Institute of Acoustics

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contents

The Institute of Acoustics was formed in 1974 through the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society and is the premier organisation in the United Kingdom concerned with acoustics. The present membership is in excess of two thousand and since 1977 it has been a fully professional Institute. The Institute has representation in many major research, educational, planning and industrial establishments covering all aspects of acoustics including aerodynamic noise, environmental, industrial and architectural acoustics, audiology, building acoustics, hearing, electroacoustics, infrasonics, ultrasonics, noise, physical acoustics, speech, transportation noise, underwater acoustics and vibration. The Institute is a Registered Charity no. 267026.

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Dear Fellow Member

The Autumn Conference at Windermere at the end of October was blessed with excellent weather. This year saw an innovation introduced to complement the normal programme of contributed papers, partly to explore whether the Institute's conferences may have a greater educational role than has hitherto been appreciated. A series of practical tutorials were arranged on various aspects of acoustic measurements. One of these sessions saw the hillsides of the Lake District studded with acousticians measuring the noise from gunshots; in another a local church resounded with nonsense syllables for intelligibility testing. The other eight exercises took place in rooms of the ever accommodating Hydro Hotel. These tutorials led to penetrating discussions stimulated by practitioners whose techniques have sometimes lapsed over years of practice from the copybook versions. Our special thanks are due to those who gave their time in the preparation and conduct of the tutorials. This issue carries a report of that conference.

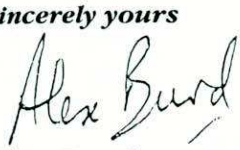
The eleventh Reproduced Sound conference has also taken place and during it the third annual Training Course for Sound System Engineers. The next issue will carry a report. The final conference of the year, the Underwater Acoustics Group's annual pre-Christmas celebration, will be in Loughborough this year where the A B Wood medal will be presented to Dr Tim Leighton.

This issue marks the end of John Tyler's Editorship. John has found it increasingly difficult to satisfy the requirements of both the Institute and of TRL and, in the end, we have had to let him go. Our grateful thanks are due to him for twelve years of sterling service. Recently, Roger Higginson has been dealing with feature articles and we are delighted that he has agreed to extend his role to cover the complete duties of Editor.

Planning for Internoise '96 proceeds apace with offers of contributed papers arriving in large numbers. Note that Internoise is now on the Internet! Several pages of conference information and colour graphics, which can be updated frequently as the programme develops, can be viewed at: http://www.npl.co.uk/npl/cira/events/internoise.html and links are being established with many other Internet sites and Net surfers worldwide can send Email enquiries automatically to the IOA office or to the NPL.

By the time this drops through your letter box Christmas will be nearly upon us. I send greetings to all members and their families with the hope that 1996 will be even more successful than 1995.

Sincerely yours



Alex Burd

Structural Boards are Strong on Sound

Dr Bob Moore of Cape Boards takes the lid off a new acoustic super roof and examines the high performance characteristics of Pyrok, one of its components.

In one of the most innovative roof constructions ever devised for a building in Britain, a double layer of 10mm Pyrok cement bonded particle board is being used within the build up of an 8,500m^2 curved and multi-layered acoustic roof deck over the new Rock Arena at Newcastle-upon-Tyne.

The composite design solution, required to prevent the noise of concerts from disturbing the neighbourhood, was jointly conceived by acousticians Moir Hands and Associates, structural engineers W.A. Fairhurst & Partners, architects Gordon White & Hood and contractors Taylor Woodrow.

It places a Hoogovens 'Kalzip' aluminium decking over 50mm of mineral fibre insulation quilt and two layers of Pyrok to form the curved profile of the roof. This in turn is carried by spacers with an air gap, then another 100mm of mineral fibre acoustic quilt and finally 150mm thick pre-formed reinforced wood wool cement slabs. The latter also provide lateral restraint to the main trusses which are arranged in pairs at 12.3 metre centres and span 70 metres across the main auditorium. The Pyrok, with a vapour barrier underneath, is mechanically fastened to the spacers, resting on the second layer of insulation and the wood wool cement slabs.

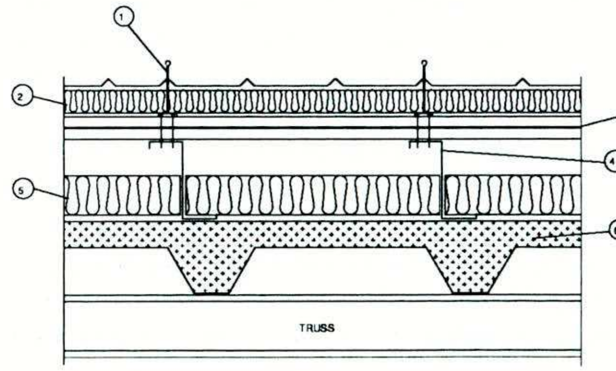
Pyrok is a cement based structural board, reinforced with engineered wood filaments.

The patented manufacturing process, which combines advanced mechanical and aerodynamic techniques, gives a uniformly graded product with no planes of weakness. It therefore has high strength, high modular elasticity and excellent internal bond strength.

A smooth, flat, highly durable and rot resistant Class 0 board for use in load-bearing applications, multi-functional Pyrok is also moisture resistant and provides good performance in fire and excellent impact resistance. The material's moisture resistant qualities became crucial during construction of the Rock Arena roof deck as sections of Pyrok were unavoidably exposed to the elements for limited periods due to the sequence of working.

With high mass being paramount in preventing the ingress or escape of airborne noise, Pyrok's density of 1250/kg/m^3 is higher than other, non-cement based particle boards. Its overall strength and stability mean it can serve as the structural deck beneath singly ply roofing membranes or conventional built-up systems. Moreover, with board thicknesses ranging from 6 – 40mm, it provides a high level of flexibility in systems design. Pyrok has been tested at AIRO to confirm its performance to BS 2750 Part 3:1980; and BS 5821 Part 1: 1984. Copies of the test certificates are available from Cape Boards on request.

Specification – The Rock Arena, Newcastle-upon-Tyne



Key

1 = Hoogovens Kalzip aluminium standing seam, cladding 400mm wide and 0.9mm thick;
2 = 50mm fibreglass insulation (25kg/m^3) 3 = 2 x 10mm Pyrok board;
4 = Purlins and spacers at 1200mm centres 5 = 100mm fibreglass insulation (25kg/m^3)
6 = 200mm pre-formed wood wool cement slab

During the tests, Pyrok took its place in a 3330 x 3360mm mock up of the real roof with the roof's estimated mass being 95kg/m^2. With a consistently good performance across the frequency range from 50 – 1000Hz, the system was credited with a weighted sound reduction index of 53dB and an average sound reduction index (100 – 3150Hz) of 49.4 Hz. The first real test of its effectiveness at the Newcastle Arena will be on 7th December when David Bowie takes the stage. Cape Boards are confident that local residents will be unable to hear him hammering out Rock and Roll Suicide.

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MODELLING OF BALANCED ARMATURE ACOUSTIC SOUNDERS

Graeme Anderson & Martyn Hill

Introduction

Moving coil acoustic sounders are used in a wide range of applications where a good reproduction of sound is necessary. The wide frequency range has made them the first choice in many audio and communications applications. Their linearity makes them an easy loudspeaker to examine and therefore design to fit a particular task. The operation of these speakers is straightforward to simulate mathematically and as such is widely covered in literature. However, there are applications for which the need for good signal reproduction is not the primary concern when selecting a transducer. The moving coil loudspeaker, while ideal for many situations, is not the easiest or cheapest to construct in large numbers, nor is it necessarily the most efficient. Prompted by a need in the security industry for a cheap, reliable loudspeaker for use in fire alarm units, an investigation has been made into alternative designs which, although not necessarily such simple systems, are nevertheless more efficient than the loudspeakers currently used in the alarm units. The efficiency of the speaker in this area is probably the most important consideration. In some applications the alarms must be capable of operating for extended periods using only battery power, but must be as loud and 'alarming' as possible. Any gain in sound power output must not be due to an increase in the current consumption of the unit. A novel design has been developed at the University of Southampton Institute of Transducer Technology which has an output comparable to those loudspeakers presently used, but draws considerably less current from the power supply. In order to further improve the design, it was decided that a computer model should be developed.

There are a number of advantages to developing a model of the loudspeaker to aid the design process, not least an increased understanding of the operation of the system. The process of modelling the system requires a thorough examination of the mechanisms that cause the loudspeaker to work, including all the transduction methods and circuits involved. This examination can only be beneficial. For a designer, the ability to predict the response of the system with respect to changes in one or more of the system parameters is vital if a particular response is required. By using an accurate model, it becomes possible to experiment with new design ideas that might otherwise be ignored for being too outrageous. The computer model can be used to determine one or more possible solutions to the problem, allowing mathematical optimization routines to be applied to the system. These techniques can reduce the design time and costs, by improving the confidence in a particular design before costly prototypes become necessary.

Balanced Armature Loudspeaker

Although the loudspeaker to be modelled is a new design, the processes involved in the operation are similar to those that feature in the balanced armature loudspeaker. This transducer is of the type formerly used in telephone ear pieces, and is currently used as the sound source in many fire alarm units. It consists of an armature pivoted at the centre and with the diaphragm attached at one end. Although the loudspeaker has been used for many years, information concerning its operation is surprisingly hard to come by, so it has become apparent that the operation of this system must be studied from first principles before the novel design can be completely understood.

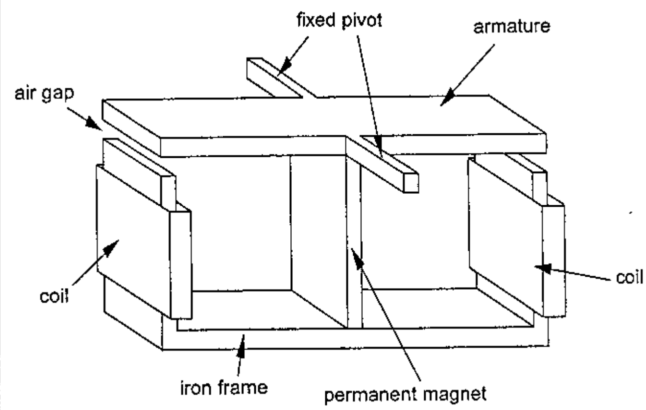

Fig. 1. The balanced armature loudspeaker

Measurements of the response of the loudspeaker to a sinusoidal input showed considerable harmonic content in the output indicating nonlinearity. By dismantling the unit, the mechanisms could be studied. The speaker consists of an iron frame with three upright poles, the centre being a fixed permanent magnet. Around the two outer poles are fixed coils, wound in opposing directions, through which the current flows. Across the top of the frame is an armature, to which the diaphragm is attached at one end. Between the armature and the two end poles are small gaps that allow the arm to rotate about a fixed pivot above the magnet. Flux from the magnet flows around each side of the system and across each gap, causing a force that attempts to move the armature. When there is no current flowing in the coils, the forces are equal and there is no motion. With a current flowing, additional magnetomotive force is produced by the coils, reducing or increasing the current correspondingly in each side of the system. In this case, there is a resultant force at one end of the armature causing motion of the arm and diaphragm. By passing an alternating current through the coils, the diaphragm can be oscillated to produce sound.

The likely source of the nonlinearity in the system is the relationship between the size of the air gap and the force acting on the armature. This nonlinearity increases as the size of the air gap approaches zero. In order to obtain the maximum output from the system, the armature must be driven so as to maximise the displacement, thus causing this nonlinear attraction to become more apparent. In the moving coil loudspeaker, a similar nonlinearity is avoided by making sure that the coil is totally enclosed by the magnetic field at all times in its cycle, so that the force is independent of the position of the coil.

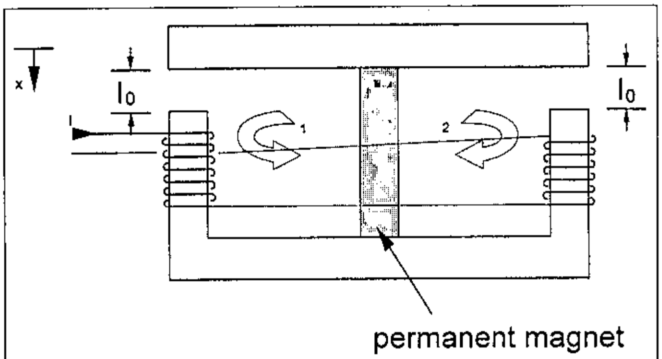

Fig. 2. Magnetic circuits

An examination of the operation of this loudspeaker must begin with the analysis of the flux. There are two magnetic circuits around which flux flows, each having the permanent magnet as a common component. This magnet produces a magnetomotive force around each loop, as do the coils. Bearing in mind the directions of the coils, the total magnetomotive force can be found for each loop. In each case, this must equal the sum of the products of flux and reluctance for all the sides of the loops, including the air gap. From this relationship, the flux around each loop can be calculated in terms of the dimensions, the coil parameters and the permanent magnet strength.

Examination of the System

The flux around each side of the circuit must be considered independently, although the permanent magnet in the centre acts as a carrier for both. This central link causes the two flux circuits to be interdependent. Considering the magnetomotive forces around each loop generates a set of simultaneous equations for the flux.

$$(\Psi+Ni)-\phi_1\left(\frac{l_{gap1}}{\mu_0 A_{gap1}}+\sum_i\frac{l}{\mu A}\right)-\phi_2\frac{l_c}{\mu_c A_c}=0 \qquad (1)$$

$$(\Psi-Ni)-\phi_2\left(\frac{l_{gap2}}{\mu_0 A_2}+\sum_i\frac{l}{\mu A}\right)-\phi_1\frac{l_c}{\mu_c A_c}=0 \qquad (2)$$

where Ψ is the permanent magnet strength, N is the number of turns in each coil, i is the input current, l is the length of the section of area A, subscript c is the centre pole and subscript i is the iron frame. By using the following constants, the equations can be simplified.

$$\beta_0=\mu_0 A \qquad \alpha_i=\sum_i\frac{l}{\mu A}$$
$$l_f=\beta_0\alpha_i+l_0 \qquad \alpha_c=\frac{l_c}{\mu_c A_c} \qquad (3)$$

Making the assumptions that the cross sectional areas of each component are the same and that the initial air gap is l_o, the flux in each loop can be shown to be

$$\phi_1=\frac{\beta_0\{(x+l_f)(\Psi+Ni)-\beta_0\alpha_c(\Psi-Ni)\}}{l_f^2-\beta_0^2\alpha_c^2-x^2}$$
$$\phi_2=\frac{\beta_0\{(l_f-x)(\Psi-Ni)-\beta_0\alpha_c(\Psi+Ni)\}}{l_f^2-\beta_0^2\alpha_c^2-x^2} \qquad (4)$$

The flux in each side of the system acts across the air gap between the end of the armature and the side arm of the iron frame. This exerts a force that attempts to close the gap and pivot the armature, the force being

$$F=\frac{\phi^2}{2\mu_0 A_{gap}} \qquad (5)$$

at each end of the armature.

With no current in the coils, the forces are equal and there is no movement. When a current flows, the total force acting at one end of the armature, to which the diaphragm is attached, is the resultant force from both ends.

$$F=\frac{\phi_1^2-\phi_2^2}{2\mu_0 A_{gap}} \qquad (6)$$

This force can be considered as acting in a standard linear mass-spring-damper system. The main source of stiffness is from the pivot, the mass from the equivalent rotational inertia of the armature and the damping from internal losses. Additional mass, stiffness and damping are exerted by the air load on the diaphragm, but initial calculations have been made assuming the diaphragm has been removed. The stiffness and mass of the diaphragm are negligible compared to those of the armature and pivot. The equation obtained is the complete equation of motion for one end of the armature, and describes the displacement for a given input current in terms of the loudspeaker parameters.

$$M\ddot{x}+c\dot{x}+Kx=\frac{\phi_1^2-\phi_2^2}{2\mu_0 A_{gap}} \qquad (7)$$

Now the equations describing the operation of the system have been developed, there are a number of options available allowing the displacement of the armature to be calculated. Using mathematical software, the equations can often be solved directly. Unfortunately, this method is not applicable to the balanced armature loudspeaker due to the nonlinearity of the model. The calculation of the flux in each loop depends on both the input current and the instantaneous size of the air gap between the armature and the frame. This gap size is obtained from the output of the system at that time step, and is not available as a direct input to the system. In effect, there is a feedback loop between the model output and input. A possible alternative is to attempt to find an exact solution to the displacement equation by substitution or iteration. If a likely form for the solution is obvious, the displacement function can be guessed as a general solution and substituted into the equation. The constants in the general function can then by solved to determine the exact solution by comparing coefficients on each side of the equation. For example, a possible displacement function given a sinusoidal input might be

$$x=X_0+X_s\sin\omega t+X_c\cos\omega t \qquad (8)$$

which assumes three components of displacement – constant, sine and cosine. This method can become very complicated to solve for anything more than the most basic of equations. To simplify this method, the solution could be attempted in stages. The nonlinear force function can be simplified by assuming an initial displacement of zero. This linearises the force, and allows a first approximation to the displacement function to be found using the substitution method as described. This approximation can then be reverse substituted back into the force function to obtain a second linear approximation of force. This process can be repeated indefinitely until the displacement function found converge to an exact solution. Again, this method can become complicated to carry out, and in most cases the final solution is no simpler to understand than the system itself. The first approximation may give a general idea of the relationships between parameters but to get a more useful solution, another method is required.

Modelling the Loudspeaker Using SIMULINK

For modelling of nonlinear systems such as this, a useful package is the SIMULINK toolbox for MATLAB. This is a powerful mathematical programming language that aids the solution of complex problems using matrix manipulation. The SIMULINK extention module uses flow diagrams to aid the construction of models involving complex interactions between various elements of the system. A typical model comprises a mix of standard function blocks and user specified equations. Mathematical iteration can then be performed to determine the solutions to the system. The system is ideal for solving time series problems of the type encountered with this example.

The flow diagram for the loudspeaker can be developed during the examination of the system. By considering the processes that act on the input variable, in this case current, the flow through the system can be followed.

A complete model of the system can be built by translating each section of the flow diagram to smaller subsystems. Each of these sub-systems represent a particular stage in the transduction process and is defined by one of the equations developed earlier. Examination of these equations whilst considering the input and output parameters allow the sub-systems to be constructed from standard blocks from the SIMULINK library, such as gain, summation and linear differential equation.

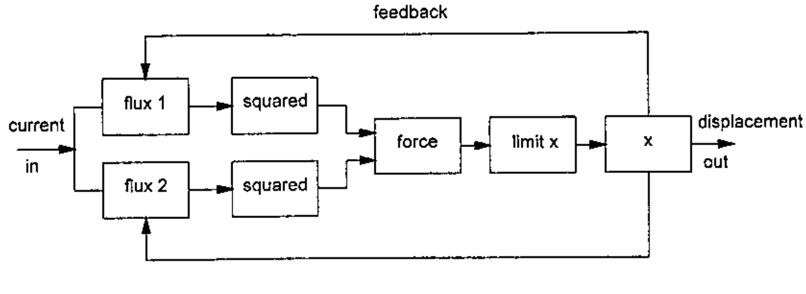

Fig. 3. Flow diagram of system

The links between these sub-systems can then be constructed in the same manner as the flow diagram. Complex interactions can be easily incorporated into the model, so the displacement feedback into the flux calculation is not a problem. The complete model can then be examined using a number of input functions (sinusoidal, square wave or white noise) and solved using one of a selection of numerical integration methods over the desired range. The output parameters can be stored as variables for later examination as time series or frequency response functions.

Confirmation of Model Using Experimental Measurements

Before a model can be used with any confidence, it must be confirmed as accurate. This is achieved by comparing results obtained from it with measurements made on a similar system. In many cases, the model will have been developed based on an existing loudspeaker, but if this is not the case, a prototype must now be constructed. The dimensions and parameters of the existing loudspeaker are measured and substituted into the model. Measurements of the loudspeaker response are then made and compared with the response of the model to the same conditions.

The model developed to simulate the balanced armature loudspeaker calculates the armature displacement for a given input current. In order to corroborate the results, the displacement of a real loudspeaker is required. This was obtained using a laser Doppler velocimeter to measure the displacement of one end of the armature when the diaphragm had been removed. The loudspeaker was driven with a sine wave input current of known amplitude and frequency. The mean displacement amplitude was then measured. By driving the loudspeaker at a range of frequencies and amplitudes, a full set of displacement amplitudes was obtained. The model was then solved for each set of conditions used. If accurate, the displacements from the model should be comparable with those obtained experimentally.

Figure 4 shows the rms displacement of the armature when driven at 1 kHz input voltage of known amplitude. The results show a linear increase in displacement with corresponding increase in voltage. The results obtained from the model using the same conditions are a good prediction of the experimental data. The results in Figure 5 were taken under the same frequency conditions as the previous set, but with an additional mass attached to the armature. This allows the accuracy of the model to be tested with respect to a parameter, other than frequency or voltage. The prediction is not as accurate as in Figure 4, but the trend is still apparent. Figure 6 shows the effect of a change in frequency of the input voltage. The linear relationship between input and displacement is still obvious, and the prediction of the model is still very accurate. A comparison between the 1 kHz and the 1.5 kHz results indicates a slight reduction in the displacement obtained at the higher frequency. In Figure 7 the major difference between the model and experimental results becomes apparent. As the voltage increases, the experimental displacement falls from the predicted levels. This is due to magnetic

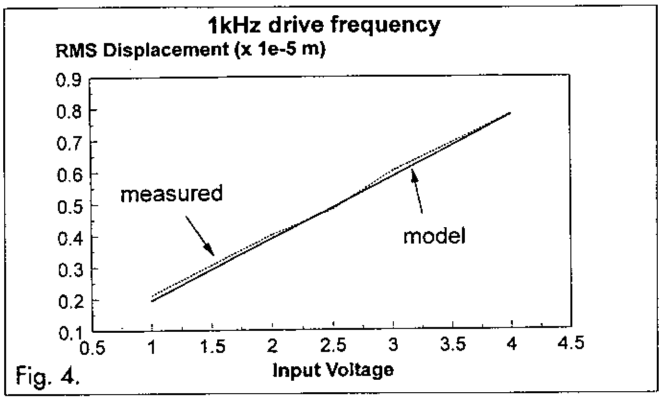

Fig. 4.

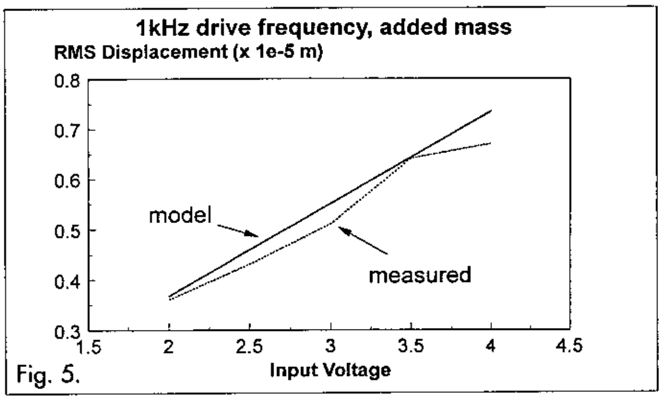

Fig. 5.

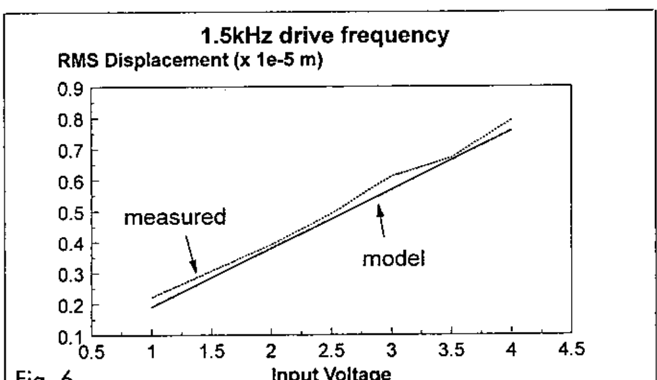

Fig. 6.

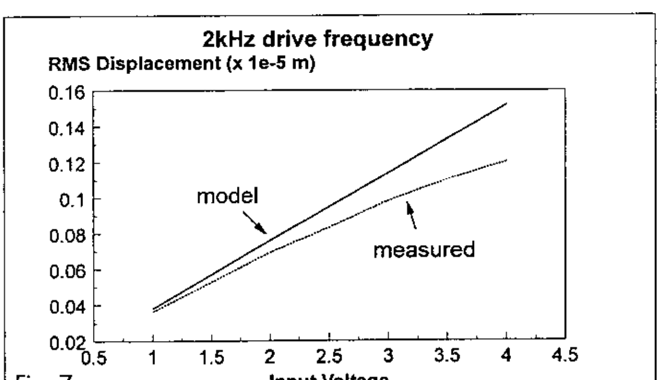

Fig. 7.

saturation which occurs in the iron frame at higher flux levels and is not considered in the model. It can be included by the addition of a saturation block to the flow diagram, but would require a detailed analysis of the magnetic circuits to determine the flux levels at which saturation begins to occur.

All the measured displacements, as well as those from the model, show a surprisingly linear trend. This is not as expected from the initial frequency response measurements. A possible explanation is the difference in operating conditions between the alarm unit and the experimental measurements. It was assumed that the loudspeaker was operated at such levels that the air gaps between armature and iron frame are never closed. The model is based on this assumption. It would appear that the current levels used in the alarm system are such that clipping – total closure of the air gaps – occurs. This would dramatically increase the high frequency content of the output signal and give the system a highly nonlinear appearance. The model can be adapted to take this clipping into consideration with the addition of a saturation block between the displacement calculation and the feedback loop, thus limiting the displacement to a specified range.

For the balanced armature loudspeaker, the method of modelling used gives results which agree very well with the experimental measurements made on the existing transducer. Where magnetic saturation of the iron frame occurs, the model begins to lose accuracy to some degree, but the model can be expanded to take this into account if the saturation point of the iron frame can be found. This can be done by carrying out a finite element analysis of the magnetic circuit, and would be useful as a final check of the model before the design is built.

Once the accuracy of the model has been proven, it can be used to redesign the loudspeaker by determining possible improvements that can be made. The model can be used to predict the effect that change in one or more parameters would make on the output. Within the given set of limitations for any loudspeaker, such as size, available power or acoustic loading on the diaphragm, the model can be used to determine the optimum set of parameters so as to give the best output available. The use of a model to aid the design process can be a great advantage, cutting development time and costs considerably. The confidence in any design can be vastly improved if an accurate model can be used to test the response of the system before any prototypes are made.

The accuracy of any modelling technique depends on the detail of the initial investigation of the system. Developing a model of any system requires a good understanding of the operation and accurate relationships between the parameters to be developed. In the majority of cases, any loss of accuracy in the final results can be traced back to this opening stage. Once equations of motion or similar have been derived, any model that is based on the implementation of these equations can be considered as accurate as the initial work. Approximations that are made during this examination may require alteration at a later stage, and features which were overlooked may be deemed critical to the operation of the system. By using SIMULINK to implement the model, improvements can be made and approximations adjusted at any stage with the addition or removal of blocks in the flow diagram. This flexibility makes this modelling technique ideal for situations such as the novel loudspeaker design, where the operation of the system is not entirely understood from the outset. The model can be developed simultaneously to the investigation and can easily be adapted as the understanding of the system improves.

Graeme Anderson and Martyn Hill are at the Institute of Transducer Technology, University of Southampton ❖

DEVELOPMENTS IN LOUDSPEAKER SYSTEM DESIGN

Martin Colloms

Introduction

It is seventy years now since the loudspeaker as we know it was first developed, an electrodynamic transducer of respectable loudness, of satisfactory and uniform amplitude versus frequency, reliable in use and with the potential for economic manufacture. That device is the familiar moving coil loudspeaker, whose principle is so effective that its key elements have remained essentially unchanged to this day.

To build one, take an affordable magnet and add a simple arrangement of magnetically permeable 'soft' iron to help concentrate much of the available magnetic flux into the narrow radial gap formed on a cylindrical pole. A small light coil or solenoid is wound onto a thin card or similar low mass former, and suspended freely in the magnetic gap, allowing axial motion of half a centimetre or so. Following Maxwell's electromagnetic equations, axial force is generated on the coil when a current flows through it. The instantaneous magnitude of the force in Newtons is given by the product *Bil, where B* is the magnetic flux density in Testa, *l* is the length of the wire immersed in that flux field and *i*, the instantaneous current flowing. The force relationship is fundamentally linear, and ignoring minor effects at high amplitudes of motion, where geometry of the coil and flux field may affect performance, there is no perceptible distortion. In fact there is no lower resolution limit for a moving coil transducer. An infinitely small electrical input will produce an equivalent and infinitely small sound output. Another excellent feature of the moving coil transducer, generally taken for granted, is that despite its operation as a moving mechanical device, it is essentially noiseless. It does not grate, or scrape or whirr.

Apply a sub-audible 5 Hz sine wave current and you can see the coil move, but silently. It is these fundamental strengths which makes the moving coil principle so effective, and so justly popular. Over 99% of all loudspeakers ever made are moving coil. The principle may be used over a very wide range, from low power speech reproducers of just 2.5 octave bandwidth and a modest 75 dB of sound pressure level output, built on a frame just 40 mm in diameter, up to low frequency monsters of 60 cm diameter, capable of generating 20 Hz sound waves at body shattering 110 dB pressure levels. Used alone, the moving coil itself generates almost zero sound output as the radiated sound level is proportional to the area of air load driven by the transducer element, and for the coil alone that is merely a thin ring element.

To couple the moving element more effectively to the air load a rigid, light diaphragm is attached to the coil. Typically, larger diaphragms have their own flexible surround suspension, coupled to a skeletal support frame or chassis, thereby aiding centration of the moving system.

Paper is a suitably strong and lightweight material for a diaphragm. As a flat sheet it is stiff in tension but very weak in bending. However, curl it up to form a cone and this structure exhibits an extraordinary axial stiffness for its mass, a marvellous means of coupling a large area of air load to the moving coil. The latter is bonded to the cone apex.

Acting as an impedance transformer the cone matches the lower acoustical impedance of the air load to the high driving force impedance of the coil, maximising the energy transfer in the path from electrical input to mechanical force, leading to radiated sound pressure.

In specialised smaller drivers optimised for high frequencies, the cone may be replaced by a light dome formed of paper, moulded sheet plastic, resin doped fabric or metal foil. In sizes down to 19 mm effective radiating diameter, the frequency response may thus be extended to beyond audibility, up to 40 kHz. By apportioning the audible frequency range, appropriate combinations of moving coil driver sizes may cover a frequency range of 10 Hz to 40 kHz; a ratio of no less than 4,000 to 1 in acoustic wavelength, 34 metres to just 8.5 mm.

Loudspeaker systems with such a wide range are actually made today for costly high fidelity installations, the near twelve octave span being achieved with typically four, frequency dedicated, moving coil drivers. Such systems can cost as much as an implausible £30,000, whilst the humblest moving coil speaker element for speech use only may cost as little as £0.15 in trade order quantities.

When the diaphragm of a moving coil driver is appropriately horn loaded, the horn further improves the matching efficiency between air load and transducer. It is then possible to stretch the conversion efficiency to almost 50% compared with the typical 1% efficiency of a high fidelity speaker. With horn designs a fairly easily obtained 40 electrical watts will result in a seriously loud 20 acoustic watts, sufficient to effectively address large audiences at realistic volume levels.

The moving coil driver has proved to be remarkably durable with many examples operating for 50 years and longer. Like the wheel, alternatives have been proposed, but it still reigns supreme.

It seems new inventions appear almost monthly in the loudspeaker field, many claiming to supplant the moving coil. However, no serious rival has as yet emerged to challenge it, and it remains pre-eminent in terms of efficiency, economy, wide performance range and application.

While this review concentrates on the moving coil

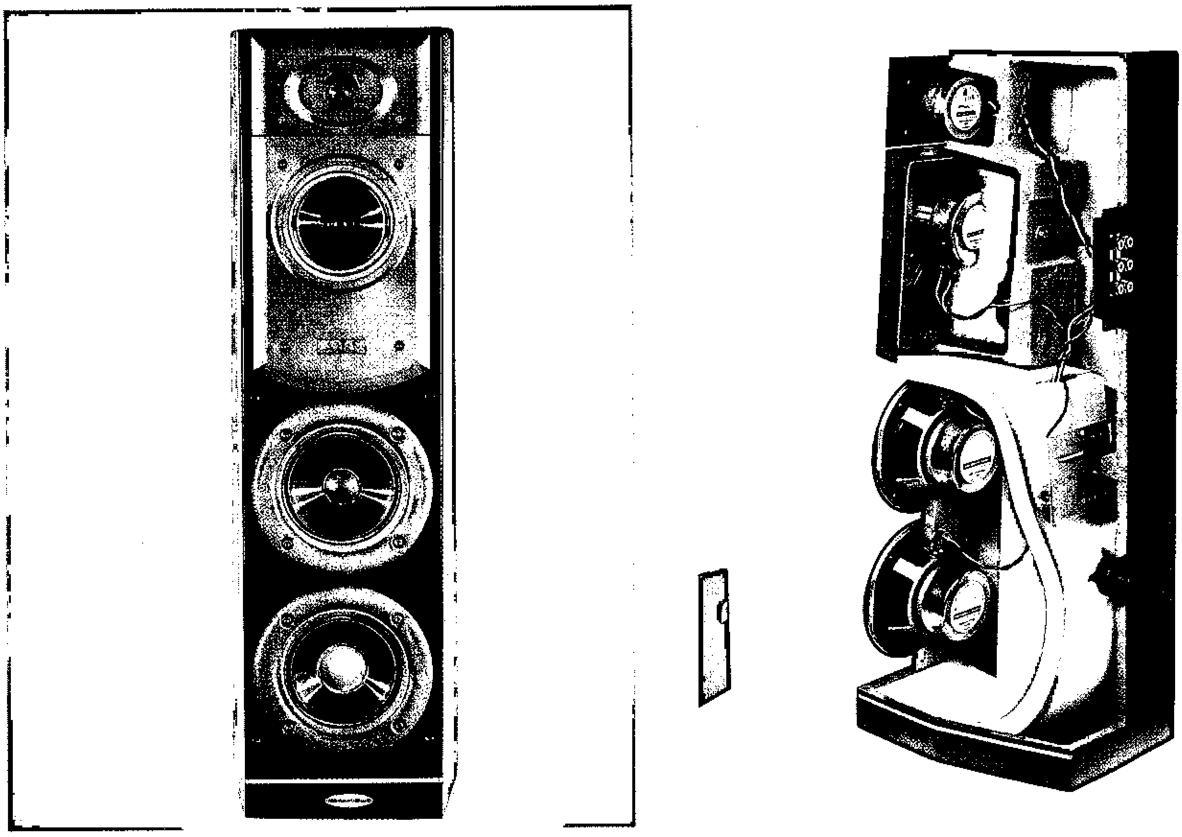

Fig. 1. Mordaunt Short Performance 860, showing mineral-loaded resin enclosure construction
(Photos courtesy of Hi-Fi News & Record Review)

applied to loudspeakers, the principle is also widely used in precision actuators such as the high speed focus and fine tracking mechanisms for laser optical heads, compact disc and optical data discs. It is also used for the most popular form of microphone, and not least for almost all headphones and earpieces, as well as for many related communication systems.

Looking at the past decade of loudspeaker design in the high quality, high fidelity field, there have been significant developments in enclosure technology; in cone diaphragm materials; in system design, and in the understanding of the acoustic properties of the typical rooms in which loudspeakers are used.

System Design

Given the extreme difficulty in attempting to cover the whole audible range with a single drive unit, a high quality speaker will of necessity comprise a system composed of an enclosure, several optimised drivers (frequency range specified), and a crossover network – a passive (ie non-powered) set of filters which direct the correct input frequency range to the appropriate drive units.

System design is the process of creating a loudspeaker which meets the target specification, both technically and subjectively. The enclosure must provide the right non-resonant support, internal and external acoustic loadings as well as the required style, appearance and finish.

Drivers must be chosen or custom designed to meet this system specification, not just for fundamental aspects such as sensitivity, power capacity and bandwidth but also with regard to the unique cone characteristics and how the resulting natural acoustic 'signature' are weighted and valued in the final sound. In addition driver size has a significant influence on frequency range and output power and also controls the directive properties according to frequency. Ideally, there should not be too great a difference in effective acoustic size at the crossover point between adjacent drivers. Otherwise, a step may occur in the off-axis frequency response and in the related power response through the crossover transition.

Some of the variables involved in system design are extraordinarily subtle and prove a source of continuing frustration for inexperienced designers. For example, long known but often overlooked, is the surprising sensitivity of overall sound quality to small changes in high frequency level relative to the mid-band. The upper crossover between mid and treble is usually placed in the 2.5 to 3.5 kHz region.

The correct, critically natural timbre for human voice, violin, acoustic guitar and the like can only be achieved when the high frequency energy is within ± 0.5 dB of the ideal target. This is rather smaller than the tolerances available for both measurement and for driver production.

If the treble range is set too 'dull' the loudspeaker system can sound too warm, veiled and muffled, lacking a sense of both air and atmosphere. Set too bright, and the result may be a sharper sound, perhaps attractive on percussive sounds but adding a 'nasal' effect to voices as well as imparting a hardened coloration and a sibilant emphasis. Vocals may also sound too close. Violin acquires a steely harshness and may dominate the instrumental grouping. In stereo reproduction the sense of depth in the image illusion is generally impaired when the treble is set too bright.

Unfortunately a touch of treble brightness helps counter a lack of definition and clarity in the mid range and many designers resort to this damaging short cut to superficially better performance.

Over the past decade we have seen a shift away from the relatively inflexible textbook approach to system design, one where frequency ranges are neatly compartmented, to a point where designers now have a far greater awareness of the broad interaction which takes place viewed via the subjective interface.

Assessing sound quality is a significant discipline, and despite a critical awareness of the many technical factors affecting the sound, it is well nigh impossible to separate or filter them out sufficiently to give precise definitions for the many associations between the objective and subjective factors.

For example two views may be obtained for the overall frequency balance of a given loudspeaker, and in this context the word 'balance' is of particular relevance. One critic describes it as 'bass light', while the next as 'treble bright'. The measuring microphone has no trouble in making the correct identification but it cannot take into account human perception which seeks a balance. In this latter context both critics are in fact correct.

On some programme material excess treble may well be heard as a lack of bass weight or balance, while on another the treble error may be recognised directly.

For the designer there are some interesting options. He or she could readjust the treble but might find the resulting sound less satisfactory perhaps due to deficiencies in the mid range. Alternatively, they could look to improve the low frequency performance and thus help to redress the overall balance.

In some designs this is surprisingly easy and may involve no more than a percentage reduction in the amount of acoustically absorbent stuffing in the enclosure, and/or a reduction in the length of the reflex port duct, if such an acoustic low frequency equaliser is fitted.

Increasing awareness of the global scope of design parameters allows today's designers to take a less dogmatic view of system design, and exploit more subtle blending and balancing methods for driver output. Aware of the need for subjectively accurate timbral balancing in the face of insufficiently accurate measured frequency responses, designers continue to use measurement as a development tool but nonetheless rely on critical listening to help bend the response curves to their intention.

To this end drive units are now designed to operate more smoothly over wider bandwidths. Designers are taking advantage of this and are reducing the complexity of their crossover networks. A decade ago manufacturers proudly boasted of the high complexity of their passive networks, highly toleranced and fully compensated for input impedance as well as for driver acoustic variation. It is now felt that such complexity runs counter to percieved naturalness, and to the ability of a good recording to communicate the composer's musical message to the listener via the loudspeaker.

Thus those 40 and 50 element crossover filters are gradually being supplanted by much simpler arrangements offering a more direct link between amplifier and drive unit.

In one exceptional example, a high quality three-way speaker system, aided by naturally well tailored intrinsic driver responses, was completed with only three elements in the crossover network. Ten years ago the design would have used typically 10–12 elements without, and 30 elements with, impedance compensation.

Physical and Acoustic Performance

Regarding physical and acoustic properties, loudspeaker designers are still busy trying to improve the uniformity of frequency response, not just at one, more or less arbitrary axial point, but over a range of angles and distances. Their aim is to generate a neutral energy balance over a forward directed solid angle encompassing the listening area. Target beam shapes are ± 10 or ± 15 degrees in the vertical plane, and ± 25 or ± 35 degrees in the horizontal plane. There is a continuing requirement to reduce enclosure size to improve acceptability in the domestic environment, especially in view of multi-speaker surround sound applications and and home cinema developments. This size reduction is in conflict with the quest for greater low frequency extension and uniformity, one of the major factors that distinguishes real hi-fi from mid-fi. There is also a trend towards genuinely higher efficiency leading to higher maximum sound levels, also in conflict with smaller enclosure sizes. The market expects speaker systems to operate at increasing loudness without a commensurate increase in input power and preferably without adverse consequences, such as a compromised electrical loading on the amplifier.

Sensitivity and Impedance

One of the anomalies in specification concerns sensitivity. Objectively, sensitivity is accepted as a measured sound pressure level at a one metre distance where the input voltage is 2.83 v rms, corresponding to one watt into a standard 8 ohm resistance. By implication there is an association with efficiency in its pure sense. However, very few loudspeakers have a uniform 8 ohm loading over their working frequency range. Even the standard allows for a range between 6.4 and 10 ohms, such variation by implication associated with reactive regions where the load impedance passes through resistive, inductive and capacitative values. In practice loudspeaker systems exhibit impedance peaks well beyond 10 ohms, often to 50 ohms, but these are considered to be harmless since they do not prejudice the nominal sensitivity value. Frequency regions where the impedance falls significantly below the 8 ohm mean are prejudicial. Firstly, designers may deliberately choose to ignore the standard and work to a lower impedance, so stealing greater current from the source amplifier; (in practice, this is a voltage source of negligible output impedance and thus capable, within limits, of providing greater current on demand). Greater current provides higher sound levels and thus a superior voltage sensitivity.

Unfortunately there is a penalty to pay here. Higher currents lead ultimately to nonlinearity in the magnetic components of the driver. It is possible to generalise loudspeaker distortion as being strongly dependent on input current and not on the more obvious parameter, sound level. In addition cables and amplifiers are subjected to higher stress; indeed, the complex nature of the electrical input impedance of loudspeakers may evoke premature current limiting or protection in the driving amplifier.

Thus, for a loudspeaker good voltage sensitivities, uncompromised by significant regions of low impedance, are to be encouraged.

Enclosures

Advances in enclosure design have been numerous. Undeniably the trend is towards heavier, more rigid construction with a double purpose – firstly, to control and minimise spurious resonances in the enclosure panels and structure, and secondly, to provide an inertial platform against which the moving coil drivers may reference themselves. If their foundation – the termination for their chassis/structure – is not solid or of sufficient mass, then the motion of the moving system will carry reaction errors. It is surprising how subtle those errors can be and still remain audible. For example, the tightness of the fixing bolts attaching a driver frame to an enclosure panel is a significant factor affecting clarity, colouration and the subjective naturalness on dynamics, the loudness contrasts heard with live sound. The difference between 'just tight' and correctly torqued may only be a matter of a quarter of a rotation in a wood or wood composite panel, yet the resulting change is often audible and significant.

MDF board has generally eclipsed older plywood and chipboard panels for enclosure construction, while complex internal bracing, effective in several planes, is commonplace. Bracing is intended to subdivide the panels into smaller unequal areas so helping to disperse the natural acoustic resonant signature of the panel. The critical importance of this aspect can only be appreciated with the understanding that even in the case of costly speaker designs, much of the false tonal 'colour' in the sound of a speaker system is still due to the enclosure and not the drive units or the crossover.

Treatments may also be applied to enclosure walls such as layering with tough phenolic laminates or with steel plates. Fibrous bitumen loaded pads offer a high mechanical resistance, effective in damping higher frequency modes.

More recently catalytic polymer resins have become available, with useful properties for loudspeaker enclosure applications. Heavily mineral loaded, the polymer mix endows the easily cast material with stiffness, mass and resonance damping. The results are encouraging and good examples show a welcome absence of woody panel sounds, hitherto a generally accepted component of loudspeaker performance, see Figure1.

Enclosures are now keyed to the floor on which they stand via hardened steel spikes, with sufficiently narrow points to pierce the usual carpet [though not your best Persian!] and thus engage the floorboards beneath. Surprising improvements in overall system definition and stereo focus result from the improved stability of the enclosure location. For tiled floors, thin felt pads are optimal; any untoward elastic coupling results in audible and measurable secondary resonances between enclosure and floor. For highly critical use some installations at ground level have apertures cut in the floor, with the loudspeakers mounted on brick piers supplied with their own unit foundations.

The external appearance of enclosures is also changing. Reduced diffraction is important; edges are bevelled or rounded, and overall shape may include tapered surfaces to enhance the smooth wavefront of the acoustic output and reduce secondary stray or parasitic sources such as re-radiation from sharp edges or corners. These can impair stereo image focus and add audible roughness to the treble range.

A slant or angle to the front panel may help compensate for differential time delay between the multiple drive units at the listener position improving phase response and acoustic integration through the crossover regions.

Drive Units

The widespread use of metal diaphragms is the most obvious development in high fidelity loudspeakers. While paper or pulp cones are still popular and widely used at all quality levels, the goal of a resonance free, pure piston performance for the cone still fascinates designers. Distortions arise when a typical polymer or pulp cone material flexes in its naturally resonant regions. This error occurs because these materials do not have the properties of linear springs. With these materials, often chosen for their good internal damping, deflection is not directly proportional to force. Several higher order terms are required for the force equation, these quantifying the nonlinearity. Nonlinearity implies the generation of false sounds together with some shift in energy from the fundamental to the harmonics. Changes in perceived timbre may result, together with a masking effect for other lower level sounds in the harmonic masking range. Thus distortion from mid-range sounds can mask quieter fundamental signals in the treble.

Certainly there are other sources of distortion but these can be satisfactorily dealt with, for example, through improvements in magnet and coil design.

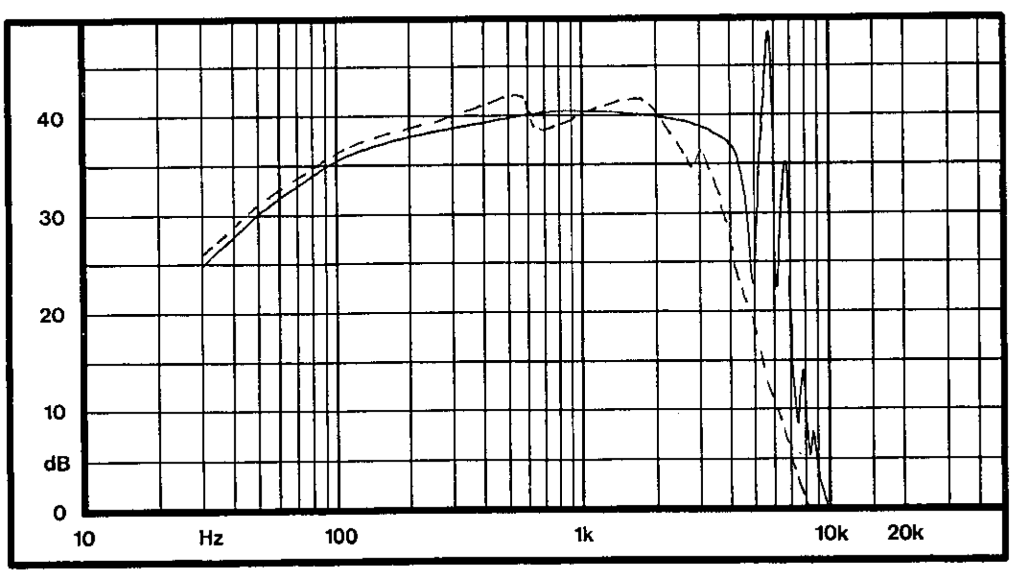

Fig. 2. Comparison of polymer and metal cone frequency responses in a low diffraction enclosure
(- - - - polymer ———— metal)

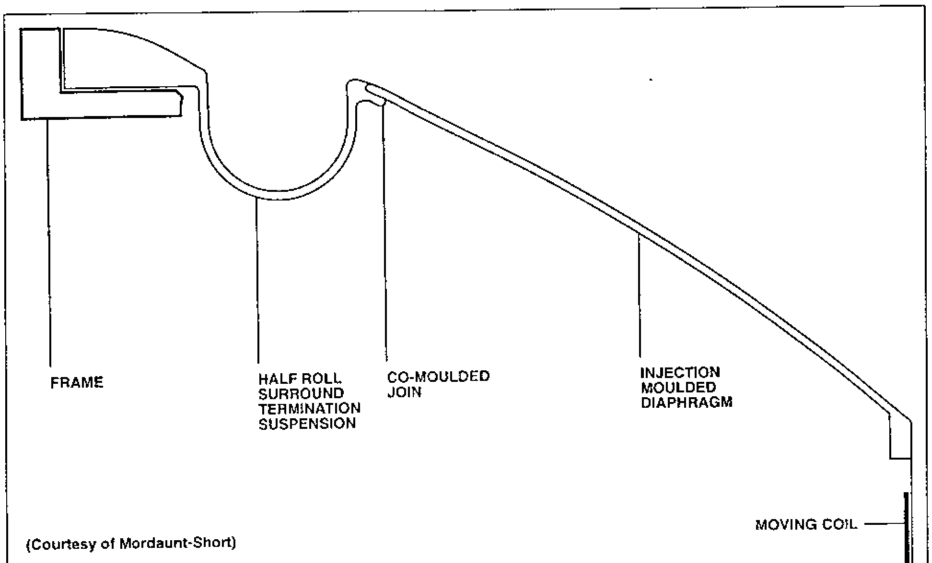

Fig. 3. Injection co-moulded polypropylene cone/nitrile surround for a moving coil diaphragm

The adoption of formed sheet metal for the diaphragm usually a light alloy, typically based on aluminium or magnesium, provides such a high stiffness that the natural resonance modes [typically 700 to 1.5 kHz for a conventional cone] are pushed up to the 5 kHz to 7 kHz region usually beyond the crossover point for a multi-way speaker design.

When a metal cone 'breaks up' and enters partial resonance, it does so with greater vigour because of the much lower mechanical losses compared with polymer or pulp constructions. What may be an amplitude 'bump' or 'glitch' of 1 to 3 dB for a high quality plastic cone will now appear as a significant resonance peak, 8–12 dB high, see Figure 2.

In return for that transparent, distortion-free, linear performance in the range below resonance, the designer must suppress that resonant peak if it is not to interfere with the performance of the usual high frequency drive unit married to it via the system crossover network. It is thus customary to fit a special filter to trap electrical input at the main cone resonance.

While metal cones are often considered a recent development, and are increasing in popularity, light alloy cone drivers were in fact developed at the audio division of GEC as long ago as the late 1950s and also by Jordan in the 1960s. Smaller pressure drive units for horn loaded public address systems have also used metal foil diaphragms for many decades.

Other developments include modern, high tensile strength, low mass fibres used in moving coil driver cones, either as a woven formed matrix reinforced with a catalytic bonding resin, or as a reinforcement to an existing diaphragm structure. Early trials with glass fibre have more recently given way to Kevlar and carbon fibre forms.

Another goal for the drive unit designer has been realised in recent years. Conventionally, polymer cones were made by hot forming a sheet of thermoplastic – bextrene, vinyl or polypropylene for example. This technique tended to thin the regions of greater stretch – the apex – and left the cone rim near the original thickness. This is precisely the opposite of what is required, namely a strong stiff driving point at the apex, the point of attachment to the moving coil, and a lighter, thinner and more easily driven region leading out to the edge.

Only recent advances in moulding precision, and the development of a free flowing, mineral reinforced, hard setting grade of polypropylene have allowed the development of close tolerance injection moulded cones. These have a near ideal mass and stiffness distribution. An addi-

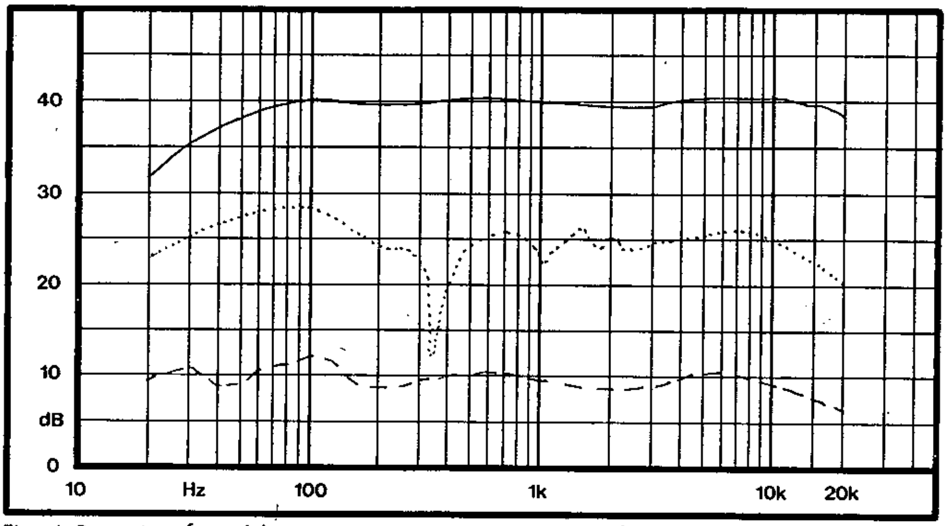

Fig. 4. Room interface. $^1/_3$ octave measurements, average of multiple microphone positions
Loudspeaker position: —— in free field (anechoic) ········ in corner (worst case) – – – – in optimum location (0.3:0.7:1) (Curves are vertically separated for clarity)

tional bonus has been the successful addition of the surround suspension, simultaneously co-moulded in the same operation. The result is higher performance polymer cone assemblies of greater consistency and significantly lower cost, see Figure 3.

The Room

Although the acoustic design of domestic listening rooms has not altered appreciably, we have improved our understanding of the way that this limited space is used.

Designers are now aware of the effects of local boundaries proximate to a positioned loudspeaker system; for example there is destructive interference in the lower mid-range resulting from out of phase reflected acoustic images. It is also possible to find augmentation at still lower frequencies where the reflection is now in phase, thanks to the larger wavelength providing good coupling.

The relative contribution of the floor, rear wall and side wall reflections can be accounted for in a practical way. Stable stereo images are aided by good left-right symmetry in placement, this including the precise angling and positioning of the loudspeakers in the room.

Cognisant of an 'acoustic centre' for a given speaker system, the most uniform low frequency drive to the room will be obtained if the distances from that 'centre' to the three nearest boundaries are displaced in an inharmonic relationship, eg the golden ratio for optimum listening room dimensions. By this means adverse standing wave modes resulting in errors in room/speaker frequency response of up to ± 8 dB may be subdued to a satisfactory ± 3 dB (weighted in $^1/_3$ octave bands) as in Figure 4.

Designers now work to such a criterion helping to achieve more uniform frequency response in real rooms and not the artificial text book design conditions of 2 or 4 steradian anechoic spaces.

Conclusion

The past decade or so has seen a significant consolidation of loudspeaker design and technology rather than the introduction of radical new inventions in the field of sound reproduction.

Such consolidation is primarily directed at the most enduring and effective sound transducer principle, that of the moving coil unit, which continues to satisfy requirements in a wide range of applications, from the least to the most expensive.

It appears that the ubiquitous moving coil loudspeaker might well be serving the audio community for another seventy years!

Martin Colloms is a journalist specialising in hi-fi publications. ❖

STRUCTURE-BORNE SOUND – THE UNHEARD ACOUSTICS

Andy Moorhouse MIOA & Barry Gibbs FIOA

Introduction

The understanding of airborne sound transmission problems of all sorts has improved greatly over recent years to the point where reliable assessments are carried out routinely by consultants and local authorities etc. By comparison, the understanding of structure-borne sound is at a relatively low level, and a large number of bodies are not well equipped to deal with such problems. Unfortunately, the view still persists among many noise control engineers that structure-borne sound is only of relevance as low frequency vibration and that the only means of noise control is by use of resilient mounts. In fact, structure-borne sound is important in a broad range of noise problems as will now be seen.

First, it is useful to define the term 'structure-borne' sound. The term simply indicates that the medium of transmission is some solid structure rather than air (as in airborne sound). The term 'sound' was originally used when only audio frequencies were of interest, although today it is used to encompass all cases involving human perception, including tactile vibration below the audible frequency range. 'Structure-borne sound' thus encompasses the physical phenomena of structural vibration and acoustic radiation, but implies that human perception of the disturbances is of importance.

Consider now some of the most common means of noise generation: impact, out-of-balance forces, air turbulence, fluid flow, magnetostrictive forces, and stick-slip friction. Of these six primary noise generating mechanisms only turbulence is exclusively airborne in nature. In other cases, structural vibration plays a vital, often dominant role. For example, in impact noise from a slamming car door, most sound energy is radiated from the structure which both provides a relatively large radiating surface area, and acts as a resonant energy store. Similarly, fluid flow noise in pipes is frequently only a problem because the pipe is attached to a central heating radiator which also acts as an efficient acoustic radiator. In these examples, and in all cases of out-of-balance forces (eg fan casing noise), magnetostrictive forces (eg transformer noise) and stick-slip friction (eg brake squeal), all the sound energy is first transmitted through, and radiated from some solid structure before it reaches our ears as airborne sound. The logical, but sometimes surprising conclusion is that the majority of sounds exist in the form of structural vibration before we hear them as airborne sound. Thus, far from being exclusively a low frequency phenomenon, structure-borne sound plays a vital role in shaping most everyday sounds across the entire audio spectrum.

It follows that an understanding of the generation and transmission of structural vibration, as well as the radiation of sound from structures is vital to the noise control engineer. The objective of this article is therefore to provide a brief overview of structure-borne sound, followed by a review of the state of current research into the least well developed aspect, namely characterisation of structure-borne sound sources.

The Source-Path-Listener Model

The source-path-listener model, as illustrated in Figure 1, has been widely and successfully used as a framework for prediction and diagnosis of airborne noise problems. (It will become clear later why we are using the term 'listener' rather than the more common term 'receiver'.) In reverse order, the 'listener' can be characterised by design or acceptance criteria as illustrated in Table 1. Almost always the criterion is set in terms of the sound pressure level at the ear of the listener, but may be given a variety of possible frequency and statistical weightings. The 'path' can be viewed as a succession of attenuations (sometimes amplifications) and Table 1 lists the typical factors which are taken into account in various situations. All path attenuations can be quantified, many by standard methods as illustrated. The source is characterised, for all common cases, by its sound power, and measurement and portrayal of this important quantity is well covered in national and international standards.

Looking at the right-hand column of Table 1 which illustrates the comparable situation for structure-borne

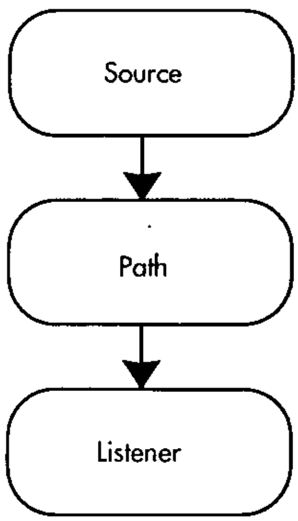

Fig. 1. Source-path-listener model

sound, things are much less well defined. Again in reverse order, the normal airborne sound criteria apply for acceptance levels at the listener. Vibration criteria might also be given, and although some standard means of assessment do exist for vibration in buildings (BS6472) and for hand-held tools (BS6842) experience in this area is less well developed and detailed than for airborne noise. Looking at the path attenuations in Table 1, the basic theory of attenuation by structural discontinuities has been established for some years [1]. Damping and radiation impedance have been extensively studied, and there is an increasing bank of experience in this area. However, sound propagation in structures is complicated and the appreciation and understanding in this field remains several years behind that of airborne sound transmission. It is partly for this reason that few standards exist relating to propagation of sound in structures.

When looking at the 'source' entry in the top right-hand corner of Table 1 a fundamental problem is exposed; how is the source of structure-borne sound to be characterised? At current state of the art there is no universally accepted answer to this rather fundamental question. Therefore, the remainder of this article is focused on reviewing the available knowledge in characterisation of structure-borne sound sources.

How 'Noisy' is a Structure-Borne Sound Source

By a structure-borne sound source we really mean a vibration source, but where the source stops and the supporting structure starts depends on the context. For example, consider Figure 2a showing a typical air handling unit (AHU) installed in a building. The installer of the AHU would like to know whether the levels of structure-borne sound it generates within the building are acceptable, and to them the entire air handling unit constitutes a single source. On the other hand, the designer of the AHU might consider two sources, the motor and the fan (Figure 2b). They might wish to purchase the quietest (in structure-borne terms) motor and fan on the market to help them produce a low noise AHU. Looking in still more detail, the motor supplier, wishing to gain a commercial advantage by producing a quiet motor, might consider buying in low noise bearings, and so to them the bearing and armature assembly is a structure-borne sound source (Figure 2c). In the above cases the same fundamental problem exists – how is the noisiness of the source to be characterised? On what basis does the installer select an appropriately quiet AHU, the AHU designer a suitable motor, or the motor manufacturer a suitable bearing? Or viewed from the supplier's side, what information can the suppliers of the bearings, the motor and the AHU provide to facilitate these decisions?

In the case of airborne sources the answer is relatively straightforward; the source is characterised by its sound power. Although a spectrum is required the sound power is essentially a single figure characterisation which represents the strength of the source at a given frequency. From the equipment suppliers point of view sound power is a readily measurable, independent property of their equipment which can be published in product specifications and provides a benchmark for development of quieter designs. From the purchasers point of view it provides sufficient information both to allow comparison of competitive products and calculation of the effect on people when installed in a given environment (although sometimes more detailed information such as directivity is also required). Unfortunately, it is impossible to characterise structure-borne sources in such a comprehensive, yet convenient way.

The nearest equivalent to sound power in structure-borne terms is the 'structure-borne emission', that is the power which is injected from the source into its support structure, (which we will call the receiver structure) through the contact points, see Figure 3. It is reasonable to assume that subsequent vibration and sound radiation is proportional to the power injected into the receiver structure in this way, and most authorities now agree that

	Environmental Noise	In Buildings	Duct Systems	Structure-Borne
Source Characterisation	Sound Power (BS4196, BS7703 etc)	Sound Power (BS4196, BS7703 etc)	Sound Power (BS848)	?
Path Attenuations	Distance	Distance	Discontinuities (CIBSE Guides)	Structural Discontinuities
	Ground Absorption (ISO/DIS9613, CRTN)	Absorption (BS3638)	Absorption	Damping
	Wind/temp gradients (ISO/DIS9613, CRTN)	Reverberation Time (ISO3382)	Attenuators (ASTM) E477-80)	Radiation Impedance
	Barriers (ISO/DIS9613, CRTN)	Transmission Loss (BS2750)		
	Reflections (ISO/DIS9613, CRTN)			
'Listener Criteria'	L_{Aeq}/L_{A10} etc	NC/NR etc	NC/NR etc	Noise L_p at ear as appropriate Vibration (BS6472/ BS6842)

Table 1

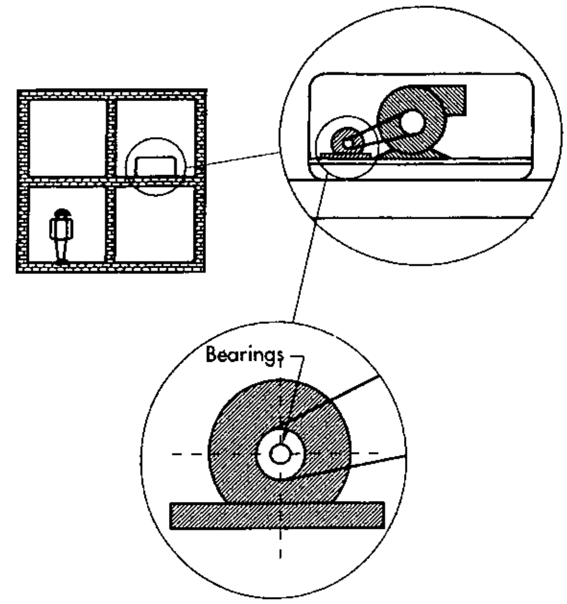

Fig. 2. Illustration of structure-borne sound sources

this is the best representation of the source strength.

However, when the source is separated from the receiver structure we see that no power can be delivered (Figure 3b), in other words the structure-borne emission is zero. Furthermore, connecting the same source to a different receiver structure we get a different emission (Figure 3c). We have all had experience of this where, for example, a typewriter is noisier when placed on some tables than on others. An illustrative example is given in Figure 4, where the same source was placed at two positions on a floor, one away from the edges and the other over a supporting wall. The emission was found to be up to sev-

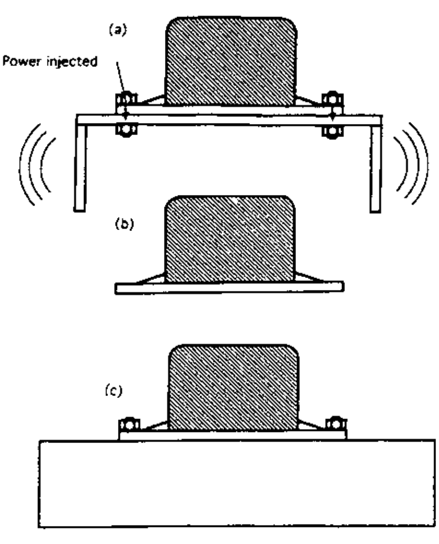

Fig. 3. Structure-borne sound source connected to different receiver structures

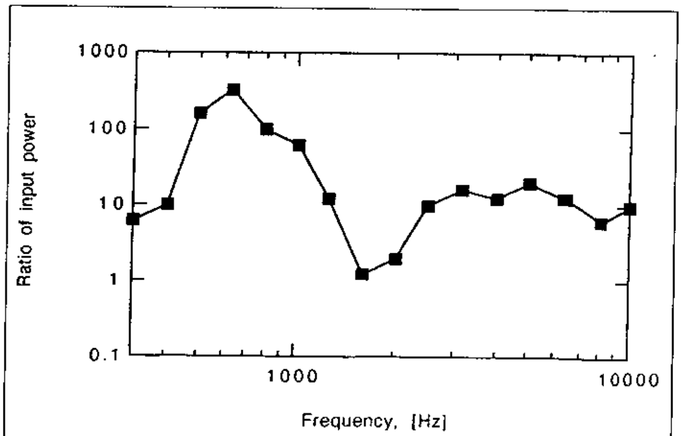

Fig. 4. Ratio of structure-borne sound power emission for a source at two locations on a floor; after Petersson [14]

eral hundred times greater in the former position even though the source itself was unaltered, as seen by the ratio of the emissions in Figure 4.

The above leads us to the important conclusion that the emission from a structure-borne sound source is not an independent property of the source but depends also on the receiver structure. This difficulty does not arise in the case of airborne sound sources because the receiving medium, the air, is to all intents and purposes invariant. It follows that, unlike the airborne case, we cannot characterise a structure-borne source by its emission, and conversely, no independent property of the source can directly give the emission because emission depends on both the source and the receiver structure. Failure to recognise this fundamental difference between airborne and structure-borne sound sources is a continuing cause of much confusion and many wasted measurements.

Since we cannot use the emission to describe a structure-borne sound source we have instead to 'characterise' both the source, and the receiver structure separately in such a way that the emission obtained when the two are connected can be calculated. At this point it is helpful to clarify a few concepts and introduce some definitions.

Definitions and Redefinitions

The general field of structure-borne acoustics is complicated by the large number of terms used a term such as source strength often confuses rather than clarifies. The following definitions (which are not necessarily standardised as yet), shown schematically in Figure 5 may help to identify the mechanisms involved and how they can be measured.

Activity is the process where internal dynamic forces in a machine produce the vibrations at the external surface of the machine or at the contact points. It is not practical, or necessary to measure these internal forces directly, but the activity can be represented by the velocity (vibration) at the contact points when the machine is operating in a 'freely suspended' state, which in practice means when it is supported on soft springs. This velocity is known as the free source velocity and is an independent property of the source. There now exist standard methods of measurement [2] [3], and it is hoped that this will encourage wider use and availability of free velocity

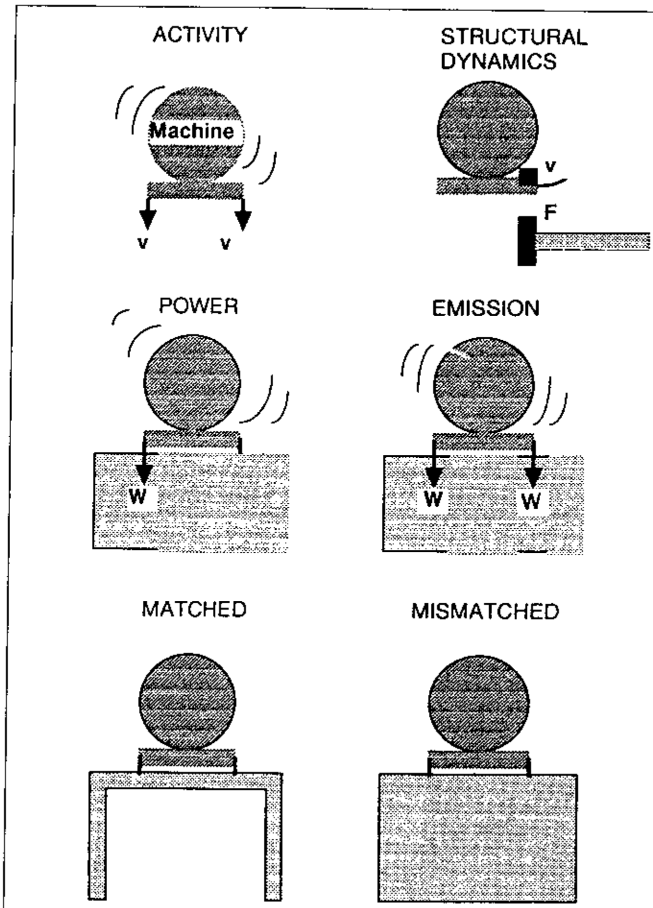

Fig. 5. Terminology

data such as in reference [4]. Various other indicators of activity are possible, but are less useful overall and will not be discussed in detail here.

Source structural dynamics is the additional quantity required of the source. It is measured as the mechanical impedance or more conveniently its inverse, the mechanical mobility, at the contact points. Mobility, Y is a measure of the willingness of a structure to respond to an applied force, expressed as the complex ratio of velocity to applied force, $Y = v/f$. Massive and stiff structures have relatively low mobility, whereas light and flexible structures have a high mobility. The mobility of structures can be calculated by various methods, (see for example [1], [5], [6]) including finite and boundary element methods, or measured (see for example [7], [8], [9]) but a review of this topic is beyond the scope of this article.

Matching is the indication of how effectively vibrations, which are a result of the source's activity will transfer into the receiver structure [10]. It is however, a function of the structural dynamics of the source and receiver and is independent of the source activity. It can be expressed as a ratio of the mechanical mobilities.

Power is the vibrational energy flow through an individual contact point into the receiver structure. Emission is the total power from the source into the receiver structure. It is the quantity of most interest since it represents the energy available for causing unwanted vibration or radiated sound. Emission increases with increased activity of the source, and with increased matching between source and receiver.

CALL FOR PAPERS/AGM

Planning Policy Guidance and Noise

(Organised by the London Branch and the Environmental Noise Group)

incorporating

1996 Institute AGM and Annual Dinner

Church House Conference Centre, London

Wednesday 17 April 1996

The DoE publication, PPG 24 Planning and Noise, has been in place now for more than a year and users have had sufficient time to gain experience in its implementation. This meeting offers an opportunity for representatives of local authorities and developers to air their views and for noise consultants to share their experience of implementing its provisions.

The organisers of this meeting seek contributions in any of the following areas:

- Interpretation of the noise exposure categories for roads, railways, air traffic and mixed sources and comparison with other noise criteria

- Case studies illustrating the implementation of the provisions of the PPG, as experienced by:
  - The developer
  - The local authority
  - The noise consultant

Intending contributors should send a 100-word abstract to the address below, indicating whether the paper is to be refereed. Abstracts should be received by 17 January 1996. Papers will be published in the Proceedings of the Institute of Acoustics, Volume 18 (1996) and a bound volume will be available to delegates at registration.

Meeting organisers: S W Turner, TBV Science and J Simson, W S Atkins Environment
Abstracts to S W Turner, TBV Science, The Lansdowne Building, Lansdowne Road, Croydon, CR0 2BX Tel: 0181 256 4800 Fax: 0181 256 4862

Institute of Acoustics, 5 Holywell Hill, St Albans, Herts AL1 1EU. Registered charity no 26702
Tel +44 (0)1727 848195 Fax +44 (0)1727 850553 email Acoustics@clus1.ulcc.ac.uk

CALLS FOR PAPERS

Low Frequency Noise
May 1996
London venue

Low Frequency Noise (say, 10 Hz to 250 Hz) continues to be a problem in both the home and work environments. This meeting is intended to give a forum for the discussion of all areas of Low Frequency Noise ranging from sources and control to physical and psychological effects in the home and effects on comfort and productivity in the workplace.

Papers are invited covering the following and other areas:

- Investigations of Low Frequency Noise
- Sources and occurrence
- Physical and psychological effects
- Low frequency noise and sound quality
- Propagation in buildings and building services (HVAC)
- Control of Low Frequency Noise at the source
- Control of Low Frequency Noise by absorptive, reactive and active means

Intending contributors should send a 100-word abstract to the meeting organiser below, indicating whether the paper is to be refereed. Abstracts should be received by 31 January 1996. Papers will be published in the Proceedings of the Institute of Acoustics, Volume 18 (1996) and a bound volume will be available to delegates at registration.

Meeting organiser:
Dr Geoff Leventhall FIOA, Stewart House, Brook Way, Leatherhead, Surrey KT22 7NA

Occupational Health Risks from Exposure to Noise and Vibration – Present and Future
(Organised by the Industrial Noise Group)
11 April 1996
London venue

The government, through HSE, are now looking at long term health risks and have launched a three-year Health Risks Campaign. The first year will highlight the risks associated with exposure to noise, and those from vibration will be featured later in the campaign.

This meeting gives an opportunity to discuss current and future developments in this area. Contributions are invited on all aspects relating to exposure to noise and vibration at work, including for example:

- Enforcement – how do we do it? Do we do it at all?
- Assessment of risks and enforcement
- Provision of information
- Control measures
- Future legislation (eg the Physical Agents Directive)
- Hand arm vibration/ whole body vibration
- Compliance with the Supply of Machinery (Safety) Regulations

Intending contributors should send a 100-word abstract to the meeting organiser below, indicating whether the paper is to be refereed. Abstracts should be received by 15 January 1996. Papers will be published in the Proceedings of the Institute of Acoustics, Volume 18 (1996) and a bound volume will be available to delegates at registration.

Meeting organiser:
Dr R J Peters FIOA, NESCOT, Epsom Centre, Longmead Road, Epsom, Surrey KT19 9BH

Institute of Acoustics, 5 Holywell Hill, St Albans, Herts AL1 1EU. Registered charity no 26702
Tel +44 (0)1727 848195 Fax +44 (0)1727 850553 email Acoustics@clus1.ulcc.ac.uk

CALL FOR PAPERS

International Conference

Arrays and Beamforming in Sonar

(Organised by the Underwater Acoustics Group)

Churchill Hall, University of Bristol, UK

26-28 March 1996

Transducer arrays and their associated beamformers are essential to any sonar, and therefore transducers and signal processing, each in isolation, are two topics that are regularly covered at Institute of Acoustics conferences. What has not received a great deal of attention, however, is the performance of the overall system. Although processors have reduced in size and increased in power, and although the quality of the hardware may have improved over the past few years, practical sonar capability is still limited by factors such as the mechanical tolerances in the array assembly, the variations in the phase and amplitude responses of transducers and associated electronics, the various wavefront distortions and fluctuations introduced by the underwater environment, and the background of noise and reverberation. The investigation of these problems is not exclusive to sonar, and has occurred in parallel with similar work in fields such as radar and radio astronomy. It is hoped that this conference can bring together workers whose interests include all aspects of sonar array and beamformer design and performance evaluation as well as those with relevant contributions from other fields. Offers of papers are invited on all topics embraced by the title, including:

Source and receiver technology
Advanced signal processing
Reverberation, noise and clutter suppression
Port/Starboard discrimination in towed arrays
Jammers and countermeasures
Signal coherence, multipaths and fluctuations
Sparse arrays
Waveform considerations
Array shape
Experimental results

Prospective authors are invited to submit a 200-word abstract as soon as possible. Successful authors will be notified by late December 1995. Complete manuscripts may be up to 10 pages long, including diagrams, and must be prepared in the correct camera-ready format for which special paper will be provided. All manuscripts must be in the hands of the conference organisers by 1 February 1996. The conference proceedings will be published in book form in Volume 18 of the Proceedings of the Institute of Acoustics (1996) and copies will be available at the start of the conference.

The conference will be held at Churchill Hall, University of Bristol, which is situated in the tranquillity of the downs to the north of Bristol, but still within easy reach of the historic city centre. Full board and accommodation will be available in a student hall of residence at very reasonable rates.

Abstracts and all other communications should be sent to:
Dr Peter F Dobbins FIOA, BAeSEMA, PO Box 5, Filton, Bristol, BS12 7QW, UK
Tel: +44 (0)117 936 8056 Fax: +44 (0)117 936 6622 email peter.dobbins@baesema.co.uk

Institute of Acoustics, 5 Holywell Hill, St Albans, Herts AL1 1EU. Registered charity no 26702
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MEETING NOTICE

Joint Meeting with British Society of Audiology

Practical Aspects of Health Surveillance in Noisy Industries

Thursday 29 February 1996

The Royal Society

6 Carlton House Terrace, London SW1Y 5AG

The ultimate audit of the effectiveness of any industrial noise control programme is the reduction in the incidence of industrial deafness. In the past opinions seem to have favoured the estimation of the improvements, partly driven by the perceived difficulties associated with Audiometric Screening. Currently the situation is changing, driven by the claims experience of many companies and new Guidance from the HSE. This joint meeting will explore these matters in more detail.

10.00 Registration and Coffee
10.30 THE HSE VIEW ON HEALTH SURVEILLANCE IN NOISY INDUSTRIES
Dr Elizabeth M Gibby, Policy Section Head, Noise and Vibration, HSE
11.10 RISK ASSESSMENT AS PART OF A PLANNED HEARING CONSERVATION PROGRAMME IN THE WORKPLACE
Stephen A Worley, Technical Manager, Safety and the Environment, Lucas Industries plc
11.40 APPROPRIATE INSTRUMENTATION FOR HEARING CONSERVATION PROGRAMMES
Graham Frost, Technical Director, PC Werth Ltd
12.10 ACHIEVING COMPETENCE IN THE DESIGN AND MANAGEMENT OF NOISE CONTROL PROGRAMMES IN INDUSTRY
Dr Bob Peters, IOA
12.30 Lunch and practical demonstrations.
14.00 THE ROLE OF THE BSA IN THE TRAINING OF INDUSTRIAL AUDIOMETRICIANS
Dr William Tempest, BSA
14.30 PRACTICAL CONSIDERATIONS ASSOCIATED WITH THE INTERPRETATION OF THE NEW GUIDANCE ON HEALTH SURVEILLANCE IN NOISY INDUSTRIES
Dr Steve Karmy, Director, S J K Scientific Ltd
14.50 Workshop and discussion.
15.40 Tea and BSA Hearing Conservation Group Inaugural General Meeting.
16.00 Close of the meeting.

Registration Information
The meeting fee is £45 for BSA and IOA members and £55 for others. This includes lunch, refreshments and a copy of the HSE Guidance Notes. Further information and a registration form from the Conference Secretary, The British Society of Audiology, 80 Brighton Road, READING, RG6 1PS. Telephone 01734 660662 Fax 01734 351915

Electrical Analogue

The above ideas can be illustrated with reference to an electrical analogue as shown in Figure 6. The free velocity, representing the activity of the source, is analogous to the open circuit voltage (Figures 6a and b), the mobility of the source to the internal impedance of the voltage source, and the mobility of the receiver to the electrical load impedance. Note that the source is completely and independently characterised by its free velocity and mobility, and the receiver by its mobility, but that the emission (analogous to the power dissipated in the load impedance) depends on all three quantities according to;

$$P=0.5v_{fs}^2\frac{Y_R}{|Y_S+Y_R|^2} \qquad (1)$$

It is well known that maximum power will be delivered when the impedances in Figure 6a are matched. By analogy, structure-borne sound sources deliver most power when the receiver construction is similar to that of the source. Conversely, to minimise emission the mobility mismatch is made as great as possible, and this fact is exploited in vibration isolation where a resilient element is added to the source to make its mobility as different as possible to that of the receiver structure.

An illustrative example is given in Figure 7 where the source is a typical centrifugal fan and the receiver structure a concrete floor. The activity is represented by the free velocity Figure 7a, and the structural dynamics of source and receiver by their mobilities, Figures 7b and 7c. The emission (Figure 7d) is the power injected into the floor with the fan rigidly attached and is obtained according to equation 1. (A simplified analysis is possible for resiliently mounted machines [11].) The emission is broadly proportional to the free velocity, but also increases where the mobilities of the source and receiver are more closely matched.

Once the structure-borne emission has been quantified in this way all kinds of comparisons and further calculations become possible. For example, also shown in Figure 7e is the airborne sound power of the same fan. Comparing Figures 7d and 7e we see that for this particular fan and floor combination more energy is emitted into the air than into the floor except at around 100 Hz, in other words the airborne emission dominates overall. (This situation may change if the same fan were installed on a different receiver structure.) This does not necessarily mean that airborne sound will dominate at the listener position because the path attenuations through the structure and through the air are different and depend on where the listener is located. However, even without further calculations, simple comparisons such as this improve the engineer's appreciation of the problem and provide a firm basis for their engineering judgements which are otherwise limited to personal experience or even guesswork.

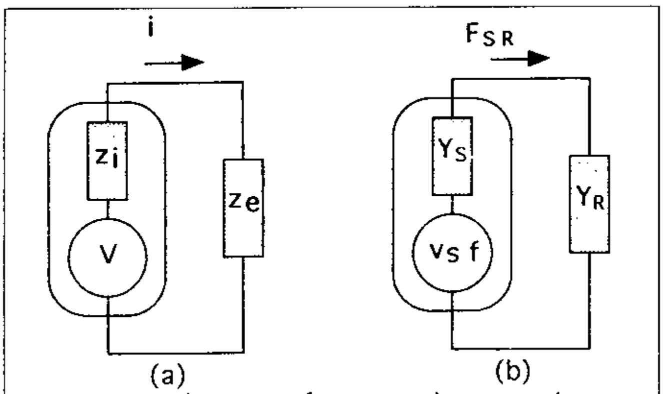

Fig. 6. Equivalent circuits for structure-borne sound sources. (a) electrical circuit (b) for a vibrational system

A note of caution should be sounded at this point. The electrical analogy and equation 1 apply strictly only when there is a single point of contact between the source and receiver. In all real sources contact occurs over multiple points, and/or over extended areas. Furthermore, energy can be transferred not just by normal forces, but also by bending moments. Both these factors can dramatically effect the emission in ways which are only now becoming understood. However, as long as these limitations are borne in mind the electrical analogy is an invaluable aid to the understanding of this complex problem.

The Reception Plate Method

An alternative approach to the characterisation of structure-borne sound sources is to measure the response of a standard connected structure, either in terms of the vibration levels or the radiated sound. Such a method is the 'reception plate method' where a thin metal plate of standard dimensions is attached to the working source and its velocity measured [12]. These methods are initially attractive because they appear to provide a single figure rating representative of the 'source strength'. However, the electrical analogy shows that the reception plate velocity is analogous to the voltage across a known electrical load impedance, which is not necessarily proportional to the emission. Thus, two machines with the same reception plate rating will yield different emissions, even when installed on identical support structures. Indeed, strictly speaking any rank ordering of machines using this method is only valid if the receiver structure is identical to the standard plate. In practice, it has proved possible to obtain sufficient accuracy using such a methodology but only within a narrow range of machines intended for a narrow range of receiver structures [13], and only then after extensive research to establish the validity of the simplifying assumptions. Because of these difficulties it is unlikely that a general rating method along these lines will ever be practical.

Conclusions

It is inevitable that in the future a greater degree of understanding and facility with calculation of structure-borne sound will be required from noise control engineers. In this article we have focused on one aspect of the subject – how to characterise a structure-borne sound source. This question is of great practical importance not just in the installation of machines in buildings, but to engineers throughout industry who wish to quantify the 'noisiness' (in structure-borne terms) of the components that they buy and of the products they sell.

The electrical analogy is the most useful basic model

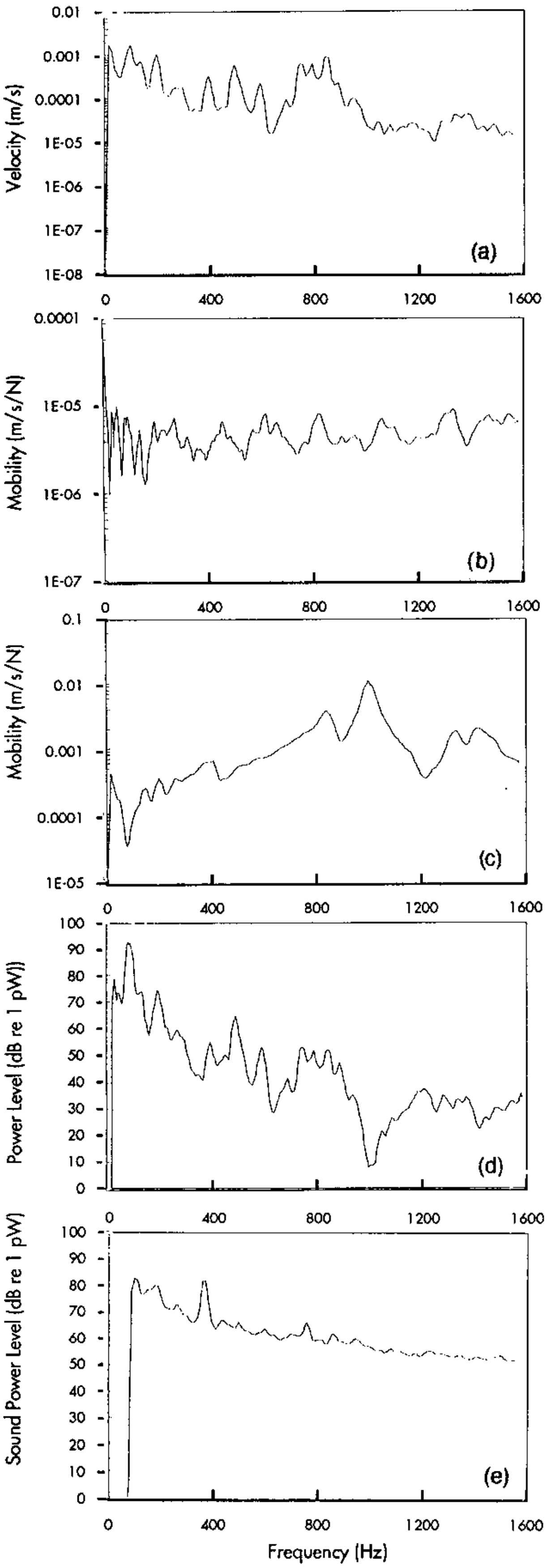

Fig. 7. Illustration of structure-borne emission from a typical fan into a concrete floor

of a structure-borne sound source. It reminds us that, unlike the airborne case, the emission depends on what it is attached to as well as the source itself. It should be borne in mind that the electrical model is a significant simplification of the complex mechanisms involved. However, it is the simplicity of the model which allows valuable insight into the various dependencies so that the engineer can employ their judgement to greater effect.

The most promising characterisation of sources available at current state of the art is the free velocity. Free velocity provides a reliable, independent and physically meaningful measure of the activity of a structure-borne source, and can now be measured according to recognised standards [2], [3]. It is, however, an incomplete characterisation, since the structural dynamic properties of the source and receiver structure also affect emission from the source. Thus, a working knowledge of the concept of mechanical mobility is required to make full use of the free velocity data. However, whilst free velocity tells us only part of the story it is at least the correct story, and in a field where misunderstanding is widespread that fact alone should be considered valuable.

Acknowledgements

The Acoustics Research Unit gratefully acknowledges the EPSRC support for their research into structure-borne noise.

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BRITISH TELECOM'S ACOUSTICS LABORATORY – 1928 TO THE PRESENT DAY

Robin Cross MIOA

Introduction

Few people either outside or inside the company realise that there has been a considerable commitment to acoustics since at least 1928, (that is the earliest reference I can find). The laboratory has undergone many metamorphoses since those early days and before it undergoes any more, I felt that it would be useful to reflect upon and capture the engineering highlights (and some lowlights).

Hopefully, it will also open a friendly window into what must seem to many to be a closed community. This article is based on a paper presented at the Reproduced Sound 11 conference in November. There are many slides of the equipment described in this article and I am sorry that I am not able to reproduce them here. Similarly, there have been many engineers who have contributed their expertise over the years and it has not been possible to mention them all.

The Early Days

The first long distance line in America was opened on the 7th of February, 1893 by AT&T. From that time onward, it became clear that there were numerous important patents and improvements pertaining to telegraphy and telephony drifting across the Atlantic. The engineering research station of the post office was already established at Dollis Hill in London NW2 and noted these patents with great interest. A laboratory was established to test out the usefulness or otherwise of the patents. It was soon realised that to objectively quantify a telephone system a range of tools would have to be designed and built in-house. This had the added advantage that home grown improvements could be quantified just as easily. And so the acoustics laboratory was born, with a mission to continuously improve the performance of telephone instruments and to develop the art of measurement.

In 1919, Webster introduced the concept of acoustical impedance with reference to the strength of sound sources as applied to horns. In 1928 the principles of the measurement of acoustic impedance were developed further in the laboratory by the then senior engineer, Willie West. In 1932, Willie went on to write his classic book 'Acoustical Engineering: The theory of sound and its applications to telephone and architectural engineering and to acoustical measurements and research'. The book contains the distillation of many ideas that are commonplace today. For instance, an early measure of the efficacy of a telephone conversation is the concept of intelligibility and is defined as 'the ratio, or percentage, of the number of ideas received correctly to the number sent; and it is the reduction of intelligibility due to the transmitting system alone that is the desirable criterion of performance of the system'. Simple isn't it.

A primary requirement in acoustical measurement is the ability to measure sound pressure accurately. Willie suggested a modification to the Rayleigh Disc free-field calibration method which measures particle velocity by producing a stationary sinusoidal wave in a tube at resonance. A high impedance source and microphone are situated at each end of the tube with the Rayleigh Disc suspended in the middle at the point of maximum velocity. The velocity stream exerts a scalar second-order torque on the disc which then turns on its quartz hair suspension to a new point of equilibrium. By directing a light beam onto a mirror attached to the disc and thence onto a glass scale, it is possible to measure sound pressure to within 2% or to ± 0.2 dB. In fact, maintaining and operating the Rayleigh Disc was my first duty in the now renamed Post Office Research Station acoustics lab when I joined it in 1967. There was a small army of moving coil probe microphones which had to be kept calibrated. These moving coil probe microphones were developed from the transducer used in the STC 4021 'ball and biscuit' microphones. The development took place in the early 1950s by Ralph Archbold, another significant engineer working in this area. The probe microphones were used in one of the first artificial ears to attempt to model the resistive component of the ear's input impedance (based on West's work from 1929) and used two coiled copper tubes filled with lambs wool. Use of a probe microphone had the additional advantage that the probe could be moved to the position of the ear reference point at the entrance to the ear canal for accurate comparison. The probe microphones had a very tight tolerance in terms of frequency response. The response could be variously altered by changing the amount and position of lambs wool in the tube, by altering the thickness of the spacers between the diaphragm and the exit or by altering the mass of the diaphragm by painting or washing off with thinners. By these techniques it was possible to adjust the frequency response to within ± 0.2 dB. For some unexplained reason, I became adept at this task and together with a similar adjustment requirement for audiometer headsets based on the STC 4026A receiver, this became another of my laboratory duties.

In the late 1920s the staff of the acoustics lab drew heavily on Rayleigh's 'Theory of Sound' and the Bell Systems' Technical Journals; of course they also performed research of their own, Suffice to say that by the end of 1932 the lab had early versions of all the essential equipment for telephony measurements and transducer development. This list is not exhaustive but includes artificial ears, a clockwork level recorder, speech level measuring equipment, probe microphones, microphone calibration equipment and an audiometer; all were designed and built in the laboratory.

Subjective Modelling

In 1935 D L Richards had joined the Post Office Engineering Department Research Branch where he worked on magnetic materials and noise interference problems. After the war in 1946 he then became engaged in speech transmission studies where he has played a significant role to this day. His greatest contribution to the discipline is probably his book, 'Telecommunications by Speech: The Transmission Performance of Telephone Networks' (1973). This work is still drawn on today as a text book for students of communication systems. The work pointed the way towards the construction and operation of sophisticated subjective tests and the incorporation of these results into a computer model. The model is able to accurately predict the likely user satisfaction of a concatenation of (linear) transmission systems. This has played an important part in the transmission equipment planning area where the 'perceived value' of the equipment to the user rather than to the transmission engineer had hardly been considered.

Although D L Richards did not work directly in the Acoustics Laboratory, the departments were all very close as there was little competition for funding. A spirit of close co-operation was endemic, to the extent that department boundaries were virtual rather than actual. The acoustics lab proper was in the business of sourcing and realising the tools required by the visionary researchers such as D L Richards.

Since the realisation of digital transmission and non-linear speech coding schemes, the requirement for a tool to enable the perceived value or usefulness of a communications link to the user has become even more necessary. Recent studies, which started life as an investigation into speech quality in the Acoustics Laboratory have matured into this new perceptual analysis tool.

By comparing processed signals with the original and applying all the known masking and psychoacoustic functions of the hearing process, it is now possible to quantify 'signal modification' in terms of user satisfaction. In other words, the argument runs, if your codec has added some distortion to the original signal and the user/listener can't perceive it, then to all intents and purposes the signal is undistorted. This work is now being advanced in the Perceptual Analysis Laboratory.

The Seventies and Eighties

During the early 1970s the concept of self polarising capacitor microphones was encapsulated in a Japanese patent. The concept looked too good to be true, opening up the possibility of cheap, reliable microphones (and possibly receivers) with a flat, or at least easily tailorable, frequency response. Initial calculations showed that the voltage sensitivity was independent of surface area, it later transpired that this was an anomaly in the patent diagrams. Two Sony electret radio microphones, which operated in the FM broadcast band were acquired from Hong Kong. These microphones did indeed have good sensitivity and a smooth frequency response. After many months of research all the process difficulties were overcome and the first half-inch diameter capsules were cased and fitted into the 706/746 range of telephones as drop-in replacements for the ageing carbon granule microphone, the transmitter inset 16.

In the early 1970s the laboratory became more and more involved with the development of hearing aids for the Medical Research Council. The laboratory had by this time built up expertise in artificial mouths, ears and measurement techniques so it seemed natural to make a contribution in this area. As the semiconductor became economically viable the laboratory began to look at miniaturised hearing aids (this means they only took up the space of one pocket!). At the same time insert artificial ears were further developed to cater for the smaller hearing aid receivers.

One such semiconductor was the pi-tran, a ridiculously expensive transistor (in development quantities) which had the property whereby a force applied to the top of its case had the same effect as driving a current into the base lead. A microphone was constructed using the large diaphragm from a carbon granule microphone, with the centre cup connected to the pi-tran case. The pi-tran was paired with a conventional semiconductor in a multivibrator circuit. Changes in sound pressure at the diaphragm were converted directly to pulse width modulation at the multivibrator output. This worked well except that the talker's breath puff heated the microphone diaphragm which then expanded and drove the pi-tran into saturation. What was clearly needed was a thixotropic material which could act as a mechanical high pass filter, transmitting the small forces experienced at audio frequencies while remaining flexible at low frequencies. Alas, no suitable material was found and the pi-tran PWM microphone was discarded.

Telegraph poles are pressure impregnated with bitumen during manufacture but can and do rot over time and become unsafe. Traditionally the pole was tested by an engineer who hit the pole with a hammer and listened to, and felt the response with a healthy pole giving a good resonant ring and a rotten one issuing an unhealthy thud. I believe a similar technique is used for testing rail wheels for cracks. It was decided that it would be desirable to remove the subjective element and build a device which would give a go/no-go response. A device was built which measured the impulse response of the pole, but the post-processing required needed a computer which was definitely not portable. Interestingly, the problem was later solved in a non-acoustic way by using an infra red camera to observe the raised temperature caused by the rotting bacteria.

Conference Systems

The International Telecommunications Union (ITU-T) defines the speech communications reference condition as a one metre airpath, ie two people communicating face to face, one metre apart. The transmission gains of the network are referenced to this ideal. With the advent of ISDN MPEG layer 3 encoding systems and real time digital signal processing, it will soon be possible to create virtual acoustic spaces whereby you will imagine that your colleague or conferee is indeed one metre in front of you and that you are sharing the same acoustic space. On route to this ideal the acoustics lab has maintained an interest in hands-free transparent communications systems, two early examples of which are described next.

In 1970 the lab developed a Surrogate Head conference system. This consisted of a simple stylized head and torso with two one inch B&K microphones mounted flush to the head and a wide-range loudspeaker fitted into the torso. The system was placed at the conference table in place of an absent conferee. At the remote location the absentee wore stereo headphones and a boom microphone. When used locally with a wide-band cable link and no voice switching, the performance of the system was astounding with the remote participant able to detect if two of the conferees exchanged places in the conference room. The outsider was able to participate in the conference with ease; however, the lateral discrimination was poor with nearly all centre stage information appearing to emanate from the top of the head. Additionally, when the bandwidth was reduced to 300 Hz to 3.4 kHz and the signal to noise ratio set to ~ 40 dB (ie replicating the conditions of a telephone link) the 'open' stereo image was lost and with it the ease of use. This is believed to be due in part, at least, to the fact that two consecutively dialled-up lines will almost certainly not be matched for phase and delay.

Around 1977 the feasibility of a conferencing system was again shown; this time with a table-top design in two forms. The first form looked rather like a 300 mm high light-house with a toroidal microphone formed from two figure of eight microphones mounted at right angles and connected via a circuit which gave a 90° phase shift between the outputs. The loudspeaker was mounted concentrically in the base and was on the null axis of the microphone. The second form had an 'end fire' loudspeaker in a conventional enclosure and a system of wooden trunking which housed figure of eight microphones; it could be extended for larger tables. The trunking was terminated at the end opposite to the loudspeaker with a cardioid microphone to fill in the end seat(s).

Again this was connected via a 90° circuit, this time to avoid perturbations in the polar response arising from interference with the nearest velocity microphone. A control unit completed the system by performing the dial-up and system equalisation functions.

In order to design, develop and commission open communications terminals it is essential to have an accurate, repeatable representation of the human acoustic interface. Such a representation is now embodied in the ITU-T recommendation P58, specifying the performance and parametrics of a Head and Torso Simulator (HATS). The HATS specification was developed from the devices already available from Brüel & Kjær in Denmark and Head Acoustics in Germany. Parameters and performance specifications which needed repeatability data were measured in the laboratory as part of an ITU-T Round Robin exercise. BT's Acoustics Laboratory was one of the many organisations which took part in this exercise.

Strange But True

Many projects which came to the laboratory in the 1960s and 1970s were as the result of requests from other government departments. Here are brief summaries of some of these projects.

In the 1960s when the M1 motorway was built it was noted by various departments that villains were disappearing from London's gang-land and since no bodies were found it was thought that the bodies were being dumped in the concrete supports of the Motorway bridges. To test this theory we were asked to do a feasibility study on the possibility of a 3D infrasonic imaging system, looking for changes in density in the bridge structure. The calculations showed that enormous forces would be required to exercise the bridges at the frequencies which would give the necessary definition. Indeed the forces would most certainly cause the bridges' destruction.

Another theoretical study concerned the possibility of acoustic levitation. I remain convinced that the strong force required for levitation is unavailable, but that a weak force such as the second order torque found in the Rayleigh Disc effect is a possibility. If anyone reading this article has further information on this subject, please drop me a line.

One department enquired into the possibility of developing a device to determine when female mice were likely to become pregnant. It had been postulated that when female mice were in their receptive phase the frequency of their ultrasonic squeaks changed pitch and encouraged the other females to do likewise. If this were true and the appropriate time could be detected then the efficacy of any poisons used would be increased. Yes, you guessed it, the equipment developed was fairly ineffective and the acoustics lab suffered from mice colonies for many years after the experiment had stopped.

The Buildings

Before the days of time domain reflectometry it was considered essential for an acoustics lab to posess an anechoic room. The first anechoic chamber was built at Dollis Hill around 1950. The room was a 4 metre cube and lined with 1/2 inch thick ex-army blankets. One metre widths of blanket were suspended at right angles to, and touching, the walls. Similar arrangements were made for the ceiling, together with blankets suspended from a raised mesh floor, to complete the treatment. A low noise level was effected by choosing a room in the middle of a single story building and by the copious distribution of 'Quiet Please' notices.

In 1960 a more conventional anechoic room was built using fibre glass wedges covered in scrim. When the move of the Research Centre from Dollis Hill to Martlesham was announced in 1972, work was set in hand to design a purpose built acoustics facility. This facility is in use today and comprises two anechoic rooms (150 Hz and 60 Hz) and a 200 cubic metre reverberant room. Each room is finished to a high standard and has excellent soundproofing, for example, the noise level in the large anechoic room is −15 dB(A). The facility is equipped with two laboratories, a workshop and a room with an anti-vibration floor for microphone calibration.

The Present Day

Since 1992 the Acoustics Laboratory has been integrated with the Dynamic Analysis Laboratory which was originally based in Birmingham and is now relocated on the Martlesham site. The dynamics team is concerned mainly with the performance of a wide range of products (from fax machines to whole racks of exchange equipment) under dynamic loading. To this end we have a Ling air suspension shaker table driven by a 24 kW water cooled amplifier. The table is controlled by a Data Dynamics computer.

The measuring equipment is based around B&K's extensive catalogue with analysers from Hewlett Packard and Solartron. A Melissa system is finding increasing use for the characterisation of transducers.

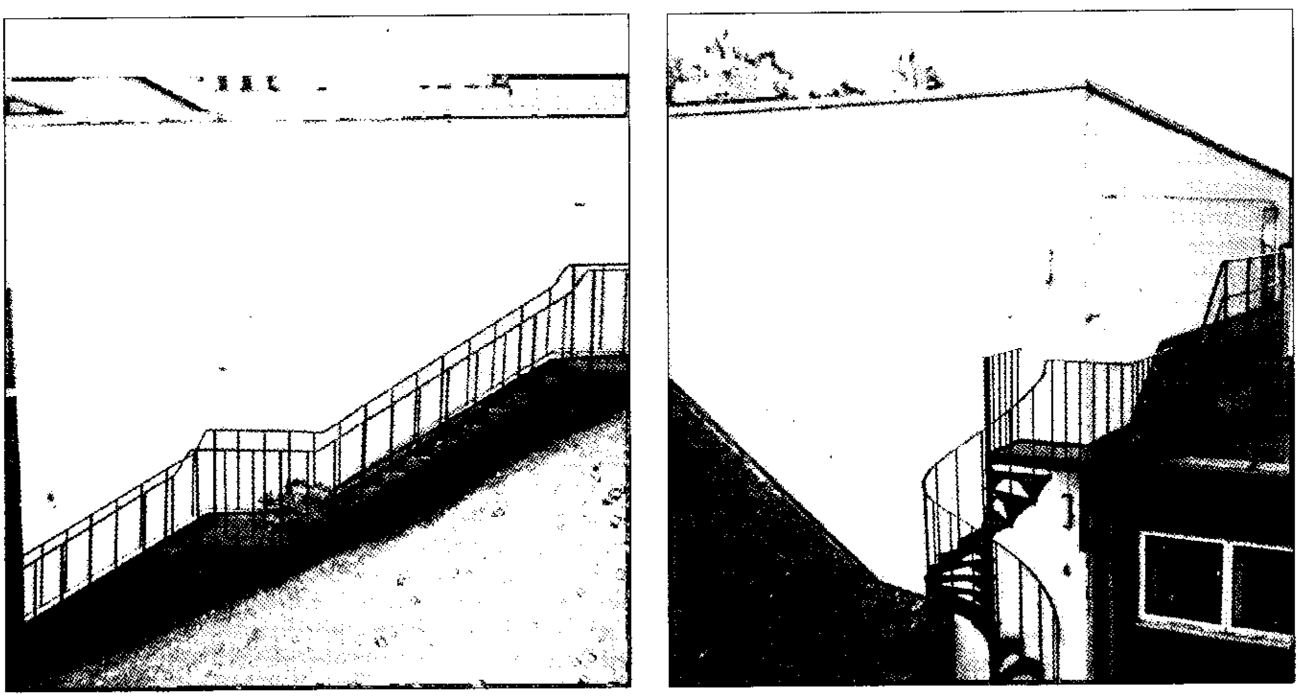
The anechoic room is furnished with an 8-loudspeaker digital ambisonic sound reproduction system for replaying sound field microphone recordings. This has proved most useful in measuring the subjective performance of mobile telephones in the presence of room noise.

The range and scope of the laboratory's work continues to grow with many exciting developments and possibilities opening up as the unit cost of bandwidth continues to fall. The focus of the laboratory is changing towards a more consultative role, operating in such diverse areas as building vibration monitoring and the development of ear simulators for lightweight headsets.

Since its inception, the laboratory has played its part in improving the quality and usability of our communications system through the continuous development of tools and metrics.

The Author

Robin Cross has worked in transmission systems modelling and electroacoustics since 1967. He is presently the Leader of the Acoustics and Dynamic Analysis team. He is a Member of the Institute of Acoustics and the Audio Engineering Society. He is also a member of BSI committees covering: acoustics, electroacoustics and telecommunications and acoustic safety. Additionally, he is the UK representative to IEC technical committee 29, Electro-acoustics; working group 3; ear simulators and an occasional contributor to ITU-T study group 12. Further relevant interests include sound reproduction/recording and loudspeaker design.



The left-hand picture is an external view of the anechoic room and the right-hand picture is the reverberation room showing how they were built into the bank.

A DAY WITH CELESTION INTERNATIONAL AT IPSWICH

John W Tyler FIOA

Note from the Editor

This is the first of an occasional series about companies, some familiar and some not so well known, manufacturing acoustic products of various kinds; their history, philosophy, current product range and their plans for the future.

Why choose a loudspeaker manufacturer to start the series? Not a product that the bulk of Bulletin readers are directly concerned with you may think. I have four excuses; firstly, as I am retiring as editor of the Bulletin with this issue I felt I could indulge myself; secondly, having had a life long interest in audio engineering including loudspeaker design, the temptation was great; thirdly, since this Bulletin has been for some time planned to be issued around the time of Reproduced Sound 11, it seemed an appropriate subject to embrace; lastly, I have to confess that in the mid-1940s for a short period before joining the Scientific Civil Service, I worked in Thames Ditton on loudspeaker design, principally on the G12, with British Rola, a founding company of Celestion International; and so I feel part of the history.

Introduction

The fact that I had met Julian Wright, Senior Acoustics Engineer at Celestion, at previous Reproduced Sound conferences at Windermere – as a result of which he wrote a couple of first class articles for the Bulletin – made a visit to Ipswich very easy to arrange.

After a long drive into the wilds of Suffolk I received a friendly welcome from Julian and Graham Bank, Research Director and we had a fruitful discussion in Graham's office (in between phone calls: they are in great demand) ranging from the history of the company to loudspeaker design techniques and future products. This was followed by a visit to the factory to see the various products and production techniques and to the research facilities; the latter included a demonstration of the laser doppler interferometry method of viewing diaphram movement, used by Celestion for the last 15 years and a look into the future with the employment of finite element analysis to study loudspeaker behaviour.

History

The trade name 'Celestion' was created during 1924 in the picturesque Thames-side village of Hampton Wick, where Mr Cyril French, set up a small business to manufacture loudspeakers and other 'wireless' products. 'Celestion' was presumably derived from 'celestial' meaning heavenly, and by wishful thinking, enlarged to 'heavenly sound', although that description would probably not have been apt for the sound quality of the day! Nevertheless, the one model made by Cyril French at that time, housed in an elegant mahogany cabinet, was one of the highest quality units available. This was the time of the infancy of wireless, which was viewed by the majority of the population as a modern miracle. The BBC had been formed in that year but had started broadcasting on 14 November 1922 on 369 metres with the call sign 2LO, to be followed the next day by 2ZY in Manchester and 5IT in Birmingham. The early broadcasts were received predominantly by crystal sets which required headphones to convert the relatively weak signals into audible sound. Although valve receivers were also used with either headphones or the elementary loudspeakers of the day, crystals outnumbered valves until 1927.

Against this background of rapid development of broadcasting, Celestion, as one of several makers, made their way. As headphones gave way to freestanding electrically driven horns, paralleling those in acoustic gramophones, and loudspeakers in separate cabinets (early valves were far too microphonic to allow the mounting of loudspeakers in the radio cabinets), the demand for loudspeakers grew rapidly. Early loudspeakers were primitive compared to what is available today. High power moving coil units did not exist and simple balanced armature types with suitably doped, stretched linen cones were the order of the day. By 1930 Celestion were producing electric gramophones; a catalogue of the time boasted three grand models of 'Electrical Gramophone and Radio Gramophone' in craftsman built cabinets of oak, mahogany and walnut and including the now famous 'Celestrola Moving Coil Loudspeaker' and priced from 75 to 125 guineas. Mains energised speakers were in common use then, due to the high cost of permanent magnets. The energised coil (an electromagnet) sometimes also served as a smoothing choke in the power supply circuit of the valve radios and amplifiers of the day.

By 1930 Celestion had moved from Hampton Wick to Kingston-on-Thames where their products included electric gramophones, loudspeakers and band repeater equipment for ships and including possibly the first public address loudspeaker (Type S/LSP) for use on land and at sea.

Just up the river from Kingston another loudspeaker manufacturer, British Rola Company, Ferry Works, Thames Ditton, an offshoot of the Rola Company of Cleveland, Ohio, USA, was making similar products. The two firms were in competition for the export and home markets and their products were influenced by the changes which came about in the design of wireless receivers. As the receiver used more advanced valves the loudspeaker began to be housed in the receiver cabinet itself, thus dispensing with the need for a separate loudspeaker cabinet and both Celestion and British Rola designed smaller units to meet this demand, often to the specification of the receiver manufacturer. However, then as now, the more discriminating listener preferred separate loudspeakers and these were produced by both firms. In the meantime Cyril French (you remember him?) had moved out of the manufacturing game and formed Cyril French Limited, still at Hampton Wick, to act as sole distributors and service agents to the wholesale and retail trades.

British Rola was registered during 1938 as electrical and general engineering toolmakers and stampers, and during World War Two produced, in addition to loudspeakers, a range of military equipment. This included for the aircraft industry, the B3 Vacuum Pump, the Rotol Airscrew Feathering Pump, which was fitted to all British multi-engined bombers, and the Integral Hydraulic Pump Mark iv. During 1942 the American Rola Company licenced British Rola the right to manufacture and sell in the British Empire, Rola products as used in the aircraft, engineering, electrical, motor and radio industries. During the war both British Rola and Celestion were restricted to the manufacture of one type of loudspeaker, the utility 'W' type, at Ferry Works and Kingston Factory, respectively. With the coming of peace both companies resumed production of a range of loudspeakers. British Rola, responsible for half the trade in loudspeakers in the UK (Investors Chronicle 1946), was the larger firm and on 13 April 1947 (1 month after I left to join RRL, now TRL) acquired Celestion together with a subsidiary firm, Pressmach Ltd and another small pressing firm, Belark Ltd. The company title became Rola Celestion and the name Celestion was adopted and registered as the trade mark for all the new company's products. Rola Celestion were then responsible for practically the entire UK loudspeaker export business.

In July 1948 Celestion ceased production at Kingston and the production machinery and personnel moved to Thames Ditton and were consolidated in Ferry Works. As the post war market developed, the resumption of television broadcasting created a demand for a large number of loudspeakers in addition to those required for the radio industry and the Thames Ditton production lines were kept busy. Another change came about in 1949 when Rola Celestion Ltd was acquired by Truvox Ltd, a company well known for its public address loudspeakers and systems. This enlargement of the public address system range combined with the development of specialised designs such as flame proof loudspeakers, enabled Rola Celestion to fulfil the demands of the new petro-chemical and allied industries and the aircraft and military industries.

Then came (in 1958) the stereophonic long playing record, demanding not one but two amplifier/loudspeaker systems. Loudspeaker manufacturers must have thought they were entering a new phase of prosperity – to sell two units where one sufficed before! Celestion responded with a conversion system which allowed radiograms to be fitted with two 12-inch (305mm) G44 bass loudspeakers together with two of the revolutionary HF1300 high frequency units. These latter units had been designed in 1956 and were immediately adopted by the BBC for use in their studios, in fact becoming known as the 'BBC HF1300'.

Although Celestion were well known for producing hi-fi driver units, it was the Ditton series of stereo loudspeaker cabinets which first brought hi-fi to the general public at a reasonable price. The MK1 Ditton 10 was introduced in 1964 as one of the first 'bookshelf' speaker systems. This was designed by Laurie Fincham (a well known name in hi-fi circles) who, when he was with Goodmans a short while before, had produced the Goodmans Maxim; these two were the first mini-sized speakers with bass performance previously associated with much larger units and which amazed the hi-fi world. Laurie Fincham went on to even greater things with KEF at Maidstone and finally was swallowed up by the American audio industry. Two years later the now famous Ditton 15 made its debut, priced at £28.11.6d! A special feature of this loudspeaker was the use of an auxiliary bass radiator (ABR) which extended the low frequency range of these relatively compact loudspeakers.

The Ditton series continued to be produced for a number of years with the flagship of the range being the Ditton 66 Studio Monitor, first produced in 1974. Such was the demand for the Ditton loudspeakers that production became a problem at Thames Ditton and the search began for a larger site. A suitable location was found in Ipswich where new buildings were constructed and some existing ones modified. First into production at the new Ditton Works, an appropriate name, were the 12" (305mm) Power loudspeakers of the G12 type. (Deja vu).

In 1970 a clothing firm, listed in the Stock Exchange, acquired Rola Celestion and together they became Celestion Industries plc.

You might have expected the textile part of the partnership to supply, say, cloth for the grilles or fabric for the suspensions, but this did not happen and the component parts remained technically quite separate. The loudspeaker part of the company became Celestion International in 1979 to reflect the fact that their products were sold worldwide.

All the above was compiled from my own information and copies of papers and publications held by the company and given to me by Graham Bank whilst he was relating to me the history of the company in the 1990s. The story continues from Graham's account. In 1992, Celestion Industries plc required capital for growth and sold Celestion International to a new owner, KH(UK) Ltd (KH stands for Kinergetics Holdings). KH(UK)Ltd have three major divisions (or sites), Celestion at Ipswich, the loudspeaker maker KEF at Maidstone (is nothing sacred) and a company on the west coast of America, Kinergetics Research, a high end audio company.

The latter manufacture amplifiers, CD players and electronic components solely for the American market.

The Company Now

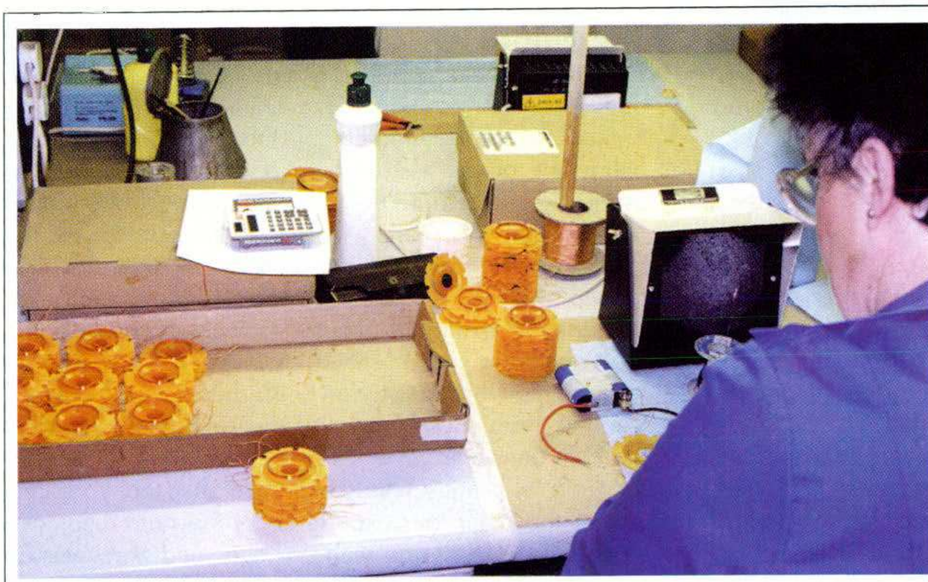
And that brings us to the present day where Celestion International sell 80 per cent of their products abroad to 65 countries including the Far East and America (through

Graham Bank, Research Director (left) and Julian Wright, Senior Acoustics Engineer

KH America). The range of products is extensive and includes, in addition to domestic hi-fi loudspeakers, from the superb 700SE and new Kingston to the more affordable 'Units' range, some electronic components including Home Theatre processors together with the necessary loudspeaker types for surround sound and controllers for public address systems. Then, there is the large range of professional loudspeakers both for the music profession and for public address. Public address and sound reinforcement speakers are available in a large range of combinations and housings while their rock music units are embodied in the products of several well known manufacturers of electroacoustic guitar amplification, for example Marshall, Vox, Torque etc. The separate specialist guitar speakers include specially voiced units for lead guitars. To celebrate Celestion's 70th anniversary last year, the company have reissued two famous professional loudspeakers of the 1960s, the G12H and G12L. Along with the classic G12M (Greenback) there is now a classic G12 trio from this period.

Ian White, Development Director Professional Products

About 200 people work on the Ipswich site of which 19 are in the research department. There, the three main groups are (1) development of Hi-Fi products, (2) development of professional products and (3) a research and instrumentation group which works on components and materials. However, the divisions are not strictly maintained and development staff are encouraged to carry out their own research on their particular problems with help from the research and instrumentation group. To help with this process internal seminars are held regularly to enable development engineers to talk about what they have been doing and air their problems and suggest solutions. This policy must surely promote staff morale and contribute to the quality of the final products. There are three technicians in the research department to help with the construction and testing of prototypes.



Voice coils being tested

Before taking me on a tour of the production areas of the factory, Julian showed me around the research department and demonstrated the laser doppler interferometry equipment; the sight of moving computer images has always fascinated me and it was certainly amazing to see the effect of the slightest defect in the material of, say, a high frequency unit, being displayed on screen; this has been a valuable tool used for many years by several of the larger loudspeaker manufacturers.

A more recent development and still very much in the early stages, is the use of finite element analysis techniques for studying loudspeaker cone and cabinet characteristics. I was shown the results of ongoing research into this area and the images on the computer screen, together with the enthusiasm of both Julian and Graham demonstrated that here was an innovative and very exciting development in the study of the transducer and cabinet and their environment, unlocking doors that previous techniques could not do; at the moment I am sworn to secrecy!; but one of the articles in Acoustics Bulletin written by Julian Wright revealed some of the details.

The various parts of the production areas revealed some very interesting techniques for ensuring quality and adherence to standards. It was fairly noisy in some parts although, I am sure, conforming to the latest 'Noise at Work' regulations! In spite of the passage of years the atmosphere was to me very reminiscent of my days at Thames Ditton; but of course production techniques have developed considerably. There were two anechoic chambers which were used for both production testing and for research purposes, one of which allowed the loudspeaker under test to be mounted in the wall of the chamber giving an 'infinite baffle' condition. One became aware during the visit of the vast range of different manifestations of loudspeakers and cabinets which make up the products of Celestion; from hi-fi to sound reinforcement, from units for public address to those to meet the needs of rock musicians and the surround sound of home theatre.

Then back to the research department to meet Ian White, Development Director, Professional Products, responsible for the professional loudspeaker branch of Celestion. He explained that there were two sides to the business; one is the supply of OEM drivers both for musical instruments and public address whose manufacturers use them in their own products. The other side is the supply of loudspeakers in cabinets in a large range of sizes for public address, sound reinforcement and musical instrument purposes.

Ian emphasised that loudspeakers supplied for musical instruments, eg electroacoustic guitars and keyboards, do not have to reproduce accurately the original input but are expected to add a quality of their own. Thus from the 1950s starting with a toughened version of the original G12 radiogram speaker fitted into the first Vox and Marshall amplifiers and producing the unique voice of Rock and Roll, Celestion have produced a series of increasingly powerful guitar loudspeakers voiced to the needs of the users. The G12 in various guises has, over the last three decades, provided the medium for such well known names as The Shadows, The Beatles, The Who, Jimi Hendrix, Led Zeppelin, Deep Purple, Genesis and Queen. The full story of the G12 and its role in the development of rock music is fascinating but space does not allow it to be told here. However, I must mention that Julian Wright showed me a review, in the 'Gramophone' magazine of March 1936, of a permanent magnet version of the G12; long before rock and roll was born.

The smaller KR series are in effect Hi-Fi loudspeakers in a more robust housing and are used for low level sound reinforcement such as quiet areas in pubs and restaurants. The SR and CR range of sound reinforcement enclosures are designed to fit any application from DJ playback to nightclub and stage monitoring and include cabinets from a 10-inch unit handling 200 watts over 60 Hz to 16 kHz, to an 18-inch subwoofer capable of 500 watts over 35 Hz to 2 kHz.

Finally, before departing Ipswich after a thoroughly enjoyable and informative day, I was treated to a demonstration of the latest, at the time, high-end hi-fi loudspeaker before its official launch. This is the innovative Kingston (another very appropriate name), a compact design incorporating its own special stand. The cabinet material, a new acrylic polymer compound called AlphaCrystal, is 'poured', ie moulded, to form a one-piece enclosure of immense rigidity and striking tapered profile; there is no back panel as such as the sides curve round to meet at the rear.

AlphaCrystal is also used for the massive (44 lb) matching stand. The Kingston is a two-way design using a 1.25 in (32 mm) aluminium dome tweeter and a 6.5 in (165 mm) bass/midrange driver. With a nominal 8 ohm impedance, the Kingston has a frequency response of 68 Hz – 20 kHz ±3 dB, a sensitivity of 84 dB/W/m and a power handling capability of 150 W.

I was most impressed with the smooth well balanced and entirely realistic sound from this speaker and was particularly surprised by the amount of low frequency output from an organ recording from such a comparatively small enclosure. I left wishing I owned a pair even after hearing the price!

The Future

The future on the high fidelity side obviously lies with the application of techniques like finite element analysis to further the understanding of the mechanical/acoustic behaviour of the elements of a loudspeaker and thus gradually to eliminate the remaining obstacles to faultless reproduction of sound; Celestion appear to be well started on that road. On the professional side, the development of new materials, construction methods and increases in available acoustic power are probably the most obvious aims.

Perhaps the best way to finish this account would be to quote from a company statement made during 1994, the 70th anniversary year '... Celestion are well equipped for the 21st century. The company's philosophy is simple and to the point: our experience of the past keeps us in touch with the present, with our eyes and ears ever cast to the future'.

John Tyler ❖

1995 AUTUMN CONFERENCE: STANDARDS, CRITERIA AND MEASUREMENT IN ACOUSTICS AND VIBRATION

Windermere, 26 – 29 October 1995

Introduction

This year's Autumn Conference offered an opportunity to mark the 21st anniversary of the formation of the Institute. The event, which was organised by Jeff Charles of Bickerdike Allen Partners, departed in its structure from the usual style of Windermere conference in two ways. Firstly, the joint Institute of Acoustics/Institute of Physics Physical Acoustics Group organised a one-day symposium reviewing some recent developments on the subject. Secondly, and mainly as a means of exploring further the potential role of the Institute's continuing education and training provision, a series of eight practical tutorials were arranged that gave delegates a chance to review the procedural details of a number of measurement methods they had been routinely applying – sometimes for many years. For this purpose, delegates were divided into eight groups; each group took part in each of the one hour long tutorials where one or more members with an expertise in that field took the delegates through a practical exercise. For this reason the cycle of activities was described collectively as the 1995 Noise and Vibration School.

A number of the tutorial exercises also performed a secondary role through acquiring interesting and useful statistical data that might have been difficult to achieve outside the conference setting. It is intended that the statistical outcome of several of these exercises will be reported as technical notes in future issues of the Bulletin.

In all one hundred and fifteen delegates attended the conference together with fifteen accompanying non-delegates. The excellent weather added to the pleasure of the small amount of free time that was available in the tightly packed programme, which this year started at Thursday lunchtime in order to accommodate all the events. Members who have been to previous Windermere Autumn Conferences will know just how intensive the programmes can be; they will doubtless be pleased to hear that this year's delegates were again subjected to late night workshops. The first, led by Nick Antonio from BRE, was a well attended discussion on changes that might be incorporated into a revised BS 5228, the construction site noise standard. An equally well attended after-dinner discussion, organised by the Institute's Environmental Noise Group, dealt with the problems of dealing with pub and club noise.

There were eight exhibitors drawn mainly from instrumentation manufacturers and on the Friday evening Larson Davis hosted a reception for all delegates and accompanying persons. A premature bonfire night party took place on the Saturday night with fireworks sponsored by European Process Management and after all these years the traditional Saturday afternoon lake cruise was still well supported.

Reports from session chairmen follow.

Technical Sessions

Industrial Noise Bill Stubbs gave the first of the 34 technical papers presented at the 1995 Autumn Conference at Windermere. He described both his initial predictions and then subsequent monitoring during the construction of the three-level underground Canada Water Station on the Jubilee Line. The noise predictions done by reference to BS5228 indicated that the daytime limit of 75 $L_{Aeq,12h}$ would be met, the monitoring confirmed the prediction. Despite the close proximity of two 20-storey residential tower blocks, one as close as 15m from the site; by careful noise control and monitoring, and good public relations, the local population's environment was adequately protected.

Bernard Berry described the work of his team in completing the revision of BS 4142, the text of which has now been submitted to the Editorial Department of the BSI; publication is expected early 1996. The considerable revisions were outlined and the further research, that may lead to further revisions in three to four years time, noted. He highlighted revisions to the sections dealing with scope, definitions, measuring equipment and its calibration, new worked examples clarifying the meaning of specific noise level, background noise level, and rating level. Bernard also mentioned the possible revision to the similar ISO document, ISO1996, in particular a new 12 dB impulse correction. Bernard sought a response from the delegates as to whether continuous revision of BS 4142 should perhaps be replaced by a completely new start in finding a method to assess industrial noise.

Nick Antonio described his work to measure adequately the industrial noise from a metal fragmentisor plant; the particular noise was that arising from the occasional explosion of metal gas bottles within the plant. The method used a technique based on vibration to trigger a measurement using equipment developed initially to measure quarry blasts. Trials showed the engineering method developed was suitable.

Norman Bolton of the National Engineering Laboratory discussed the noise emission from the vast range of fans and pumps, and the difficulties of measurement. Norman warned that although airborne noise emission from a pump is concentrated around the pump casing, the noise emitted as a result of structure borne and fluid borne transmission can arise at a considerable distance from the pump. He then concentrated on the practical problems that will have to be overcome to provide the

The manufacturers exhibition

measurements of sound power needed to meet the EC Machinery Directive and achieve a CE mark, essential before sale.

Harry Lester responded to some of the concerns raised by the previous speaker, and gave a full explanation of the machinery directive, and the considerable number of related standards most of which it is hoped will be finally issued in 1996. Harry mentioned that although the Directive applies only to certain machines, discussion is currently taking place on extending the policy to machines used outdoors.

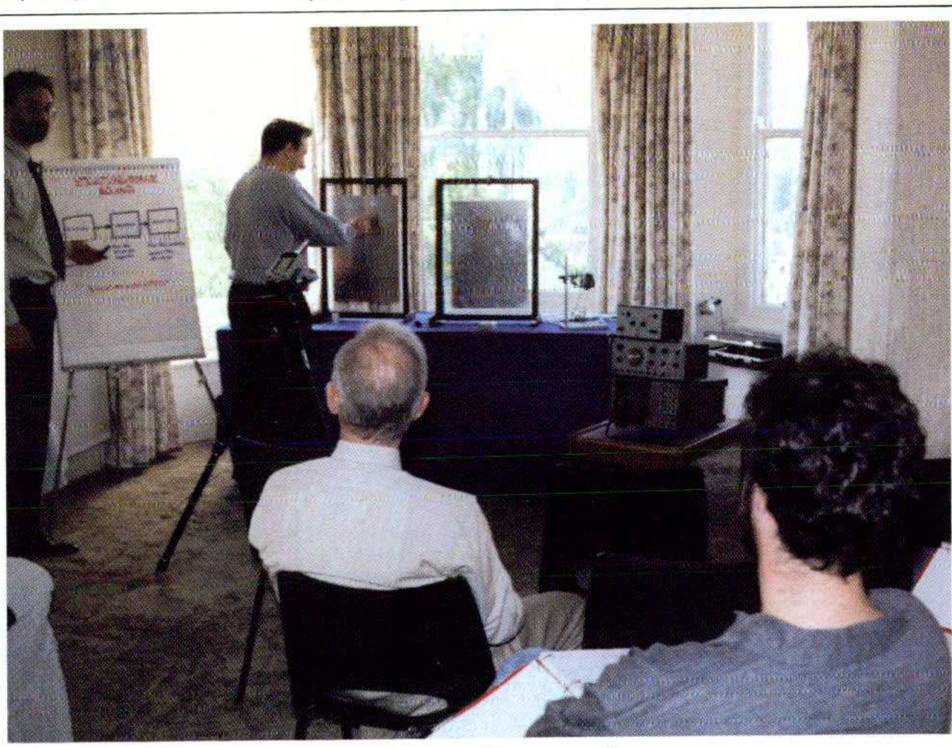
Keith Broughton gave an historical introduction to the consideration of the comfortability of hearing protectors. He mentioned that research had highlighted that the pertinent parameters include head band force, cushion pressure, weight, seal surface area, softness of seal, colour, shape, size, design and quality. Keith noted that legislation did not require a comfort index, but suggested that it might be helpful to both manufacturers and purchasers if one were included. The author then sought advice from the delegates on whether a comfort index should be sought.

Hearing & Speech The session was opened by Nicole Porter (NPL), with an account of experimental and theoretical studies on the masked thresholds of amplitude and frequency modulated tones. The work was carried out within the EC-funded SAVANTE network, at the Istituto di Acustica in Rome, with Giovanni Brambilla and Francesca Pedrielli who had left the warmth of Italy to be at the conference.

Douglas Campbell of the Department of Electrical and Electronic Engineering at the University of Paisley outlined the problems faced by those with sensorineural hearing loss in separating speech from undesired sounds, especially in reverberant environments. He then described a sub-band adaptive processing approach to speech enhancement for hearing aids.

John Hinton from Birmingham City Council stepped in at short notice for Alan Whitfield of the University of Birmingham, who was otherwise occupied in a hospital maternity Department. His paper presented results of a survey which confirmed that bar staff in night clubs and discos are exposed to hazardous noise levels and that the problem is not being addressed by management.

The session ended with two papers on different aspects of speech recognition systems. Christine Cheepen dealt with strategies for automatic correction of repairs in speech-input computer systems. She contrasted the ISDIP



Practical tutorial on structure-borne sound word processing system with the more recent CALE system and emphasised the importance in ensuring useability and user-friendliness of having human-computer dialogues which are clear, unambiguous and as unobtrusive as possible.

James Monaghan (University of Hertfordshire) closed the session with a fascinating insight into the real-world problems of designing a totally hands-free workstation for disabled school children, and the ups and downs of introducing the developing prototype into the Lonsdale School in Stevenage.

Measurement On Saturday and Sunday morning the newly formed Instrumentation and Measurement Group presented two paper sessions entitled Measurements. In the first paper on Saturday, entitled the Virtual Instrument in Practice, Bob Lorenzetto of Quantitech set out to persuade the audience that a PC can now make all necessary acoustic measurements with the aid of suitable plug-ins and software. Next Paul Darlington of Salford University presented a paper, co-authored by Iain Strachan of AEA Technology and Richard Tyler of CEL Instruments, on source recognition in sound level meters. In this contribution, the idea of adding suitable signal processing and neural network analysis techniques to a sound level meter, to enable machine identification of a specified acoustics event, was demonstrated to be technically viable. Sunday morning started early with Tim South of Leeds Metropolitan University describing his work with Bill Davies, now of Salford University, on

measuring absorption coefficients of polyurethane foam using intensity techniques. Three papers presented by members of the NPL then followed. Duncan Jarvis spoke on measurement standards for acoustics, with particular reference to the IEC 1094 series for measurement and working standard microphones and how calibration of these microphones was now undertaken at NPL. Peter Hanes addressed IEC 942 and its current revisions in a paper entitled Sound Calibrators: Calibration, Verification and Pattern Evaluation and explained that NPL will soon be offering a service for all aspects discussed. Nigel Milton discussed the verification of sound level meters to BS 7580 Parts 1 and 2, with reference to the new Type 2 meter tests soon to be added to the standard. After coffee, a paper by Glynne Parry and Richard Tyler of CEL Instruments asked, 'How Good is *Your* Decibel?'. An analysis of the errors and omissions often made by users of acoustic calibrators and sound level meters showed that errors of ± 2 dB could be commonplace, without the user being aware of them. The final paper was presented by Steve O'Rourke of Cirrus Research on the design and operation of a device called the Dosebadge which was described as a small, robust, cableless data gatherer used in conjunction with a readout device and PC. It was shown to have some novel features for measuring personal sound exposure. Altogether the sessions offered some interesting ideas and explanations that were both well presented and received.

Building Acoustics The topics covered in the first session devoted to Building Acoustics included contributions on site survey techniques, studies of sound insulation and of airborne sound propagation. Carl Hopkins of the Building Research Establishment described a statistical energy analysis (SEA) model for sound transmission via cavity wall constructions which took account of cavity damping and foundation coupling parameters obtained from laboratory tests.

Ole-Herman Bjor described a new approach to the measurement of airborne sound reduction being developed in Norway by Norsonic AS. By using maximum length sequence (M-sequence) excitation and a Hadamard transformation correlation technique, it was shown that reliable results could be obtained even in test situations affected by extraneous noise disturbance – a process likened to 'removing the cream from cafe au lait'.

The sound-insulating performance of lightweight roofs comprised of profiled sheet metal sections was reviewed by John Medlock of Axter Acoustics. The results of an extensive test programme indicated that high orders of both sound and thermal insulation could be achieved from optimised formulations of the component elements forming multi-layered roofing and cladding systems.

Practical techniques for field measurements of reverberation time using software incorporated into Larson-Davis test instrumentation was described by Robert Chanaud. The built-in flexibility of the system enables operators to incorporate intuitive expectations of site conditions and thus maximise the data acquisition while minimising the time spent on site.

Ken Ratcliffe of ISVR Consultancy Services reviewed the practical difficulties encountered in the conversion of an existing building into a wine bar and residential accommodation. Sound reaching the upper level flats from amplified music played in the wine bar was required to be held to a maximum of 35 dB(A) by a combination of control procedures.

Finally, Professor Anna Snakowska of Rzeszow Institute of Physics described theoretical and practical studies of the sound field radiated from the termination of a circular duct. The system was proposed as a reference sound source. Experimental studies of the sound field distribution showed close agreement with that predicted by modelled multimodal excitation in the duct.

Physical Acoustics Symposium

On the Friday of the conference, in parallel with the main sessions a symposium on Physical Acoustics was organised, with a varied and interesting programme. The first session started with a brief historical review, and look ahead in the field of ultrasonics by Dr Robert Chivers from the University of Surrey. Based on the review of Dr R W B Stephens presented at Ultrasonics International, 1975, Dr Chivers concentrated on developments that have taken place in the last 20 years. As an applied science, the history of ultrasonics can only partly be culled from the scientific literature. The processes and devices (eg ultrasonic welding, ultrasonic 'tape measures') which have been successfully integrated into industry or developed commercially, disappear from the literature. The extraordinary influence of the developments in semiconductor electronics on ultrasonic technology were illustrated by particular reference to medical imaging, including the presentation of a short video. In suggesting 'growth' areas of the future he mentioned sonochemistry, surface acoustic wave biosensors, the NDT of adhesive joints, ultrasonic applications in the paper industry, the increased use of ultrasonic surgery, non-linear NDT approaches, the diagnostics of inhomogeneous materials including composites and the enhancement of growth in plants. In concluding, Dr Chivers quoted Dr R W B Stephens in 1975 (which reflected the opening remarks of the Chairman, Professor Richard Challis). 'Born in the adversity of war ultrasonics has become a servant of peace, improving the quality of life in industrial processing, by helping the blind, and sick and as a diagnostic tool in medicine and material testing. Let us not make again the mistake of the 1930s by neglecting fundamental research which is so necessary for the support of technological advances.'

The next group of three papers dealt with ultrasonic velocity and attenuation techniques. Firstly David Hibberd from the Institute of Food Research, Norwich described a discrete frequency spectrometer operating between 5 and 150 MHz, although the device appears to have been validated only up to approximately 100 MHz. An absolute accuracy of ± 0.034% for velocity and ± 0.5% for absorption is claimed based on comparison with the data for water of del Grosso and Mader. The main intended use of the device is on colloidal suspensions. The next paper of the group was presented by Dr R Freemantle from Keele University on progress in ultrasonic wave parameter measurement in thin polymer samples. The technique used was a Fourier transform approach. While this is normally used in situations where the individual reflected pulses can be segregated in time (and is thus suitable for 'thick' specimens), the method had been extended using a parameter fitting techniques, to 'thin' samples, when the sample thickness approaches the wave length of the highest frequency propagated in the sample (as small as 25 μm for the present work). The results agreed well with those made on thicker specimens and the improved techniques had potential importance in the characterization of thin polymer coatings, paint layers and adhesive bonds. This paper was followed by a presentation by Professor Challis, also from Keele, on the choice of simple mechanical models for the estimation of 'wave absorption' and phase velocity in filled and unfilled polymers. He demonstrated that while the single-element Maxwell and Kelvin-Voigt models for viscoelasticity give physically unreasonable results, that of Zener can provide a reasonable approximation.

The second session of the symposium started with two papers from the University of Surrey concerned with methods and results of ultrasonic transducer characterisation. The first presented by Dr R Chivers detailed a new design of miniature piezoelectric needle-type sensors for ultrasonic field investigations. Based on a carefully designed submersible pre-amplifier, with a bandwidth up to 100 MHz, the needle elements are simply clipped onto the front of the amplifier. The elements available range in size from 75 μm to 1 mm diameter, exhibit excellent frequency response and directivity characteristics and have a typical sensitivity of 15 mV/MPa (for a 75 μm element). The value of these high specification probes was demonstrated in measurements on a focused bowl transducer that exhibited strongly non-pistonlike vibration of its surface which was undetected by amplitude beam plots in the focal region. The second paper, presented by Ajmal Bangash gave detailed results of measurements on four transducers, comparing the use of the hydrophones described in the previous paper, with the optical tomography method at the PTB in Braunschweig. The excellent agreement between the results from the two methods validates both techniques as means of full transducer and field characterisation, although both require high mechanical precision and thermal stability. The last paper in the session was presented by Professor Victor Krylov from Nottingham Trent University, on the theoretical basis of surface acoustic wave chemical sensors. In conventional approaches to the problem, the influence of the molecules absorbed onto the sensor is treated simply as a mass loading whereas in reality they may not only affect the elastic properties of the sensor films, but this influence is likely to vary with depth into the film. Prof Krylov's approach using non-classical boundary conditions represents a considerable improvement on the available theory, albeit still for rarely distributed adsorbed gas molecules.

The third session of the symposium was devoted to two application areas of ultrasound. Dr Chris Langton from the University of Hull identified the problem of calibration and quality assurance for instruments aimed at assessing osteoporosis using ultrasonic velocity or attenuation. The increasing commercialisation of the field makes it less easy to identify what processing is being applied to the basic measurements in order to produce the index upon which the degree of osteoporosis is assessed. As an approach to the problem, the use of 'phantom' materials would appear helpful, but no suitable materials have yet been found with the range of parameter values exhibited by human bone. An electronic phantom was described which appears to have promising qualities. The second application area of the use of ultrasound in fluid level monitoring was described by Dr K Henthorn from Nottingham Trent University. The importance of the problem from both economic and ecological points of view was clearly demonstrated by statistics on the filling of soft drink bottles on a production plant. Whereas ultrasonics can provide a highly accurate measurement technology, its benefits can only be fully exploited if it is linked to an on-line intelligent process control system. A neural network based adaptive prediction control strategy suitable for the problem was described and appears to have adequate characteristics, although its implementation on the production line has yet to be achieved.

A particular feature of the symposium was the detailed and extensive discussion that took place between the papers, and in a special discussion session after tea. It was a rewarding day enhanced by the excellent organisation and beautiful location in which it took place.

The 1995 Noise and Vibration School

On Friday afternoon sixty delegates travelled to an open field site near Staveley taking nineteen sound level meters with them. Professor Bob Craik of Heriot-Watt University and Alistair Sommerville of Edinburgh City Council arranged a measurement programme with groups of delegates placed at various distances from the point at which a shotgun would be fired to a pre-arranged schedule. Measurements were made of two hundred gun shots using a pre-determined sequence of time weighting parameters. The intention was to obtain statistical information about variations in propagation parameters and also on the consistency of meters measuring the same event at effectively the same location. Some finger troubles, made worse by the speed at which the event progressed, meant that not all the intended data were recorded satisfactorily; the outcome was nevertheless an impressive amount of information that would have been difficult to collect under different circumstances.

It could be argued that in the circumstances the exercise was less than rigorously controlled, but it is worth remembering the sound levels were collected under the sorts of conditions that practitioners frequently work. The two organisers of the event have produced their statistics for an article in a future issue.

That was one of a series of practical exercises forming the 1995 Noise and Vibration School. Another activity, that involved all those who had earlier participated in the first one, took place at Kendal Parish Church where Peter Barnett, Rob Dolling and Richard Knight of AMS Acoustics took the assembled delegates through a prepared speech intelligibility experiment. Delegates were clustered towards the front and towards the rear of the church in order to listen to pre-recorded words from a loudspeaker under different propagation and noise conditions. Reporting the words they thought they heard, delegates built up phonetically balanced word score lists that were collected for analysis. The results were instructive, particularly when set against the RASTI, reverberation time and noise values recorded at the time. The collected results will also be reported in the next issue of the Acoustics Bulletin.

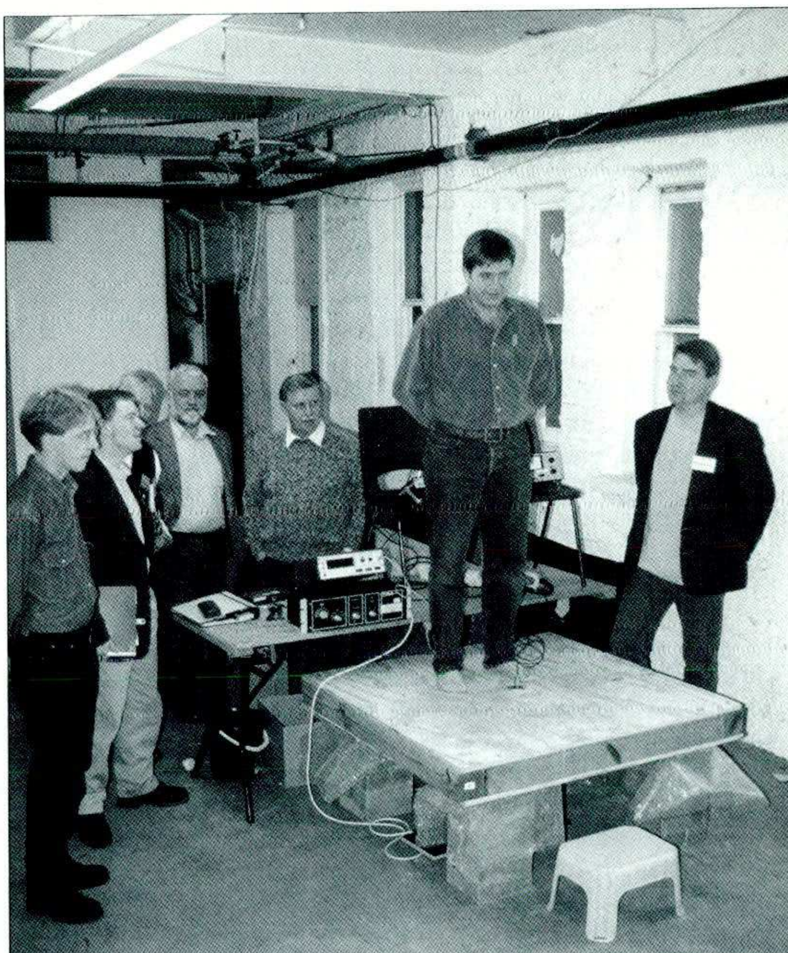
The rest of the school consisted of eight practical exercises or demonstrations that took place at various points within the hotel. Delegates were divided into eight groups and each group was scheduled to spend one hour at each location. Some of the practicals involved the recording of data by individual participation and these produced interesting data for subsequent consideration. Andy McKenzie of the Hayes McKenzie Partnership had the individuals in each group listen to a series of ten pre-recorded sounds. Each was asked to judge whether, following the general advice of BS 4142, as practitioners they would give a 5 dB(A) correction on the basis of a perceived tonal content. The sounds ranged from domestic refrigerator and windfarm noise to various synthetic combinations. Again the point could be made that listening conditions were not rigorously controlled, but on the other hand they were close to the sort of situations which practitioners frequently operate under. The results raised more than a few eyebrows and will be reported in a future issue.

Geoff Kerry of the University of Salford and Tina Emmanuel of the Building Research Establishment used Norsonic Building Acoustics Analyser to take their groups through a BS 2750 evaluation of the partition between two hotel bedrooms. They did this with a programmed variation in some of the experimental parameters so that the overall effects of these changes could be recorded. In the same vein John Seller and John Sargent, both of BRE, illustrated the proposed CEN short method for sound insulation determination by having delegates make their own assessment of another bedroom wall. At the completion of the whole exercise the two parties measured each others' walls. The results will also be reported later.

Richard Knight and Rob Dolling of AMS Acoustics conducted another exercise that called for audience participation. The subject was speech privacy and delegates assessed their ability to comprehend words from phonetically balanced word lists under variable conditions. Firstly the apparent sound reduction index of a simulated partition was varied to allow for the introduction of a small airgap; secondly the listening room noise level was varied. In this way PB word scores were determined.

Andy Moorhouse and Gary Seiffert of the University of Liverpool presented instructive demonstrations of the factors to be borne in mind when considering the possible effects of structure borne sound. Steve Wray of Wimpey Environmental used a Brüel & Kjær Intensity Meter to remind the groups of the use of intensity measurements for determining the sound power of a small source.

Bill Stubbs, also of Wimpey Environmental, and Bob Peters from NESCOT undertook an examination of the issues surrounding the use of root mean quad and VDV procedures in vibration signal processing. Tape recordings of vibrations from trains were used as signal sources. Also in the vibration field Roy Lawrence and Bob Peters invited members of each group to stand on a solid timber vibration table measuring 4 foot square. The table was made to vibrate at a various excitation levels as personal reactions were invited. Initial surprise was frequently expressed, for example, at the relative low level, subjectively, of a vibration matching the 'times 4' curve in BS 6472. Constant vibration levels above that curve are taken as being excessive for industrial environments; there was, upon reflection, broad agreement that levels above that curve would be undesirable. ❖



Determining the threshold of vibration sensitivity

Group & Branch News

London Branch

In May and June of this year, the Branch turned its attentions to the proposed Institute CPD scheme. Discussions were held at the end of London Evening Meetings on 24 May (at TBV Science, Croydon, and was introduced by Greg Watts of AIRO) and 21 June (at NESCOT introduced by Bob Peters of that institution). The views of participants were collated and submitted to the institute's CPD committee to assist in their further deliberations.

The Autumn session of London Evening Meetings commenced on 20 September at the offices of BDP Acoustics when John Simson described the work leading to publication of the Report of the London Heliport Working Party in March this year. Noise was one of a number of factors to be considered under the terms of reference, which included safety and operational factors, demand, surface access, air traffic control constraints and existing helicopter provision in London. A comparison was made of six sites serving Central London and the work included a social survey and a consideration of future development trends. A prediction model was developed and this is to be published as a DORA report in the near future. Major difficulties in making accurate predictions relate to the lack of source noise levels, for which certification data is not usually available, and the allowance to be made for propagation in built-up areas. Early indications suggest that 6 dB per doubling of distance applies over hard ground, 9 dB over soft ground and 12 dB over built-up areas. Screening corrections have been based on the work of Maekawa.

On 18 October, Colin Stanworth, who after many years with BR is now an acoustic consultant acting for Crossrail, presented a talk entitled 'Keeping Quiet about the Railway'. The meeting was hosted by Crossrail at Telstar House, Paddington. Colin described the Crossrail scheme, which links Shenfield in Essex to Reading and Aylesbury to the west of London. The track will run in tunnel under Central London from a point to the west of Paddington to one east of Liverpool Street. Colin dealt with the surface noise considerations of the scheme and considered vehicle noise, track noise and noise from structures. For each aspect he described the main factors to be considered in controlling noise and which had been considered by Crossrail in their scheme to minimise noise impact on the communities adjacent to the line to the east and west of Central London.

The 1995 Branch Annual Dinner was held on 22 November at the Foreign Press Association, 11 Carlton House Terrace, London SW1 when the Institute President, Alex Burd, was the speaker.

Turning to the future programme, on 13 December John Shelton of AcSoft will present a talk entitled 'Instruments and PCs: The Great Divide?' The meeting will be held at the offices of WS Atkins at Woodcote Grove, Ashley Road, Epsom. It commences at 6 pm and light refreshments will be available from 5.30 pm. The Branch AGM will be held on 17 January 1996 at South Bank University (Borough Road entrance) commencing at 6 pm. After the AGM, Bridget Shield will describe the results of an audience questionnaire survey into concert hall acoustics.

John Miller MIOA

Environmental Noise Group

The Group has been very active over recent months. September saw another in the series of regional environmental noise assessment workshops, this time in Northern Ireland where the University of Ulster were our hosts. Around thirty people, including some from Dublin, attended and considered the requirements for the noise part of an environmental statement. The Institute of Environmental Assessment again collaborated in this workshop, further consolidating the close links that have been developing between our two institutes. This liaison has led to the setting up of a steering group tasked with forming a working party to produce a guidance document on the subject under discussion. It is intended that this will be added to a series of documents already published by the IEA that give guidance for other disciplines on the environmental assessment process. This proposal took a step forward at an open meeting on 12 October at the National Physical Laboratory when over 50 people discussed the scope of the proposed document. The first meeting of the inter-institution working party is scheduled for early December and the IOA representatives on the steering group are Stephen Turner (TBV Science), Ken Collins (Ashdown Environmental) and Graham Parry (RPS Group).

The Group organised an evening workshop discussion on Pub and Club Noise at the 1995 Autumn Conference, in Windermere. The outcome of the deliberations will be published in a future issue.

In the new year, the workshop format will be continued through meetings being planned for Birmingham at the end of March and at NESCOT in September.

Stephen Turner FIOA

DOE Research Projects

The Department of the Environment are setting up four research projects relating to

- Noise Mapping
- Clay Target Shooting
- Domestic Noise Complaints
- Assessment of PPG24

If you would like more information and are interested in receiving an invitation to tender for any of the above, please contact:
Nicole Porter MIOA, Department of the Environment, Room A211, Romney House, 43 Marsham Street, London SW1P 3PY, Tel 0171 276 8345 Fax 0171 276 8403, no later than 15 December 1995

Hansard

16 October 1995
Noise Limits (Heathrow)
Ms Walley: To ask the Secretary of State for Transport if he will list by airline company the number of noise limitation breaches committed over the last 12 months at Heathrow airport.
Mr Norris: Penalties for infringements of the noise limits set by my right hon. Friend are imposed by Heathrow Airport Ltd. The airport company provides information on the infringements and fines collected to the Heathrow Airport Consultative Committee. I have asked the company to send the reports for the last 12 months to the hon. Lady.

23 October 1995
Transport: Traffic Noise
Mr William O'Brien: To ask the Secretary of State for Transport what plans he has to reduce traffic noise in urban areas; and if he will make a statement.
Mr Watts: Further reductions in noise limits will be introduced for all new vehicles entering into service from 1 October 1996. Levels of noise from individual vehicles have been dramatically reduced in the last 10 years so that 10 of today's heaviest lorries make no more noise than a single lorry in the early 1980s.

25 October 1995
Railway Noise
Mr Gordon Prentice: To ask the Secretary of State for Transport for what reasons the Noise Insulation (Railways and other Guided Transport Systems) Regulations 1995 do not set standards to be applied to the mitigation of railway noise at source.
Mr Watts: The enabling legislation for the Noise Insulation Regulations for new railway lines in section 20 of the Land Compensation Act 1973. This section authorises the Secretary of State to make regulations imposing a duty or conferring a power on the authority responsible for the public works to insulate buildings against noise from the construction or use of public works. This means that regulations made under the Land Compensation Act 1973 cannot include standards for the mitigation of noise at source.
However, the existence of regulations for railways and the noise trigger levels included in them, will encourage authorities constructing new lines to incorporate noise mitigation at source into the design of the lines.

26 October 1995
Noise Legislation
Mr Atkins: To ask the Secretary of State for the Environment when he expects to announce his proposals to improve the current noise legislation.
Mr Gummer: I am aware of my right hon. Friend's continuing interest in this important subject. We are currently considering both the written responses to the recommendations in the consultation paper on neighbour noise controls and the results of recent trials of the proposed new night noise offence. We hope to announce shortly how we propose to take forward the recommendations.

1 November 1995
Highway Noise
Mr Tyler: To ask the Secretary of State for Transport what consideration will be given to including within the work programme of the Standing Advisory Committee on Trunk Road Assessment the assessment of the impact of noise from highways and the justification for various means of ameliorating this nuisance.
Mr Watts: In 1989 the Standing Advisory Committee on Trunk Road Assessment was asked to review the Department of Transport's methods for assessing environmental costs and benefits, including the impact of noise. The committee's report, 'Assessing the Environmental Impact of Road Schemes', and the Government's response were published in March 1992. Subsequently, the Department's guidance on the assessment of environmental impacts has been updated – volume 11 of the design manual for roads and bridges. Also research is on-going into the valuation of nuisance, including noise, in the home, due to road traffic. I have no plans currently to ask SACTRA to revisit this issue.

21 November 1995
Noise Controls
Mr John Marshall: To ask the Secretary of State for the Environment what representations he has received about restricting noise.
Mr Clappison: My Department receives representations about all forms of environmental noise on a regular basis. The vast majority of this correspondence relates to neighbour noise issues.

22 November 1995
Aircraft Noise Limits
Mr Allen: To ask the Secretary of State for Transport if he will list all the occasions on which airport companies have fined those who have infringed noise limits under their charging powers in the last year for which figures are available (a) at Heathrow and (b) at other airports.
Mr Norris: The Secretary of State may set requirements for limiting noise at airports designated for the purposes of section 78 of the Civil Aviation Act 1982.
The only airports so designated are Heathrow, Gatwick and Stansted. The noise limits are 110 PNdB (97 dB(A)) by day (0701–2300) and 102 PNdB (89 dB(A)) by night (2301–0700).
From 1 April 1993 at Heathrow and Stansted and from 1 May 1993 at Gatwick, the airport companies have imposed financial penalties for breaches of the night noise limits and are progressively introducing financial penalties for the breaches of the daytime noise limits. Information on breaches of the noise limits and on the fines collected is provided by each of those airport companies to their respective airport consultative committees. I have asked the three airport companies to send the reports for the last 12 months to the hon. Member for Nottingham, North.
At other airports, noise mitigation measures are the responsibility of the airport operator.

Abstracts provided by Rupert Taylor FIOA ❖

New Products

Brüel & Kjær (UK) Ltd

B & K 2260 Investigator

B & K 2260 Investigator gets to the bottom of noise nuisance quickly and easily.

A four page brochure from Brüel and Kjær describes the 2260 Investigator, which, the company claim, provides a clearer picture of noise problems than any other hand held meter on the market. This instrument not only measures all relevant parameters simultaneously for fast data acquisition, but also combines with new Multi-D software to lead to the most efficient solution in the shortest possible time. PCMCIA cards provide maximum flexibility for expansion of the analyser's capability and are also the storage medium for set-ups and results. Applications are mastered simply by loading the software into the instrument and following self explanatory menus and icons. Back in the office, the data can be downloaded to a PC running B & K's Evidence software for quick, easy report generation.

For further information please contact Graham Turgoose, Brüel and Kjær (UK) Ltd, 92 Uxbridge Road, Harrow HA3 6BZ. Tel: 0181 954 2366, Fax: 0181 954 9504.

B&K is a Key Sponsor of the Institute.

CEL Instruments Ltd

Cel-301 Human Vibration Analyzer

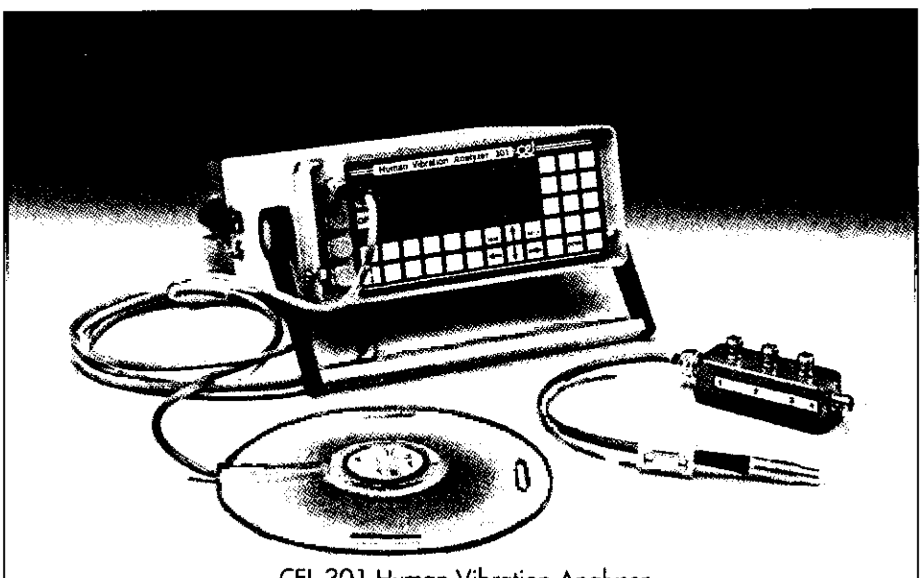
CEL Instruments have introduced a new 4 channel analyzer which is designed for vibration tests in a laboratory, on the shop floor, or in the field. With a tough, die-cast metal case providing protection against dust and splash water it is light enough to be carried with a shoulder strap or placed easily in restricted areas like vehicle cabs. The instrument meets the needs of manufacturers and consultants to assess the vibration levels in buildings, land vehicles and water borne crafts and from products like lathes, angle grinders, saws and pneumatic drills. There are two versions: the CEL 301.1 is a dedicated 4 channel vibration analyzer whilst the CEL 301.2's fourth channel can be used for both vibration and real-time sound level analysis. When a measurement is taking place, two measured values (instantaneous and maximum) are displayed as bar graphs as well as one or two numerical values as numbers for each channel. The numerical parameters can be scrolled on the measurement screen rather than return to the set up menu. Any single measured value can also be selected and enlarged for easy reading. The values of up to five measured quantities can be simultaneously displayed and overload, pause and data erase facilities are also available via the measurement screen. Data is stored in the memory with date, time and duration details for each measurement sequence and this can be downloaded to a computer. The CEL 301 has a complete, alphanumerical keyboard so that any letters or numbers can be keyed in and used to identify any measurement sequence. Digital filter banks give true, real-time $^{1}/_{1}$, $^{1}/_{3}$ and $^{1}/_{12}$ octave analysis for both sound and vibration measurements. For vibration measurements, a choice can be made between single or two-channel analysis. The analyzer can be powered from its own integral, rechargeable battery, from a car battery or AC supply. A carrying handle can be locked into place to enable the large, clear screen to be viewed at various angles. The CEL 301 houses four measuring amplifiers each with a 16 bit ADC. The measurement and processing, including the digital filter banks are implemented by a digital signal processor in conjunction with an internal controller. It has four charge amplifier inputs and four ICP/AC inputs which can be used uniformly or in a mixed mode. The instrument is supplied with a battery unit and a set of storage batteries, a mains unit and battery charger, a carrying belt and an instruction manual. FFT narrow-band analysis capability can also be added as a software option. A comprehensive range of accessories are also available to enable the analyzer to be used for many applications and these include: cables, transducers, a vibration calibrator, preamplifiers, adaptors, printer, tripod and transportation cases. Further information can be obtained from: CEL Instruments Ltd, 35–37 Bury Mead Road, Hitchin, Herts SG5 1 RT Tel: 01462 422411 Fax: 01462 422511.

CEL Instruments is a Key Sponsor of the Institute.

Quantitech Ltd

eNVi Instrumentation

Conventional approaches to noise and vibration monitoring could change following the introduction of eNVi (environmental Noise & Vibration instrumentation) from Quantitech Ltd. Designed by experienced engineers keenly aware of the gaps in current technologies, the sophisticated but user-friendly eNVi system



CEL 301 Human Vibration Analyser

simply plugs into any notebook PC to perform a host of functions at the touch of a button. Consolidating all the functions required for any noise or vibration investigation, eNVi streamlines the analysis, manipulation and interpretation of raw data right through to final report production. Dedicated sound level and vibration meters are instantly upgraded by connection to this system and all operations are quickly and simply controlled through the software. Live narrow and octave band spectra can be displayed on screen in a 'What You See Is What You Measure' (WYSIWYM) manner. Information can be easily manipulated in a number of ways. For instance, SPL, L_{eq} and L_{90} can be displayed as meters and graphs in separate windows, filters can be added or subtracted, tapes automatically analysed, past results compared and product databases used to assess, for example, the effect of hearing protection or silencers. In addition to providing monitoring for environmental and health protection, eNVi can as readily be used in production line testing, machine noise diagnosis, building vibration and other commercial applications. For further information please contact: Bob Lorenzetto, Quantitech Limited, Unit 3, Old Wolverton Road, Old Wolverton, Milton Keynes MK12 5NP. Tel: 01908 227722, Fax: 01908 227733

Civil Engineering Dynamics

Nomis Series 6000 Seismograph

Civil Engineering Dynamics have announced the new Nomis Series 6000 Seismograph. This powerful highly accurate microprocessor and ADC allows sample rates up to 100,000 sample/sec and no wait time from event to event. It has a memory that can store up to 2000+ events and options include 3.5 inch high density disk and flash card. The viewing of events stored in the memory is fast and simple with 8 line x 40 column LC backlit graphic display. This means that graphic wave forms as well as text can be viewed immediately after each event. It has a fast printer for permanent records printed in full within 15 seconds of the event. The triaxial accelerometer coupled with a powerful microprocessor allows vibration reading down to 0.5 Hz and low levels at 0.01 mm/sec to 1000 mm/sec. This unit only weighs 5.5 kg. For further details contact Civil Engineering Dynamics Ltd, 83/87 Wallace Crescent, Carshalton, Surrey SM5 3SU. Tel: 0181 647 1908 Fax: 0181 395 1556.

Bay Systems Ltd

Miniature Accelerometers

Tesis AP-Series of miniature accelerometers offers unique characteristics permitting the measurement of acceleration and shock where small size and mass are of prime importance. The design provides an optimal relation between transducer mass and sensitivity. AP-Series is available in a variety of mounting styles suites for a wide range of applications. The titanium alloy housing makes it resistant to mechanical damage and ultra-light. All transducers are fitted with standard low noise microdot connectors and a flexible thin cable. A calibration certificate is provided with each accelerometer. The ultra-light AP-19 miniature accelerometer offers one direction measurement of shock or acceleration with minimum mass loading effect on the structure. It has a sensitivity of 0.3 pC/g. With mass of only 0.15 gram and extremely small size it is suitable for measurements on scale models or other small and very light structures. The titanium alloy housing and rugged design eliminates the fragility normally associated with miniature transducers. A miniature triaxial AP-20 accelerometer was developed for multi-directional simultaneous measurements of shock and vibrations of fuel pins in the nuclear reactor. It has a sensitivity of 2.4pC/g. The titanium alloy cube-formed housing permits mounting in any triaxial configuration. The extremely low mass of only 5 grams is minimizing the mass loading effect while testing very light structures.

Further details are available from BAY SYSTEMS Ltd., Crysnal House, Main Road, Westhay, Somerset. BA6 9TN. Tel. 01458 860393 Fax: 01458 860693.

LMS International Ltd

Experimental Statistical Energy Analysis (SEA)

LMS announces the world's first Experimental Statistical Energy Analysis product. SEA is used to model the flow of vibro-acoustic energy between the various components of a multi-assembly system, as well as the dissipation of the energy within each one. The system is modelled by the internal and coupling loss factors of the components. Further insight into the system's vibro-acoustic behaviour is obtained by using the model to predict the energy flow between the subsystems, as well as to evaluate the sensitivity of a target response to the model parameters. In this way, you can see how much energy flows, say, into the muffler system and from there into the rear window, the floor pan, the passenger cavity – or anywhere else.

SEA is particularly suited to model high frequency noise and vibration problems where the modal overlap is high, and where the modes are mostly localized. Just as low frequency vibration problems can be approached both analytically (FEA) and experimentally (modal analysis), SEA has its analytical and experimental counterparts. The module now introduced by LMS is believed to be the world's first commercial experimental SEA system, and uses a technique referred to as the Power Injection Method to derive the SEA model.

Acoustic Holography LMS CADA-X

Acoustic Holography performs a spatial transformation of sound fields – in other words, it takes a measurement of sound pressures along a certain plane and predicts what the readings would be at any other plane. This plane can be towards the nominal source (back propagation towards the far field, or perpendicular to the measurements. In many respects, Acoustic Holography is a test-based equivalent to the acoustic radiation predictions of SYSNOISE .

Further details on these products are available from LMS UK Ltd, Unit

10 Westwood House, Westwood Business Park, Westwood Way, Coventry CV4 8HS. Tel: 01203 474700 Fax: 01203 856310.

News

Wimpey Environmental

Wimpey Wins BRE Contract

Wimpey Environmental, the noise and vibration consultancy company, has been awarded a major contract by the Building Research Establishment to carry out sound insulation tests on separating walls in recently built dwellings. BRE has established a substantial database of information on the sound insulation provided by a large number of different constructions. The contract with Wimpey Environmental is to increase this information.

Up to 30 sets of tests will be performed over the next 12 months. The tests will gather more low frequency information than the standard sound insulation tests and will be concentrating on wall types that use heavy aggregate blocks, namely types IB, ID, 2B and 2D of the 1992 edition of Approved Document E of the Building Regulations.

Wimpey Environmental has for many years advised and measured the sound insulation of the company's dwellings, carrying out research and development to improve the sound insulation with new forms of construction. Experience to date includes over 2000 site tests on all types of buildings for both Wimpey and other clients.

Information from Wimpey Environmental Ltd, Beaconsfield Road, Hayes, Middlesex UB4 0LS Tel 0181 573 7744 Fax 0181 848 1554.

Sampson Windows

Copy-Cat MODUL Windows in Sheffield City Centre

Steel City House, the former telephone exchange and post office which was built in the late 1920s, has been extensively refurbished for the Department of the Environment to update the building into high-tec offices to be used by the Employment Service. As part of the face-lift, all the original single-glazed, steel windows have been replaced with ultra-performance MODUL A37 windows from Sampson.

Steel City House Sheffield

Strict planning constraints had been imposed to ensure the preservation of the building's imposing external elevations. It was essential, therefore, that the replacement windows closely mimicked the appearance of the originals.

Working closely with the architects Ferguson Cale and Sayell Partnership the window manufacturer produced a customised version of their MODUL A37 aluminium-clad timber window supplied to site ready-glazed and complete with faithfully positioned glazing bars and feature bosses. These new windows are visually identical to the old windows yet offer the very highest performance.

The A37 MODUL windows have been double-glazed in a 6:12:6 configuration with sealed units incorporating body-tinted green 6mm Antisun glass and Pilkington 'K' low emissivity glass. This glazing combination provides a high standard of heat retention and glare resistance for maximum internal comfort.

Designed and produced in Scandinavia, the high precision Swedish Redwood sash casements of the new MODUL windows provide a natural thermal break. EPDM weatherseals and multipoint espagnolette locking ensure a high standard of weathertightness and acoustic attenuation. Low maintenance was another important factor in the choice of window for Steel City House. In this case long-term durability has been ensured by the powder coated, inherently corrosion resistant, aluminium facing of the windows coupled with pressure-preservative treatment of the internal timber frame.

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