrical chimes and for other non-harmonic instruments, will undoubtedly be a fascinating process.

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NOISE REDUCTION FOR SHEET METAL INDUSTRY ACHIEVED WITH AUTOMATIC STACKER

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ABSTRACT: The aim of this study was to demonstrate the noise reduction which could be achieved in a roll formed sheet metal production line when manual handling was replaced with automatic stacking. The handling noise was generated when finished sheets of profiled thin metal were moved from a runout table, and placed or dropped onto a stack. Sources of noise included impact or sliding contact between the product and parts of the machinery, and impact or sliding contact between product pieces. Considerable noise is normally generated when sheet product is dropped from a height onto a stack or the floor. While the primary incentive for the automatic stacker was to reduce the risk of back injury by eliminating much manual material handling, the noise exposure for the operator was also reduced with little additional cost by careful consideration at the design and implementation stages for the project.

1. INTRODUCTION

This study was part of a collaborative research project sponsored by Worksafe Australia, undertaken by the Acoustics and Vibration Unit (AVU) and BHP Building Products (BHP-BP). The aim of the project was to demonstrate techniques for the reduction of impact noise in industry using simple, cost effective retrofit noise reduction measures. Roll formed sheet metal products, which come in a variety of profiles, thicknesses and surface coatings, are used extensively for roofing, walling and fencing of industrial and domestic buildings. The flat sheet metal is uncoiled and passed through a series of rollers to form the finished product profile. Once formed, the profiled product is cut to length using a shear which typically impacts the sheet at high velocity, see Figure 1. It was found that once significant reduction had been achieved for the impact noise from the shearing process [1], the next main source of noise for the operator of the production line was the stacking process where sheets of profiled thin metal are moved from the runout table, in some cases turned over, and dropped onto a stack. Replacement of manual stacking with an automatic stacker has the potential for reducing two major occupational health and safety concerns. One is back injuries from materials handling and the other is high noise exposure, particularly that which occurs when the metal sheets are dropped onto a stack.

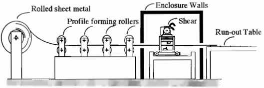

Figure 1 Schematic diagram of roll forming operations

A roll formed sheet metal production line for the manufacture of a product called Bondek was selected for this case study. Bondek is made from high strength zinc-coated steel which is used as both a permanent formwork and positive tensile reinforcement in suspended concrete slab construction. It is formed from sheet steel of thickness varying from 0.75 to 1.0 mm into a profiled product normally 600 mm wide. A Bondek line was selected for study because it was known that high noise levels were associated with manual handling and stacking of this product. The design and development of an automatic stacker for this production line was carried out by engineering staff at BHP-BP in consultation with members of the AVU. Detailed noise assessment and evaluation of the manual and automatic stacking processes were carried out by the AVU and are the subject of this case study report.

2. THE MANUAL STACKING PROCESS

The finished sheet metal products, after being roll formed and cut to length, continue onto a run out table for stacking. In the manual handling procedure, either one or two operators, depending on the product and the length, drag the sheet from the runout table, turn over every second sheet and drop it onto the nearby stack, see Figure 2. This operation has to be done quickly to ensure that the sheet is removed from the table in time for the next sheet coming through the roll former. When the required number of sheets have accumulated in the stack for an order, the stack is strapped ready for dispatch.

Figure 2 Manual stacking of roll formed product

One of the operators normally stands very close to the shear, which in itself can be a source of high impact noise. The noise during the dragging of the sheet from the run out table is generally not too high. The noise as the sheet drops onto the stack can be quite high depending on the length, mass and profile of the sheet, the height of the drop and the orientation of the sheet as it hits the stack. All those in the vicinity can be exposed to high impact noise levels requiring personal hearing protection.

3. MEASUREMENT PROCEDURES

Sound pressure level measurements were conducted using a Brüel & Kjær (B&K) type 2231 sound level meter fitted with a BZ7110 Integrating Module. For more detailed analysis, the sound level meter was connected to a Toshiba T3200SXC personal computer and noise measurements were recorded via a Boston Technology PC30DX analog to digital data acquisition card.

The data acquisition system provided a continuous record of noise levels so that a detailed analysis of noise levels during the various stages of the stacking process could be carried out. The microphone was placed at a height of 1.5 m and close to the operator's normal position for all tests. The product size was kept to a standard size, 6 m length and 1 mm product thickness so that comparisons could be made between the noise from manual stacking and from automatic stacking as well as assessment of the effects of modifications during the development of the automatic stacker.

4. DESIGN OF STACKER

The functional requirements for the automatic stacking process were the same as those for the manual stacking. The formed sheet must first be moved from the run out table. Every second sheet must be turned over so that stacking is efficient and stable. The sheets must also be moved longitudinally to ensure that the ends are lined up when they are added to the stack. The automatic stacker uses pneumatic rams plus some driven rollers on the table to perform these various movements and also caters for a range of product lengths from 1.5 m to 12 m.

The goals of efficiently performing the stacking and minimising the noise were treated as equally important considerations during the design of the stacker. The prototype was initially installed in a testing environment so that all the aspects of its performance could be checked and modified as necessary before it was put into the production environment. While it was immediately obvious that the main impact noise from the sheet drop had been significantly reduced, design modifications were made to further reduce the noise during operation. This noise analysis guided changes which were made to the design to further reduce the operating noise level. Once this modified stacker was shown to work satisfactorily it was installed in a production environment where it has continued to perform effectively for over two years.

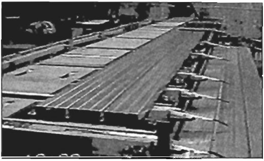

Figure 3 The sheet has been cut to length and pushed from the runout table prior to being rotated. The "rubber fingers" can be seen on the end of the horizontal arms.

5. RESULTS AND DISCUSSION

The detailed noise data from individual stacker operations were examined during the development process for the automatic stacker and changes made to the design to further reduce the operating noise level before the stacker was placed in the production environment. Typical modifications included polyurethane coatings applied to the rollers, reduction of the speed for the turn over and installation of rubber "fingers", on the ends of the horizontal stacker arms to allow the sheet to be placed more gently onto the stack. These "fingers" were of 10 mm thick rubber, as used in conveyor belts. The effects of some of these modifications can be seen from Figures 4 and 5.

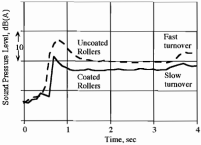

Figure 4 Sound Pressure Level during the push across from the run out table and the turn over of the sheet. The reduction in noise level from the use of the coated rollers and the reduced turn over speed can be clearly seen.

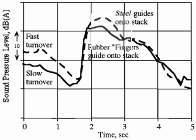

Figure 5 Sound Pressure Level for the completion of the turn over of the sheet and the drop onto the stack. The reduction in noise level from the use of the reduced turn over speed and the rubber "fingers" on the guide arms can be clearly seen.

The comparison of the noise for the operator when manual stacking in the Bondek production environment was replaced by the automatic stacker can be seen in Figure 6. The very high impact noise from the new sheet dropping onto the stack has been removed. The maximum noise level during the process has been reduced by over 20 dB(A). The L_{Aeq} for one cycle in the stacking process, over a period of 15 sec, has been reduced by 8 dB(A).

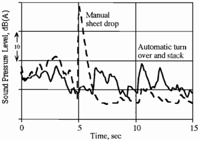

Figure 6 Noise levels for the operator for the manual and the automatic turn over and drop.

6. CONCLUSIONS

This case study has shown that the high levels of impact noise from manual stacking of profiled roll formed sheet steel can be greatly reduced by the use of a well designed automatic stacker. The major impact noise was from the dropping of the sheet onto the stack. The level of this noise depended on the length, mass and profile of the sheet, the height of the drop and the orientation of the sheet as it contacted the stack. In this study, the automatic stacker was designed to move the sheet from the run out table, to rotate every second sheet, to line up the end of the sheet and to place the sheet onto the stack ready for packing. These movements were performed with pneumatic rams and driven rollers.

The prototype stacker performed all the required tasks and a detailed noise investigation identified the parts of the stacking process where further noise reduction could be achieved. The modifications, which further reduced the noise of individual parts of the process included:

- polyurethane coatings on the rollers for the run out table and the stacking table;
- reduction in the speed of the turn over ; and
- rubber "fingers" on the ends of the horizontal stacker arms.

Noise measurements in the production environment showed that the maximum noise during stacking was reduced by over 20 dB(A) and that the L_{Aeq} during the 15 second stacking process was reduced by 8 dB(A). The additional costs for these modifications were very minor in the total cost for the stacker, of the order of 2%.

The above achievements in noise reduction apply to the specific roll forming operation used for this study. However, techniques which can be used to achieve significant noise reduction in product stacking applications in the sheet metal industry have been illustrated.

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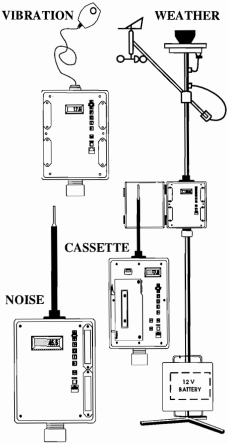
6. ACKNOWLEDGMENT

This project has been sponsored by Worksafe Australia and BHP Building Products.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Books...

Acoustical Aspects of Woodwind Instruments

C.J. Nederveen

Northern Illinois University Press, 1998, 147pp., Soft cover, ISBN 0-87580-577-9. Available from NIU Press, DeKalb IL 60115 USA , US$28.00

In 1969 Cornelius (Kees) Nederveen published what was, I think, the first book to treat carefully and quantitatively the physics of musical woodwind instruments, and it deservedly became a classic. The first edition, published in Amsterdam, has been out of print for some years, and this new edition is a most valuable addition to the available acoustical literature. It reprints the text of the first edition unchanged, except for a few minor corrections, and supplements this with a new 28 page section summarising advances in understanding since 1969.

After a brief introduction, the first third of main text examines the excitation mechanisms in woodwinds, concentrating on reed instruments rather than flutes. The next third is devoted to a detailed treatment of the behaviour of woodwind air columns, with particular attention to bore perturbations, and the calculation of finger-hole sizes and positions and the effect of open and closed pads. The final third applies these principles to a detailed discussion of flutes, clarinets. saxophones, oboes and bassoons, in most cases giving detailed measurements and numerical calculations. The addendum, about the same length as the other three sections, shows that there have been no revolutionary insights developed since 1969, but simply a deepening of our understanding in all areas.

The physical format of the book is unusual – almost square – following that of the original. It is set in two columns, with diagrams of only single-column width, as in a journal paper. This means that it is physically easy to read, and that there is a lot of material on a page. There are six pages of tables giving numerical data, such as bore and finger-hole dimensions, for various woodwind instruments, and a good selection of references – 120 from the original edition and a further 118 for the up-date.

I can recommend this book warmly to anyone with more than a passing interest in the acoustics of woodwinds.

Neville Fletcher

Neville Fletcher is a physicist and woodwind player who has written widely on various topics in musical acoustics. He has visiting appointments at ANU and ADFA.

The Physics of Musical Instruments

Neville H. Fletcher and Thomas D. Rossing.

2nd edition, Springer 1998, 756 pages, hard or soft cover; ISBN 0 387 98374 0 Australian Distributor: DA Information Services, 648 Whitehorse Rd, Mitcham Vic 3132, tel 03 9210 7777, fax 03 9210 7788. Price A$118.50

My copy of the first edition of this book is well worn from regular consultation: in our laboratory for musical acoustics, it is an essential reference. The fact that it has been reprinted several times and that a new edition is published shows that it appeals to many thousands of readers, not all of whom can be researchers in musical acoustics. This appeal is quite understandable: music is fascinating to a large section of the population, and many of us (perhaps especially those with some training in physics, mathematics and engineering) are interested to learn how musical instruments work.

What delighted me about this book (both editions) is how quickly and easily it leads from general discussion of physical first principles to quite specific and practically useful analyses of instrument families, and then to features of individual instruments. "The reader we had in mind in compiling this volume", the authors wrote in the preface to the first edition, "is one with a reasonable grasp of physics and who is not frightened by a little mathematics". Certainly the necessary mathematical rigour is there, but the presentation is always so clear that I suspect that the book has also found readers who were prepared to overcome qualms about mathematics in order to appreciate the insight that it offers.

In the decade since the first edition, important progress has been made in several areas of musical acoustics. In several chapters, these developments have been included by extending the existing material and giving modern references. Other chapters have required more extensive reorganisation, and there are many new sections.

Most notably, the chapter on non-linear systems has been comprehensively reorganised and extended to reflect the important advances in this area. Throughout the book, many new instruments are treated: more non-European instruments and more ancient and folk instruments are included. The analysis of concert instruments has been expanded. To give an example, the chapter on the violin family now includes the new technique of producing very low notes with high "bow pressure", more discussion of transient response and descriptions of new scientific techniques such as Weinreich's "reciprocal bow".

Fletcher's own recent work on the general theory of wind instruments is included in a completely revised chapter and now includes the effect of dynamic resistance of the reed (important in double reeds), a resolution of the problem of the operation of the lip-reed and discussion of the involvement of the player's vocal folds. His recent work on blowing pressures and on the flute jet are two further important inclusions.

An entirely new chapter on materials for musical instruments is one that will be of great interest to makers as well as to acousticians.

This already excellent book has been improved and brought up to date. Anyone interested in understanding how musical instruments work will find this book a delight to read.

Joe Wolfe

Joe Wolfe works in musical acoustics at the University of New South Wales (http://www.phys.unsw.edu.au/music). He is also a minor composer and a player of wind instruments.

Applications of Digital Signal Processing to Audio and Acoustics

M Kahrs and K Brandenburg

Kluwer Academic Publishers, 1998, pp 584, Hard cover, ISBN 0 7923 8130 0, Australian Distributor, DA Information Services, 648 Whitehorse Road, Mitcham, 3132, Australia, tel 03 9210 7777, fax 03 9210 7788. Price A$271.00

There are many books on Digital Signal Processing (DSP), and many applications of DSP to audio and acoustics, but there are very few books covering that application of DSP. The book under review nicely fills that gap. It is a well-edited collection of papers giving an overview to most of the key applications to audio and acoustics. The contributions are authoritative, in most cases having been written by the leading experts in the field.

The technical level of the book is such that someone with a basic undergraduate course in signal processing should be able to understand it in detail. The book does not include a tutorial review of the basic theory (there are plenty of books on that) but rather concentrates on the specifics of applying DSP to audio problems. An example of this is the problem of time-scale modification of audio signals. The basic idea sounds straightforward: use a computer to speed up or slow down an audio signal without changing the pitch. This problem elicits many questions in discussion groups on DSP. The present book contains the best review of the topic I have seen (written by Jean Laroche). (The reader specifically interested in this should also read the chapter on sinusoidal analysis/synthesis).

Another obvious application for DSP that has sorely lacked a nice overview is digital audio restoration — the cleaning up of old and perhaps damaged audio recordings. The review by Godsill et al here nicely collects together the panoply of techniques now available. Other papers in the book are "Audio quality determination based on perceptual measurement techniques" ; "Perceptual coding of high quality digital audio"; "Reverberation algorithms"; "Digital Audio Restoration"; "Digital Audio System Architecture"; "Signal Processing for Hearing aids"; "Wavetable sampling synthesis"; "Audio signal processing based on sinusoidal analysis/synthesis"; and "Principles of digital waveguide models of musical instruments".

Overall the book is a handy reference for the sort of hard to track down information that one simply does not find in the traditional academic journals. Anyone interested in using DSP for audio and acoustics will find this book useful, but it is not a cookbook; you need to approach it with some technical background already in place.

The chapters are up to date, clearly written and the book is nicely produced. I noticed very few typos.

Robert Williamson.

Bob Williamson is a reader in the Department of Engineering at the Australian National University. He is interests in signal processing are currently centred on microphone arrays.

3D Audio Using Loudspeakers

W Gardner

Kluwer Academic Publishers, 1998, pp 168, Hard cover, ISBN 0 7923 8156 4, Australian Distributor, DA Information Services, 648 Whitehorse Road, Mitcham, 3132, Australia, tel 03 9210 7777, fax 03 9210 7788. Price A$185.00

This book is derived from Gardner's PhD dissertation, and is concerned with the implementation of 3D audio systems using a pair of conventional loudspeakers. To create virtual sound sources in space around a listener, the binaural signals arriving at the listener's ears must be precisely controlled. This can be easily achieved using headphones. However, if loudspeakers are used, it is necessary to cancel the crosstalk signal that arrives at each ear from the opposite side loudspeaker. This is achieved using a crosstalk cancellation system that equalises the responses from loudspeakers to ears. The main problem with these systems is that the listener must be precisely positioned. If the listener moves away from the equalisation zone, which is typically quite small, the crosstalk signal is no longer cancelled and the 3D illusion is lost. The central idea of Gardner's book is to track the position of the listener's head and steer the equalisation zone to that position.

The first chapter motivates the problem and outlines the main ideas to be covered in the remainder. Chapter 2 contains a good review of human /sound localisation cues, and techniques for delivering binaural signals using loudspeakers. This chapter provides a useful brief introduction to the field for the non-specialist.

The bulk of the book's material is contained in Chapter 3, which presents (sometimes in excruciating detail): the measurement procedure for obtaining the HRTFs (head-related transfer functions) used in the system implementation; a comprehensive discussion of crosstalk cancellation theory; and design techniques for implementing crosstalk cancellers. This chapter represents the book's main contribution.

Acoustic simulations and measurements are presented in Chapter 4 to demonstrate that the proposed system can effectively cancel the crosstalk signals, and that the zone of equalisation can be steered. The following chapter presents the results of sound localisation experiments undertaken to subjectively validate the performance of the system for human subjects. Finally, Chapter 6 summarises the contributions of the work and points to future research directions. A simple numerical technique for inverting FIR filter responses is presented in an appendix.

The results of Gardner's experiments show that steering the equalisation zone to track the position of the listener's head greatly improves localisation performance relative to an untracked system. It is not surprising that this is the case, although Gardner's results serve to show that the tracking and steering can be performed in real time. The book is very clearly a doctoral dissertation, and should not be considered as a general reference for 3D audio systems (for which other books provide a more comprehensive source). However, for anyone wishing to implement a 3D audio system using loudspeakers, this book provides a very thorough and detailed presentation of techniques that have been demonstrated to work in practice.

Darren Ward

Darren Ward is a Lecturer in the School of Electrical Engineering at the Australian Defence Force Academy, University College, UNSW, since June 1998. Previously he was a Postdoctoral Fellow in the Acoustics and Speech Research Department at Bell Labs, Murray Hill, NJ, USA, working on signal processing algorithms for microphone arrays and 3D audio.

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Seminar Papers, AS/NZ 1269 1998

Standards Australia, 1998, pp 108, Soft Cover, Standards Australia, PO Box 1055, Strathfield, NSW 2135, Tel 1300 65 4646 Fax 1300 65 4949, Price A$35 ($28 for members). http://www.standards.com.au

The eight papers in this booklet were prepared for the series of Seminars organised by Standards Australia and held in the major capital cities in August 1998. These presentations were primarily designed to discuss the various aspects of the recently introduced Standard AS/NZ 1269 1998, Occupational Noise Management.

John Macrae and Dick Waugh provide a general introduction to occupational noise management with the reasons for the greater emphasis on managing occupational noise in the new standard. Part 0 of the Standard, the Overview, is discussed by Ken Mikl from Workcover NSW.

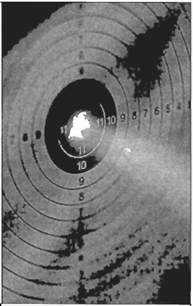
Part 1 of the Standard on Measurement and Assessment of noise immission and exposure is discussed by George Bellhouse from NZ. He refers to the proforma that are in the Standard and gives some data and assessment sheets which are variations of those given in the Standard.

Colin Tickell from BHP Engineering summarises the part of the Standard on Noise Control Management and includes a case study on noise emission from a plant room. This is followed by papers on parts 3 and 4 of the Standard by Warwick Williams (NAL) on Hearing Protector Programs and John Macrae (NAL) on Auditory Assessment. The final two short papers are by Warwick Williams on managing an occupational noise program and by Ken Mikl on determining a representative working day.

The new Standard is rather daunting as it is much larger and includes many changes. For those who find it difficult to work through, and were unable to attend the seminars, these papers would be of assistance. The focus of many of the papers is on the changes and hence they give a good introduction to the parts of the Standard. However it is essential that these papers are only used as background and not in place of the consultation with the Standard.

Marion Burgess

Marion Burgess is a Research Officer with the Acoustics and Vibration Unit at the Australian Defence Force Academy in Canberra.



Australian Acoustical Society CODE OF ETHICS

As some years have passed since the current version of the Code of Ethics was produced, it is time to consider possible revision (refer to the Editorial from the President in this issue). While all members should have their own copy of the code, it is reproduced here as a reminder and to stimulate discussion among the membership of the Society. Any comments should be forwarded to the General Secretary, PO Box 4004, East Burwood, Vic 3151 or watkins@melbpc.org.au by August 1999.

1. Responsibility

The welfare, heath and safety of the community shall at all times take precedence over sectional, professional and private interests.

2. Advance the Objects of the Society

Members shall act in such a way as to promote the objects of the Society.

3. Work within Areas of Competence

Members shall perform work only in their areas of competence.

4. Application of Knowledge

Members shall apply their skill and knowledge in the interest of their employer or client, for whom they shall act in professional matters as faithful agents or trustees.

5. Reputation

Members shall develop their professional reputation on merit and shall act at all times in a fair and honest manner.

6. Professional Development

Members shall continue their professional development throughout their careers and shall assist and encourage others to do so.

EXPLANATORY NOTES

1. Responsibility

In fulfillment of this requirement members of the Society shall:

(a) avoid assignments that may create conflict between the interests of their clients, employers, or employees and the public interest.

(b) Conform to acceptable professional standards and procedures, and not act in any manner that may knowingly jeopardise the public welfare, health, or safety.

(c) endeavour to promote the well-being of the community, and, if over-ruled in their judgment on this, inform their clients or employers of the possible consequences.

(d) contribute to public discussion on matters within their competence when by so doing the well-being of the community can be advanced.

2. Advance the Objects of the Society

Appropriate objects of the Society as listed in the Memorandum of Association are:

object (a)

To promote and advance the science and practice of acoustics in all its branches and to facilitate the exchange of information and ideas in relation thereto.

object (f) (in part)

To encourage the study of acoustics and to improve and elevate the general and technical knowledge of persons engaged or intending to engage in the science and practice of acoustics.

object (i)

To encourage the discovery of and investigate and make known the nature and merits of processes and inventions relating to the science, profession or practice of acoustics.

3. Work within Areas of Competence

In all circumstances members shall:

(e) inform their employers or clients if any assignment requires qualifications and/or experience outside their fields of competence, and where possible make appropriate recommendations in regard to the need for further advice.

(f) report, make statements, give evidence or advice in an objective and truthful manner and only on the basis of adequate knowledge.

(g) reveal the existence of any interest, pecuniary or otherwise, that could be taken to affect their judgement in technical matters.

4. Application of Knowledge

Members shall at all times act equitably and Fairly in dealing with others. Specifically they shall:

(h) Strive to avoid all known or potential conflicts of interest, and keep employers or clients fully informed on all matters, financial or technical, that could lead to such conflicts.

(i) refuse compensation, financial or otherwise, from more than one party for services on the same projects, unless the circumstances are fully disclosed and agreed to by all interested parties.

(j) neither solicit nor accept financial or other valuable considerations from material or equipment suppliers in return for specification or recommendation of their products, or from contractors or other parties dealing with their employer or client.

5. Reputation

No member shall act improperly to gain a benefit and, accordingly, shall not:

(k) pay nor offer inducements, either directly or indirectly, to secure employment or engagement.

(l) falsify or misrepresent their qualifications, experience, or prior responsibilities nor maliciously or carelessly do anything to injure the reputation, prospects, or business of others.

(m) use the advantages of privileged positions to compete unfairly.

(n) fail to give proper credit for work of others to whom credit is due nor to acknowledge the contribution of others.

6. Professional Development

Members shall:

(o) strive to attend their knowledge and skills in order to achieve continuous improvement in the science and practice of acoustics.

(p) actively assist and encourage those under their direction or with whom they are associated to advance their knowledge and skills.

News...

1999 AAS Conference

Acoustics Today is the title for the 1999 Australian Acoustical Society Conference to be held at the Hilton Hotel, Melbourne from 26 - 28 November, 1999. A registration form is included as an insert in this issue of the Journal and note the special rates for registration before 6 September.

This conference has been dedicated to the memory of H. Vivian Taylor, M.B.E., one of the pioneering members of the acoustics fraternity. However, Acoustics Today is not about the past, but about current developments and expectations. Papers are invited from any area of acoustics which demonstrate the exciting advances currently being made.

The closing date for abstracts has been extended until Monday, 17 May, 1999. A panel will review all abstracts and authors will be notified of their acceptance by mid June. Details of paper format will be provided then. An abstract of not more than 200 words is required for each paper to be presented at the Conference. The paper title and author's name, affiliation and a mailing address should be in a heading above the abstract text. Where possible, an e-mail address should be included for the contact author.

The President's Prize will be awarded for the best paper submitted to the conference. On Thursday night there will be first class travel on the vintage "Puffing Billy Night Train" to the Conference Dinner in the picturesque Dandenong Ranges. As part of the Conference, there will be an exhibition of products relating to the acoustic industry.

Further information: Mr Geoff Barnes, c/o Acoustical Design Pty. Ltd., 2/72 Bayfield Road, Bayswater, Victoria 3153, tel: 03 9720 8666, fax: 03 9720 6952, Acousticdes@bigpond.com

ACTIVE 99
INTER-NOISE 99

ACTIVE 99, the fifth in a series of international symposia on active control will be held at the Marina Marriott Hotel in Fort Lauderdale, Florida, USA, 2-4 Dec 1999. Prof Scott Sommerfeldt of the Brigham Young University (BYU) in Provo, Utah, USA will serve as General Chairman and co-chair of the technical program with Prof Jiri Tichy of Pennsylvania State University. The proceedings will be edited by Prof Scott Douglas of the University of Utah. Cheryl Van Ausdal of BYU will serve as the secretariat for the technical program. The Call for Papers, abstract details and reply coupon are all available from the www and the deadline for abstracts is 4 May 1999.

INTER-NOISE 99, will immediately follow ACTIVE 99 in the same hotel. Registration will open on Dec 5 and the congress will run through to Dec 8. Prof Joseph Cuschieri of the Florida Atlantic University (FAU) and Dr. David Yeager of Motorola in Fort Lauderdale, Florida will be the general co-chairs. Prof Stuart Glegg of FAU will serve as Technical Program Chair, and will be the editor of the Congress Proceedings. The technical program secretariat will be operated by Susan Fish of FAU. A major exposition of instruments, software, facilities, and materials for noise control will be held in conjunction with INTER-NOISE 99. The Call for Papers, abstract details and reply coupon are all available from the www and the deadline for abstracts is 4 May 1999.

Information: INTER-NOISE 99 Congress Secretariat, INCE, P.O. Box 3206 Arlington Branch, Poughkeepsie, NY 12603, USA, Fax +1 914 4624006, INCEUSA@aol.com, http://ince.org

INTER-NOISE 2000

The 29th International Congress on Noise Control Engineering to be sponsored by I-INCE, the International Institute Noise Control Engineering, will be held in Nice on the French Riviera from August 28-30, 2000. A major topic for discussion at INTER-NOISE 2000 will be Transport and Community Noise which remain the greatest sources of noise problems in the world. INTER-NOISE 2000 will take place among several coordinated workshops or conferences to be held in the same period. Check for more information on the www pages accessible via the INCE home page.

Information: INTER-NOISE 2000 , INRETS-LEN, 25 Avenue François Mitterand, Case 24, 69675 BRON Cedex, France Fax +33 4 72 14 23 42, Michel.Vallet@inrets.fr, http://ince.org

Events on www

The International Commission on Acoustics (ICA) has recently listed its calendar of events on the www. It can be accessed either via the Acoustical Society of America site http://asa.aip.org or directly at http://gold.sao.nrc.ca/ims/ica/calendar

Pacific 2000

UDT (Undersea Defence Technology) Pacific 2000 - Asia Pacific's only established undersea defence conference and exhibition - will take place at the Sydney Convention Centre, Australia, 7-9 February 2000. This conference offers the opportunity for interaction between Defence, contractors and researchers. It follows the tremendous success of the inaugural event, when over one thousand delegates and visitors attended UDT Pacific 98. The deadline for submission of abstracts is 14 June 1999, with complete papers by 1 Dec 1999.

Details from http://www.udtnet.com

CATGUT CDs

The CATGUT Acoustical Society has recently released two CDs presenting both the range of violins and the skills of the performers. One features the St Petersburg Hutchins' Violin Octet and the second presents Grigori Sedukh of St Petersburg playing the treble, soprano and mezzo violins accompanied by Inga Dzekster, pianist. More details can be found from the web http://www.marymt.edu/~cas/ which has won the Study Web Excellence Award.

STANDARDS AUSTRALIA

Committee News

Standards Australia Committee AV/3, Acoustics, Human Effects, is currently revising AS 1270-1988, Acoustics-Hearing Protectors. The major changes from the 1988 edition concern the method for measurement of the real-ear attenuation of hearing protectors. The revised requirements are modelled on the corresponding sections of ANSI S12.6-1997, Methods for measuring the real-ear attenuation of hearing protectors, and reflect the extensive research on which that Standard is based. Subject management procedures are specified in greater detail than in previous editions of AS 1270, but the principles underlying them remain the same. Publication of the revised Standard is anticipated in late 1999.

Committee AV/4, Acoustics, Architectural, is in the process of reviewing the ISO 140 and ISO 717 series of Standards with a view to adoption of relevant ISO Standards to replace older Australian Standards. The Committee has recommended adopting ISO 717-1:1996, Acoustics-Rating of sound insulation in buildings and of building elements, Part 1: Airborne sound insulation to replace AS 1276-1979, Methods for determination of sound transmission class and noise isolation class of building partitions. Committee AV/4 is also proposing the adoption of ISO 140-4:1998, Acoustics-Measurement of sound insulation in buildings and building elements, Part 4: Field measurements of airborne sound insulation between rooms to supersede AS 2253-1979, Methods for field measurement of the reduction of airborne sound transmission in buildings. Comment on this proposal is being solicited through the Standards Australia public comment process. Committee AV/4 recently initiated a revision of AS 2107-1987, Acoustics-Recommended design sound levels and reverberation times for building interiors. The main objectives of the revision are to update and expand guidance on design sound levels and to provide more extensive recommendations regarding reverberation times. A draft for public comment is in preparation and is expected to be available later this year.

Committee EV/11, Aircraft and Helicopter Noise, is revising AS 2021-1994, Acoustics-Aircraft noise intrusion-Building siting and construction and AS 2363-1990, Acoustics-Assessment of noise from helicopter landing sites. The main objectives of the revision of AS 2021 are to update the aircraft noise tables, simplify the noise attenuation calculations and include a method for measuring the attenuation achieved. The revised version of AS 2363 will provide methods for the measurement of noise from existing or proposed helicopter landing sites and helicopter overflights, as well as technical guidance for local planners, government agencies, and operators in calculating the acoustic environment near existing and proposed helicopter landing sites or routes as a result of helicopter operations. The draft versions of both Standards are currently being modified by Committee EV/11 in response to comments received. Publication is anticipated in late 1999.

Enquiries about the above activities should be directed to Jill Wilson, Projects Manager, Standards Australia,
PO Box 1055, Strathfield, NSW 2135,
tel (02) 9746 4821, fax (02) 9746 4766,
e-mail jill.wilson@standards.com.au.

Jill Wilson

Free Draft Standards

Copies of current Draft A/NZ Standards for public review can be downloaded from the web via www.standards.com.au at no charge. This latest service compliments the other services available via the Standards web shop which include buying Standards 24 hrs per day and saving of 10% by downloading Standards.

Fiji Adopts A/NZ Standards

Fiji has become one of the first Pacific Island countries to have its own national Standards following its recent adoption of 40 Standards from Australia and New Zealand. Only three of these standards required changes to suit the conditions in Fiji. the adoption of common standards will be important n facilitating trade between the countries.

from The Australian Standard 20(1)

NOHSC Standard Update

The National Occupational Health and Safety Commission (NOHSC) will be updating the NOHS Standard for Occupational Noise NOHSC:1007(1993) and its accompanying Code of Practice NOHSC:2009(1993) in the light of recent national and international developments in measurement. In particular the changes will should maintain consistency with the new A/NZ Standard on Occupational Noise Management.

OHS for Small Business

The OHS Web Site for Small Business is one of the new information modules on the commonwealth government's business information service known as Business Entry Point(BEP) www.business.gov.au. The site provides specific information for six industry groups as well as Health and Safety Laws in plain English, how to get an OHS program started and dealing with hazards which are common in most workplaces. These can be accessed directly via www.worksafe.gov.au/worksafe/protect/ohs

Further information and comments: NOHSC, Tel (02) 9577 9555 or 1800 252 226, fax (02) 9577 9202.

Entertainment Noise Code

The Western Australian revised 'Draft Code of Practice for Control of Noise in the Music Entertainment Industry' was released in early 1999 by WorkSafe Western Australia Commission. The Code is designed to provide practical advice on how people in workplaces can minimise the risk of hearing damage resulting from the performance of live or recorded music. It represents an update and revision of the former code released in 1992 in WA.

The public comment period extends till 30 April and comments from those outside WA are welcomed. The document can be downloaded from :

http://www.wt.com.au/safetyline/codes/noisent/draft99/noisent_ind.htm or contact WorkSafe Western Australia, tel (08) 9327 8777, fax (08) 9321 2148.

AUSTRALIAN FOUNDATION FOR SCIENCE

Along with 27 other Australian scientific societies, 24 corporations, 64 other institutions and 291 individuals, the AAS is a member of the Australian Foundation for Science, which was founded several years ago by the Australian Academy of Science for the benefit of science in Australia. Projects are supported by contributions from members, which now amount to over $3 million.

The Foundation's first major project was development of a whole-school program titled "Primary Investigations" for teaching of science, technology and environment in primary schools. This was launched three years ago after extensive writing, experiment development, and in-school trialling, and the program has now been purchased by 37% of all the 7500 primary schools in Australia. The program is supported by 300 "trainers" across Australia, and video materials are available for teachers in remote schools. http://www.science.org.au/pi

The Academy has, over the years, produced many books for science subjects in upper levels of high schools, and the Foundation is now investigating the possibility of developing a science program for the first four years of high school. Another major educational initiative is the Internet-based material NOVA: Science in the News, which is designed for teachers and high-school students. There are now 36 topics available on the site, ranging from Mad Cow Disease to Wind Power and Uranium Mining. Typically a new topic is added every two weeks, with help from sponsors in government and industry.

http://www.science.org.au/nova/

To preserve Australia's heritage, the Foundation is also producing a series of video interviews with famous Australian scientists. Some have already been screened on Optus educational Channel 55. The interview with Sir Rutherford Robertson is available on the Internet.

http://www.science.org.au/educatio/rr.htm

The Foundation has received grants from the Australian Heritage Commission and the Centenary of Federation program to restore and conserve the Academy's historic Dome building in Canberra. Other projects under development include a Population and Environment Research Fund and a variety of public lectures.

The Society is proud to be one of the supporters of the Foundation and, though our financial contribution is modest, we are able to influence the development of new projects.

Neville Fletcher

FASTS

Top Ten Policies for 1999

Professor Peter Cullen, President of the Federation of Australian Scientific and Technological Societies (FASTS), said the list this year was dominated by two issues: funding university science, and commercialising the best ideas of Australian scientists and technologists. "I want to propose a New Year's Resolution to the Government: that they resolve to sort out the mess in our universities before it is too late," he said. Professor Cullen said that universities are slowly being squeezed to death, and the quality of Australian science is being affected by increasing workloads and a failure to renew equipment and laboratories. Australians needed to view public support for R&D as an investment rather than a drain on the public purse, and pointed to massive boosts to research budgets by the Governments of the USA and Britain.

1. **Universities At The Crossroads**
2. **Peer-Review Funding: The Best Way To Go**
3. **Incentives For Science And Maths Teachers**
4. **Science In The Bush S&T**
5. **Australia: An Attractive Place To Invest**
6. **Keeping Up With The Joneses**
7. **Investing In Australia's Health**
8. **Scientists Thinking Commercially**
9. **The Benefits Of Being International**
10. **Landmark Projects To Mark 2001**

Further information on all these policies: FASTS, PO Box 218, DEAKIN WEST ACT 2601, tel 02 6257 2891, fax 02 6257 2897, fasts@anu.edu.au
http://www.usyd.edu.au/su/fasts/

Comments to Aust Acoustical Society President, Graeme Yates
gyates@cyllene.uwa.edu.au

FASTS Lecture

On 2 February the 1999 Australian Achiever of the Year, Professor Graeme Clark AO FAA FTSC, delivered the Federation of Australian Scientific and Technological Societies (FASTS) Lecture at the annual meeting of the Australian Neuroscience Society (ANS) in Hobart "Hearing For Deaf People Into The 21st Century". Professor Clark described the problems researchers have overcome in the last thirty years to provide hearing for profoundly and totally deaf children and adults across the world. He outlined the challenges facing researchers if the dream of providing near-normal hearing for all hearing impaired children and adults is to be realised in the 21st Century. Other potential major advances in the new Millennium could include a pharmaceutical cure for deafness, and an invisible Bionic Ear which relies on a tiny device attached to the eardrum.

A new recently funded research program was announced which has the potential to lead to significant advances in the design of medical prostheses, including the Bionic Ear. Professor Clark and his world-leading research team developed the world's first fully implanted multi-channel Bionic Ear in 1978 that has been commercially developed by the Australian firm Cochlear Limited. The Nucleus cochlear implant system developed by Cochlear now provides hearing to over 20,000 deaf children and adults around the world.

New Members...

NSW	
Member	Mr Andrew Todoroski, Mr Mark Latal, Ms Victoria Labban, Mr Peter English, Mr Nagib Seif
Associate	Mr Stephen Brady, Mr Rodney Linnett
Subscriber	Mr David Luck, Ms Tracy Gowen,
QLD	
Member	Mr Colin Speakman
SA	
Member	Mr Jason Turner, Mr Christopher Turnbull, Mr Carl Howard, Mr Stewart Kanev, Mr Paul Clarke
VIC	
Member	Mr Andrew Rogers
Graduate Member	Mr Kerry Dumicich
WA	
Member	Mr Chong Hoe Ong

MEETING ON BLACK BOX

The final Victoria Division technical meeting for 1998 was held on Nov 25 at the Malvern Valley Golf and Reception Centre, East Malvern, as a dinner with invited after-dinner guest speaker. With it was held the national AGM, deferred from Oct 29 and Nov 12 through delays in the auditing of the national accounts. A total of 32 members and friends were present.

The speaker was Dr David Warren who, as an Australian, and inventor of the black box flight recorder, spoke of its development and of the long time taken to gain its general acceptance in defence and commercial aircraft.

After training in England in rockets and fuels, he returned to Melbourne to the DCA and ARL to work in aviation on jet engines. An early and baffling problem the department was called on to investigate arose from Comet jet airliner crashes, for which no immediate explanation was available. While possibilities that such crashes could have resulted from kerosene vapour (flammable at low pressures), metal fatigue, or servo-assisted control failure, Dr Warren considered that much useful information could be obtained if the pilots' conversation and basic instrument readings up to the time of the crash had been recorded.

At that time the most useful recorder available was the German 'miniphon' pocket wire recorder which, after obtaining his superior's approval he investigated and developed for this use. Because the chrome steel wire used in it could hold its magnetic record up to temperatures approaching red-heat, he insisted on its use rather than the magnetic tape which was soon to replace this wire.

While the early tests showed that technical problems in developing the 'black box' included the need for 700 to 3 000 Hz pass band filters and fixed directional microphones in recording pilot conversation to achieve a 96% Articulation Index, the largest problem lay in getting the invention accepted for use in aircraft. Initially, the RAAF commented that such a recorder wasn't needed !

However, Dr Warren reported that with much persistence he and his colleagues in 1958 achieved the making of flight recorders mandatory by British airlines, and in 1961 their use by Australian airlines. In all, it had taken 14 years from initial idea to final installation in aircraft. Those present found this talk most interesting and enjoyable.

Louis Fouvy

ANYONE FOR TENNIS ?

Organised by Ken Mikl and David Eager for Friday afternoon 5 March 1999, the Inaugural AAS Corporate Tennis Event at White City was a great success. Lured by the chance to demonstrate their skills on the hallowed grounds once played on by the tennis greats such as Ken Rosewall, Lew Hoad, John Newcombe, a free lunch and a low $10 fee, about 16 players turned up complete with wooden rackets, clamp frames, sun visors, pith helmets, blockout cream, white tennis shirts with collars, Bermuda shorts and football socks.

It was an inspiring sight to behold. They just got stuck straight into it Pulling no punches they gave their very best. No favouritism, no looking back, no hesitation, with no thought of personal injury, no thought for stiff jaw muscles the next day, they just launched straight into that delightful barbequed steak and salad lunch.

After lunch, a team of aspiring Davis Cup champions, all regular tennis coaches at White City, took our brave bunch or lads and showed us some of the tricks that regular White City players use. Many that you would think had never held a tennis racket in their life, did just that. Then spurred on by our coaches we served, volleyed, smashed, stroked, intercepted and lobbed. You may have thought that such intense activity would have been the end for some of us .. so did I. The very thought of playing tennis at White City spurred us on.

Champions of the day were Ken Mikl (champion of champions) and Frank Wetherall, who were both awarded White City Tennis Caps for their outstanding tennis prowess. However, the match of the day ended in a final Tie Breaker between Peter Nagiel and Frank Wetherall. It was an amazing demonstration of skill, with Frank serving underhand into the blazing sun, and winning by the small margin of 6 to 1. As Frank walked off the court smiling and waving to the cheering crowd I noticed him screwing his racket back into its slightly twisted wooden frame with the detached and casual air of a true professional. His jaunty swagger seemed to say "Better luck next year chaps".

Athol Day

New Products...

RION Vibration Analyser

The Rion VA-11 Vibration Analyser is a portable analyser designed for examining machinery vibrations and performing diagnostic routines on various kinds of equipment. The unit has a vibration meter mode and an analyser mode encompassing FFT analysis.

In vibration meter mode, simultaneous measurement of acceleration, velocity and displacement is carried out. Acceleration rms value, peak value and crest factor can also be displayed simultaneously. In analyser mode, FFT analysis is used to determine the power spectrum and vibration waveform. The capacity to perform envelope processing before FFT analysis is highly useful for equipment diagnostics.

The VA-11 comes with PCMCIA card slot for the speedy transfer of data to a PC. The VA-11 also comes with RS232 interface allowing the control of the VA-11 from a computer and the transfer of data to a computer.

Further information: Acoustic Research Laboratories Tel 02 9484 0800, Fax 02 9484 0884 or your local branch of ARL.

AUTOSEA 2

AutoSEA2 is the second generation of AutoSEA, a high quality software program introduced in the early 1990s, using statistical energy analysis for noise and vibration problems in a variety of industries. This was the first easy-to-use SEA tool with simple graphical interface to model noise and vibration problems before prototypes are built and tooling begins

AutoSEA2 can be run on laptop computer for immediate feedback to the design team. It uses the probabilistic engineering methods of SEA and room acoustics. This has the advantage of simpler model substructuring, making the process very fast. All the improvements make this powerful technology accessible to much wider group.

LARSON DAVIS Meter

The Larson Davis Personal Exposure Meter, model 706, is based on the model 705 Noise Badge and comes with an improved dynamic range and LCD. It weighs only 200 g and is the world's smallest production noise dosimeter.

The Graphical User Interface (GUI) and BLAZE software navigates the user through a variety of set up and measurement parameters. It has low power consumption with typically 80 hours of measurements. High speed data transfer is by infrared technology.

Further information: Vipac Engineers & Scientists, 275 Normanby Rd, Port Melbourne VIC 3207, Tel 03 9647 9700 Fax 03 9646 3427, http://www.vipac.com.au.

BRUEL & KJAER

2 Channel Analyser

The new Windows NT based 2-channel sound and vibration analyser system serves as the entry-level to the B&K PULSE analyser platform. The 2-channel system is fully integrated from the transducers on the front end to analysis, post processing and reporting. The PULSE software is fully integrated with Microsoft Word for reporting and Excel for data processing. The system can be easily updated in terms of system performance, channel count, processing power and application software.

Sound Level Meter

The type 2238 Mediator is a new versatile range of sound measurement instruments. The main applications are evaluation of environmental noise, noise in the workplace and product noise assessment. The dedicated software provides direct support for application and measurement practices.

The 2238 Mediator range provides four different software packages spanning from on-the-spot noise level checks to logging of time histories and frequency analysis. Adding functionality and performance is a matter of downloading software from a PC.

Further information: Bruel & Kjaer Australia, Tel 1800 802 852, bk@spectris.com.au or http://www.bk.com.au.

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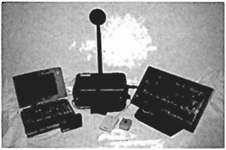

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Diary...

1999

May 10-14, TRIESTE
4th Int. Conf. Theory & Comput Acoustics
Details: Fax: +39 40 327040, ictca99@ogs.trieste.it

May 24-26, ATHENS
2nd Int. Conf. On Emerging Technolgies in NDT.
Details: Ms. M. Bourlau, Free University Brussels, TW-KB, Pleinlann 2, 1050 Brussels, Belgium, Fax: +32 2 6292928, mbourlau@vub.ac.be

May 24 - 27, GDASK
2nd EAA Int Symp on Hydroacoustics.
Details: Department of Acoustics, Technical University of Gdask, ul. G. Narutowicza 11/12, 80-952 Gdask, Poland; Fax: +48 58 347 1535; www.hydro.eti.pg.gda.pl

May 30 - June 3, NORWAY
16th Int. Evoked Response Audiometry Study Group Symposium
Details: Otorhinolaryngology Dept, University Hospital, PO Box 34, 9038 Tromso, Norway, Fax: +47 77627369, einar.laukli@rito.no

June 28-30, RUSSIA
EEAA Congress - 1st Int. Cong. East European Acoustical Society
Details: EEAA, Moskovskoe Shosse 44, St Petersburg 196158, Russia, Fax: +7 812 1279323, krylspb@sovam.com

June 28-July 1, LYNGBY
Joint Conf. Ultrasonics Int '99 & World Congress Ultrasonics '99
Details: Dept Industrial Acoustis, Denmark's Technical University, Bldg 425, 2800 Lyngby, Denmark, Fax: +45 45 930190, lb@ipt.dtu.dk, www.msc.cornell.edu/~ui99/

July 5-8 DENMARK
6th Int. Congress on Sound & Vibration
Details: Dept Acoustic Tech, Tech Uni of Denmark, Bldg 352, DK-2800 Lyngby, Denmark. Tel: +45 45 881622 Fax: +45 45 880577 icsv6@dat.dtu.dk, http://www.icsv6.dat.dtu.dk

August 2-6, VITEBSK
Int Symp on High-Power Ultrasonics.
Details: Institute Technical Acoustics, National Academy of Sciences of Belarus, Ludnikov av. 13, Vitebsk 210717, Belarus, Fax: +375 212 24 39 53; lpm@ita.belpak.vitebsk.by

September 1-3, MANCHESTER
DYMAC 99
Dynamics, Condition Monitoring and Control for 21st C
Details:
http://www.eng.man.ac.uk/mech/dymac99.htm or Dr. Wenyi Wang, AMRL, P.O. Box 4331, Melbourne, VIC Tel (03) 9626 7138, Fax: (03) 9626 7083 wenyi.wang@dsto.defence.gov.au

September 1-4 GERMANY
15th Int. Symp. Nonlinear Acoustics (ISNA-15)
Details: W. Lauterborn, Drittes Physikalisches Inst., Universitat Gottingen, Burgerstr 42-44, 37073 Gottingen, Germany, Fax: +49 551 39 7720, lb@physik3.gwdg.de

September 12-15, LAS VEGAS
Int Symp Acoustic Scattering ASMEConf Vibration & Noise).
Details: P. K. Raju, Mech Eng, Auburn University, Auburn, AL 36849-5341, USA, Fax: +1 205 844 3307; pkraju@eng.auburn.edu)

***September 22-24, SYDNEY**
Metrology Conference
Details: Dr Suszanne Thwaites, National Measurement Laboratory, PO Box 218, Lindfield NSW. Tel; (02) 9413 7416, Fax; (02) 9413 7161, suszanne.thwaites@tip.csiro.au

November 1-5, COLUMBUS
138th Meeting of ASA
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797 USA. Fax +1 516 576 2377, asa@aip.org

***November 24-26, MELBOURNE**
Acoustics Today
AAS Annual Conference
Details: Acoustical Design, 2/72 Bayfield Rd, Bayswater, Vic 3153. Tel: (03) 9720 8606, Fax:(03) 9720 6952, Acousticdes@bigpond.com

December 2-4, FORT LAUDERDALE
ACTIVE 99

December 5-9, FORT LAUDERDALE
INTER-NOISE 99
Details: INCE, PO Box 3206 Arlington Branch, Poughkeepsie, NY 12603, USA, Fax: +1 914 4624006, inceusa@aol.com http://ince.org

December 3-5, AUCKLAND
Taking OH+S into 21st Century.
Details: F. Lamm, Dept Management & Employment Relations, University Auckland, Private Bag, 92019 Auckland, New Zealand, Fax: +64 9373 7402, f.lamm@auckland.ac.nz

2000

*** February 7-9, SYDNEY**
Pacific 2000
Undersea Defence Technology
Details: http://www.udtnet.com

May 17-19, AALBORG
9th Int Meet Low Frequency Noise & Vibration
Details: W. Tempest, Multi-Science Publishing Co. Ltd., 5 Wates Way, Brentwood, Essex CM15 9TB, UK Fax: +44 1277 223453

May 30 - June 3, ATLANTA
139th Meeting of ASA.
Details: Fax: +1 516 5762377, Web: asa.aip.org

June 6-9, ST.PETERSBURG
5th Int Symp Transport Noise & Vibration
Details: EEAA, Moskovskoe Shosse 44, 196158 St.Petersburg, Russia; Fax: +7 812 127 9323; noise@mail.rcom.ru

July 4-7, GERMANY
7th Int. Cong. on Sound and Vibration
Details: H. Heller, DLR, Lilienthalplatz 7, 38108 Braunschweig, Germany Fax: +49 531 2952320, hanno.hellor@dir.de, http://www.liav.org/icsv7.html

Aug 31 - Sep 2, LYON
Int Conf Noise & Vib Pre-Design & Characterization Using Energy Methods (NOVEM)
Details:LVA, INSA de Lyon, Bldg. 303, 20 avenue Albert Einstein, 69621 Villeurbanne, France; Fax: +33 4 7243 8712; www.insa-lyon.fr/laboratoires/lva.html)

August 28-30, NICE
INTER-NOISE 2000
Details: M. Vallet, INRETS-LEN, 25 avenue François Mitterand, Case 24, 69675 Bron Cedex, France. Fax: +33 04 7214 2480, mvallet@inrets.fr

October 3-5 KUMAMOTO
WESTPRAC VII
Details: Dept Computer Science, Kumamoto Uni. 2-39-1 Kurokami, Kumamoto, 860-0862. Tel: +81 96 3423622 Fax: +81 96 3423630 westprac7@cogfni.eecs.kumamoto-u.ac.jp http://cogni.eecs.kumamotou.ac.jp/others/westprac7

October 16-20 BEIJING
6th Int. Conf. on Spoken Language Processing
Details: ICSLP 2000 Secretariat, Institute of Acoustics, PO Box 2712, 17 Zhong Guan Cun Rd, Beijing 100 080, China, Fax: +86 10 6256 9079, mchu@plum.ioa.ac.cn

December 4-8, NEWPORT BEACH
Meeting of the ASA
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797 USA. Fax +1 516 576 2377, web: asa.aip.org

2001

June 4-8, CHICAGO
141th Meeting of the Acoustical Society of America
Details: ASA, 500 Sunnyside Blvd, Woodbury, NY 11797-2999, USA, Fax: +1 516 576 2377, Web: asa.aip.org

September 2-7, ROME
17th Int. Cong. on Acoustics
Details: A. Alippi, 17th ICA Secretariat, Dipartimento di Energetica, Universitá di Roma "La Sapienza", Via A. Scarpa 14, 00161 Roma, Italy, Fax: +39 6 4424 0183, www.uniroma1.it/energ/ica/html

COURSES

May 25-26, SYDNEY
Occupational Noise Competency Seminar
Details: Noise & Sound Services, Tel/fax (02) 9449 6499, 0411 648 153

May 5-7, CANBERRA
Basics of Noise and Vibration Control

June 23-24 CANBERRA
Basics of Underwater Acoustics
Details: Acoustics & Vibration Unit, ADFA, Tel (02) 6268 8241, Fax (02) 6268 8276, avu@adfa.edu.au, http://www.adfa.edu.au/amec/avu/activities.htm

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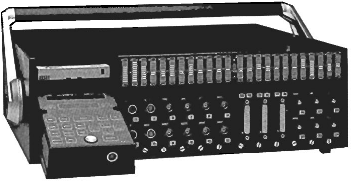

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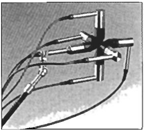

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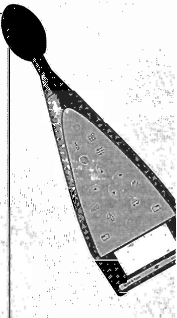

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